Application of fuzzy multi-criteria decision making methods for financial performance evaluation of Turkish manufacturing industries

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ABSTRACT

For manufacturing industries, financial performance evaluation is very important in a highly competitive environment. Therefore, an accurate and appropriate performance evaluation is critical. As financial performance indicators reflect the competitiveness of a company, they must be carefully identified in the evaluation process. Generally, traditional accounting-based financial performance (AFP) measures are used for performance evaluation. However, these measures are not sufficient for performance evaluation solely in the modern industry time. So, value-based financial performance (VFP) measures have recently been introduced to express the company value. In this paper, we propose a new financial performance evaluation approach to rank the companies of each sector in the Turkish manufacturing industry. For this purpose, a hierarchical financial performance evaluation model is structured based on the AFP and VFP main-criteria and their sub-criteria. We use fuzzy analytic hierarchy process (FAHP) to determine the weights of the criteria. The companies are ranked according to their own manufacturing sector by using TOPSIS and VIKOR comparatively. The results show that the obtained ranks of the companies by these methods are almost same with respect to their own sectors.

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1. Introduction

In today’s competitive world economy, evaluating the financial performance of a company has a great importance not only for managers, creditors and current/potential investors but also for the companies taking place in the same sector. Performance evaluation of companies is generally carried out within the context of financial analyses. As the concept of financial performance is considered under different meanings such as return, productivity, output and economic growth, using the financial ratios in the performance evaluation process can be suitable for both companies and related sectors. Financial ratios derived from the data in income statement and balance sheets are considered as crucial measurement tools in determining performance and financial assets of companies. For many years, a great number of studies in the literature have shown the benefits of the financial ratios (Chen & Shimerda, 1981). They allow the user to summarize and analyse related data to provide meaningful information for making decisions (Singh & Schmidgall, 2002). And, the significance of the financial ratios also demonstrates the strong and weak sides of companies in terms of liquidity, growth, and profitability.

In the performance evaluation, the most common used financial ratios are traditional financial indicators that are usually related to profitability. Traditional financial measures known to be as accounting-based financial performance (AFP) measures have basically been used to evaluate the company’s financial situation and performance. These measures provide useful quantitative financial information to both investors and analysts so that they can evaluate the operation of a company and analyze its position within a sector over time (Gallizo & Salvador, 2003). In the literature, there are approximately twenty five traditional financial performance measures reported for the manufacturing industry. However, these measures are gathered into one group within itself because they provide similar information. In other words, AFP measures can be classified as liquidity ratios, financial leverage ratios, profitability ratios, activity ratios, and growth ratios with respect to the information they provide.

Because of the competition conditions, increase in liberalization and internationalization of financial markets, diversification of the activities in these markets and increase in the mobility of capital, the importance of the efficient usage of resources in the companies has become vital and activities aimed at appreciating the company values has also gained importance. The changes in companies’ aims require improving the tools used for the financial performance measurement. In connection with the attempts intended for increasing company value, the development of new performance...
measures based upon this value is inevitable. Traditional AFP measures have long been criticized for their inadequacy in guiding strategic decisions. In the 1990s, new measures and analysis instruments appeared to measure a company's performance. Modern value-based financial performance (VFP) measures have attracted an increasing attention to traditional AFP measures as alternatives for using in value creation for the manufacturing companies (Sandoval, 2001).

The shareholders are directly interested in value creation as this is the payment they expect in return of the capital invested and risks taken. The strategic objective to increase company’s performance and new value creation also satisfies the immediate interest of the managers and the employees. For a national economy, value creation means the efficient usage of the national economic potential and the increase of gross domestic product that contributes to the increase of social welfare (Camelia & Vasile, 2009). Thus, the theoretical and practical background for the development of modern finance systems was created. Later, a value creation-based management system was developed. Consequently, measures that give importance on value creation by management for the owners have emerged. In this way, this evolution period is described as three phases: profit maximization is the old-age term, wealth maximization is matured term, and value maximization is today’s wisdom term (Shih, 2009). By this way, the performance evaluation of companies is based on the analysis that measures company value. There are numerous consulting companies marketing their own measures of value-based measures, such as Stern Stewart’s EVA and MVA, Holt Value Associates’ Cash Flow Return on Investment (CFOI), Boston Consulting Group’s total business return (TBR) and Cash Value Added (CVA), McKinsey's economic profit and LEK/Alcar’s shareholder value added (SVA).

According to the International Monetary Fund (IMF) data, Turkey has been among the nations that are growing up rapidly with regard to the economy in recent years. The main reason of the economic growth and also the development in Turkish economy is the industrialization. The significant part of the industrialization belongs to manufacturing industry that has a popular role in incorporating these developments to production process.

The aim of this study is to propose a new evaluation approach by using both AFP and VFP measures together to rank the companies in a considered sector in the Turkish manufacturing industry. Turkey’s manufacturing industry is mainly grouped in seven sectors and each sector has several companies. These companies are evaluated by using the 2007 data obtained from Istanbul Stock Exchange (ISE). A hierarchical structure depending on the main criteria of AFP and VFP is firstly constructed by an expert group from ISE. Each main-criterion is divided into four sub-criteria with respect to the frequently used financial indicators by this expert group. In the evaluation procedure, FAHP is used to determine the weights of the criteria and two multi-criteria decision making methods TOPSIS and VIKOR are used as comparatively to rank the companies in the same manufacturing sector.

The remainder of this paper is organized as follows. In Section 2, a literature review of financial performance measures and MCDM techniques focused on performance measures are given. In Section 3, AFP and VFP financial ratios that are used in the performance evaluation of the companies are briefly explained. In the next section, we mention the importance of the MCDM techniques. This section is separated into two subsections. The first subsection includes the explanation of the FAHP method used to determine the weights of the criteria. The second subsection is on the ranking methods TOPSIS and VIKOR. In Section 5, an application for financial performance evaluation of the companies in the seven sectors of the Turkish manufacturing industry is given. At the last section, results of the application are presented and suggestions for further research are given.

2. Literature review

In the financial performance literature, many studies are generally focused on determining the relationships among the financial measures and also the effects of these measures on the performance of companies. These studies are often related to conduct a regression model to show how much financial measures explain the performance of companies. While some of these studies use either VFP or AFP measures, others use both measures together. Many studies related to the financial performance evaluation in various sectors are summarized in the following.

The first empirical study regarding the association between EVA and MVA was proposed by Stewart (1991). In this study, a sample of 1000 industrial companies was selected for the years 1987–1988 and these VFP measures were analyzed to examine if any association of them affects the company value. Uyemura, Kantor, and Pettit (1996) used a sample of the 100 largest US banks for a ten-year period to calculate MVA and tested its correlation with EVA, and three AFP measures that are ROA, ROE and EPS. Lehn and Makhija (1996) proposed a study including companies operated in the manufacturing industry to find out how well EVA and MVA related to share price performance. Chen and Dodd (1997) suggested a regression model to compare EVA with the other traditional AFP measures such as EPS, ROE and ROA. John, Balakrishnan, and Fiet (2000) hypothesized that there was a non-linear relationship between corporate strategy, short-run financial variables, and wealth creation measured as market value added (MVA), and used neural networking to model this relationship. Yook and McCabe (2001) investigated the effectiveness of MVA as an investment tool by examining its relationships to other commonly used VFP measures and rates of return on common stock. Worthington and West (2001) studied a synoptic survey of EVA’s conceptual underpinnings and the comparatively few empirical analyses of value-added performance measures in Australian companies. Johnson and Soenen (2003) used monthly data of 478 companies to investigate the possible indicators of financially successful companies, using three measures of financial performance i.e., the Sharpe index, Jensen’s alpha and EVA. Warr (2005) investigated inflation’s effect on EVA and found that inflation had significant distorting effects on EVA as traditionally computed. Dutta and Reichelstein (2005) developed a multi-period principal-agent model in which a manager must be given incentives to undertake investments and to exert personally costly effort. Kyriazis and Anastassi (2007) investigated the relative explanatory power of the EVA. Hejazi and Oskouei (2007) suggested that both of CVA and P/E ratios had an explanatory power to each other. Erasmus (2008) analyzed that the incremental information content tests indicated that their components added significantly to the information content of earnings, but that the level of significance was relatively low. Wang and Lee (2008) proposed a clustering method in which the financial ratios of different companies with similar variations were partitioned into the same cluster. Lahtinen and Toppinen (2008) examined the effects of cost and value-added components on the firm-level financial performance large and medium sized companies evaluated by using regression analysis.

Performance evaluation is regarded as a MCDM problem, which selects an option from a set of alternatives characterized in terms of their attributes. The aim of the MCDM is to obtain the optimum choice that has the highest degree of satisfaction for all of the relevant attributes (Yang, Chen, & Hung, 2007). Several studies on performance evaluation are focused on ranking the units according to their performance measures included in their comparison environments. Feng and Wang (2006) constructed a performance evaluation process for airlines with some financial ratios. They used the grey relation analysis to select the representative indicators and used the TOPSIS method for outranking Taiwan’s five major


3. Financial performance measures

The measures used in the financial performance evaluation have been attained variety and generality as parallel to the developments in the technology and the perception of a company management. In this study, performance measures are a mixture of traditional and modern financial ratios that are known to be as AFP measures and VFP measures, respectively. These two measures have sub-measures that are crucial for performance evaluation especially in the manufacturing industry. In the following, the sub-criteria measures of each main-criterion are explained briefly.

3.1. Traditional accounting-based financial performance measures

In this study, four traditional measures are determined as the sub-criteria of the AFP main-criterion to evaluate all the companies of each sector in the Turkish manufacturing industry by the expert group from ISE. These measures are return on assets (ROA), return on equity (ROE), earning per share (EPS) and price/earnings ratio (P/E). These sub-criteria are briefly explained in the following.

3.1.1. Return on assets (ROA)

This measure relates to a company’s after tax net income during a specific year to the company’s average total assets during the same year. ROA, a measure of a company’s profitability, is expressed as a percentage. Because this measure determines how effectively a company has used the total assets at its disposal to generate earnings, it has a great importance for manufacturing industries. In other words, ROA shows that how much profit a company is able to generate for each dollar of assets invested (Palepu, Healy, & Bernard, 2000). The formulation of this measure is defined as follows (Moyer, McGuigan, & Kretlow, 1992):

\[
ROA = \frac{Net \ Income \ Available \ to \ Common \ Stockholders}{Total \ Assets}\]

As seen from the ROA formulation, the higher return means the better profit performance for a company. ROA gives an idea how efficient the management uses its assets to generate earnings. In other words, ROA is a convenient way of comparing a company’s performance with that of its competitors.

3.1.2. Return on equity (ROE)

It measures the percentage of profit earned on common stockholders’ investment in the companies. Because ROE is useful for comparing the profitability of a company to that of other firms in the same industry, it is an important and widely used financial ratio in manufacturing companies. Actually, in theory, a company attempting to maximize the wealth of it stockholders should be trying to maximize this ratio. Consequently, it can be said that this performance measure is aimed at measuring the return that stockholders expect from their shares in the company. Although it can be defined by several ways, the most common used formulation is given here as follows (Livingstone & Grossman, 2002):

\[
ROE = \frac{Net \ Income \ Available \ to \ Common \ Stockholders}{Stockholder's \ Equity}\]

(2)

Because only the stockholder’s equity appears in the denominator, the measure is directly influenced by the amount of debt which a company is using to finance assets. The higher the ratio, the more efficient management of the equity base utilization and also the better return to its investors.

3.1.3. Earnings per share (EPS)

EPS is another important measure indicating a company’s strength. EPS is generally considered to be the most important variable in determining a share’s price. It is also a major component used to calculate the price-to-earnings valuation ratio. It is a significant measure because the market reacts to a company’s ability to meet its earnings expectations (Jordan, Clark, & Smith, 2007). To calculate this ratio, simply divide the company’s net income available to shareholders by the number of shares outstanding during the same period (if the number of shares outstanding in the market has changed during that period such as a share buyback, a weighted average of the quantity of shares is used). EPS allows us to compare different companies’ earnings power to make money. The most widely used ratio usually defined as follows (Chen, Kim, & Chen, 2007):

\[
EPS = \frac{Net \ Income \ Available \ to \ Shareholders}{Number \ of \ Shares \ Outstanding}\]

(3)

A good way to determine whether a company is growing is to look at their earnings per share compared to previous years. It is often considered as the single most important measure to determine a company’s profitability.

3.1.4. Price earnings ratio (P/E)

The P/E ratio indicates how much investors are willing to pay per dollar of current earnings. Although there are other important measurement factors which an investor should consider before taking an investment decision, P/E ratio is the most popular measure for performance analysis (Kumar & Warne, 2009). It is calculated by dividing the current market price per share of stock by EPS (Truong, 2009):

\[
P/E = \frac{Market \ Price \ per \ Share}{Earnings \ per \ Share}\]

(4)

Though earnings per share are reported in the income statement, the market price per share of stock is not reported in the financial statements, but must be obtained from financial new source. The main idea of P/E ratio is what the market is willing to pay for the company’s earnings.

3.2. Modern value-based financial performance measures

In this study, four modern measures are determined as the sub-criteria of the VFP main-criterion to evaluate all the companies of each sector in the Turkish manufacturing industry by the expert group from ISE. These measures are determined as Economic Value
Added (EVA), Market Value Added (MVA), Cash Flow Return on Investment (CFROI) and Cash Value Added (CVA). These sub-criteria measures are briefly explained in the following.

3.2.1. Economic Value Added (EVA)

EVA, firstly developed by Stern Stewart and Co., is viewed as an estimation of a company's true economic profit that differs from accounting profits (Lin & Zhilin, 2008). Over the course of the 1990s, EVA has increasingly become popular tool to measure corporate financial performance measure. A key component of EVA is to consider cost of capital in estimating the performance measurement. Only when a company generates return exceeding cost of capital, a company's value becomes enhanced (Lee & Kim, 2009). EVA is a measure of residual income, which focuses on the concept that a company must earn an adequate risk adjusted return on its investment in assets.

EVA can be calculated by two different ways. First calculation way is by subtracting the company's cost of capital times total capital employed from its net operating profit after taxes. Algebraically, it can be stated as follows (Stewart, 1991):

\[
EVA_t = NOPAT_t - (WACC_t \times CE_{t-1})
\]

where NOPAT_t is the company's net operating profit after tax in period t. It deals with the net operational income. WACC_t is the weighted average cost of capital in period t and represents the minimum income requested by the shareholders or lenders. And, CE_{t-1} is the company's total invested capital in period t - 1.

A more intuitive way to calculate EVA for any year is to multiply a company's capital employed at the beginning of the year by the spread between its return on investment in capital in the end of the year and its weighted average cost of capital in the end of the year. Under this circumstance, it can be rewritten as follows (Kramer & Pushner, 1997):

\[
EVA_t = (ROIC_t - WACC_t) \times CE_{t-1}
\]

where ROIC_t is after-tax operating income in period t divided by the beginning replacement value of operating assets in place. If the EVA is positive, the company creates value for its owners. If the EVA is negative, owners' wealth gets reduced. EVA can also be computed as the difference between ROA and cost of capital, multiplied by the beginning book value of assets. Therefore, a correct measure of EVA requires a correct measure of ROA. With an incorrect ROA, reported EVA will also be incorrect (McIntyre, 1999).

3.2.2. Market Value Added (MVA)

The way in which shareholder wealth is increased is by maximizing the difference between an organization's total market value and the amount of capital that investors have supplied to the companies. This difference is called as MVA (Gapenski, 1996). This measure was introduced in the 1980s and since then, this measure has received considerable attention by both businesses and academicians as a new measure of a firm's valuation in a variety of fields such as performance evaluation systems. MVA is known as the best external measure of management performance in the long term (Ehrbar, 1999). MVA is a market-generated number that we calculate by subtracting the capital employed in a company CE_t from the sum MW_t of the total market value of the company's equity and the book value of its debt (Kim, Ahn, & Yun, 2004; Kramer & Peters, 2001):

\[
MVA = Total\ Market\ Value - Total\ Capital\ Employed
\]

This formula shows that MVA is a cumulative measure of the value created by management in excess of the capital invested by shareholders. In other words, MVA can reflect the cumulative wealth created for shareholders over the existence of the company beyond the capital employed (Yook & McCabe, 2001). From a practitioner's perspective, MVA can capture the market's assessment of how effectively a company's managers have used the scarce resources under its control in addition to how well management has positioned the company (Cheng, Tsao, Tsai, & Tu, 2007). If MVA is negative, then the market does not believe in the company's capacity to create value and the employed capital is eroded. On the contrary, a positive value proves that the company is very attractive on the market, because it can reward its shareholders.

In theory, there is a direct connection between MVA and EVA (De Wet & Hall, 2004). MVA is a closely related to the measure in that it is the present value of all expected future EVA and can be thought of as the net present value of the company (Fatemii, Desai, & Katz, 2003). We believe that MVA is a reasonable proxy for the measurement of owner wealth maximization while taking into account the relative risk-based costs of doing so.

3.2.3. Cash Flow Return on Investment (CFROI)

This measure is the most formidable competitor of EVA in the Metric Wars. It was originated in the 1970s by Callard, Madden & Associates and subsequently advanced by Holt Value Associates, which was acquired by Credit Suisse in 2002. CFROI as a more accurate reflection of a company's ability to generate shareholder value is increasingly being mirrored on the corporate side by executives looking for ways to evaluate the performance of business units. One measure widely used by institutional investors but seldom available to individuals is CFROI. It measures the real cash return on the capital invested in a company as a percentage. Unlike traditional AFP measures such as ROA or ROE, CFROI is adjusted for accounting differences and inflation, so it often paints a truer picture of corporate financial performance. Because CFROI incorporates the real rates of return and also attempts to correct for inflation's distorting effect on the asset (Warr, 2005). Two different calculation ways can be defined for CFROI. One way is multi-period approach. With this way, CFROI for a company can be thought of the internal rate of return (IRR) of all a company's projects. CFROI is the rate of return that makes the present value of a company's future cash flows, including a "terminal value" from the release of non-depreciating assets, equal to the company's gross cash investment. The other way for calculation is single-period approach. CFROI can be converted to a simpler single-period ratio. With this approach, we calculate CFROI as follows (Young & O'Byrne, 2001):

\[
CFROI = \frac{Sustainable\ Cash\ Flows}{Current\ Dollar\ Gross\ Investment}\times\frac{1}{1 + WACC}
\]

where sustainable cash flow is the company's operating gross cash flows less economic depreciation (ED). ED is the annual investment and gives the company's opportunity cost of funds in order to accumulate a sum equal to the original cost of the depreciable assets at the end of the asset's life. In this sense, assuming an asset life of t years, ED is computed as follows (Martin & Petty, 2000):

\[
Economic\ Depreciation = \left[ \frac{WACC}{1 + WACC} \right]^{t-1} - 1 \times Depreciating\ Assets
\]

CFROI indicates whether the company has earned returns superior to its cost of capital and thus created value for this shareholders. In this sense, it shows an important similarity to EVA. Both measures assume that management creates value by earning returns on invested capital greater than the cost of capital. For the owners of the company or shareholders, high CFROI is an advantage because less money has to be invested to generate future growth.

3.2.4. Cash Value Added (CVA)

This measure is an alternative residual income measure designed to produce a profit figure even closer to cash flow than
adjusted version of EVA, while retaining EVA’s advantage of accounting for all capital costs. CVA is a concept promoted by Boston Consulting Group (BCG). It has also been developed as a measure of economic profit and called CVA. BCG contends that it is an improvement over EVA because CVA is based on cash flows, not earnings (Martin & Petty, 2000). CVA is used in value-based company management for strategic and operational financial planning in order to measure economic performance and its control.

CVA is measured as operating cash flows less economic depreciation less a capital charge on the total amount of cash invested in the company. It is called direct calculation by BCG. Thus, CVA can be calculated as follows (Camelia & Vasile, 2009):

$$\text{CVA} = \frac{\text{Gross Cash Flows (operating)}}{C_0} - \frac{\text{Economic Depreciation}}{C_0} - \frac{\text{Capital Charge}}{(10)}$$

where capital charge assigns a cost for the use of all capital the company is using, which is equal to the company’s cost of capital times the amount of gross capital invested. Another calculation method for CVA considers the company’s profitability measured as a difference between CFROI and WACC. It is called indirect calculation by BCG (Hejazi & Oskouei, 2007). In this study, we use this indirect calculation formulated as follows:

$$\text{CVA} = \left(\frac{\text{CFROI}}{C_0} - \frac{\text{WACC}}{C_0}\right) \times \text{Current Dollar Gross Investment}$$

4. MCDM methods

Multi-criteria decision making (MCDM) is the process of finding the best alternative from all of the feasible alternatives where all the alternatives can be evaluated according to a number of criteria or attribute (Tan & Chen, 2010). MCDM refers to screening, prioritizing, ranking, or selecting a set of alternatives under usually independent, incommensurate or conflicting attributes (Hwang & Yoon, 1981). Over the years, some MCDM methods have been proposed. All of the MCDM techniques generally are enabled to structure the problem clearly and systematically. One of the most common used MCDM methods is the analytical hierarchy process (AHP). It has been applied successfully in many practical decision-making problems.

The main objective of this paper as mentioned above is to select the best company in each sector of the Turkish manufacturing industry. For this purpose, we use FAHP to determine the weights of all criteria, and then choose the best company in each sector of the manufacturing industry by TOPSIS and VIKOR methods.

The evaluation procedure in this paper consists of four main steps as summarized in Fig. 1.

Step 1. Identify the evaluation criteria considered as the most important performance measures for the manufacturing industry.

Step 2. Construct the hierarchy of the evaluation criteria and calculate the weights of these criteria using FAHP method.

Step 3. Conduct the TOPSIS and VIKOR methods to achieve the final ranking results.

Step 4. Evaluate and compare the ranking results according to both methods.

The detailed descriptions of each step are illustrated in the following sections.

4.1. Determining the criteria weights by FAHP

The analytic hierarchy process (AHP) is widely used for tackling multi-attribute decision-making problems in real situations (Chan & Kumar, 2007). The AHP method firstly proposed by Saaty (1980) constructs a hierarchical structure for complex problems. Although the traditional AHP can handle experts’ opinions and make an evaluation based on multi-criteria, it is not fully capable of reflecting the human judgments since it uses exact numerical values in the pairwise comparison matrices. As some of the evaluation criteria are subjective and qualitative in nature, fuzzy analytic hierarchy process (FAHP) is developed as an alternative to remove the deficiencies of the classical AHP and to ease the adaptation to real life problems. Different methods used in FAHP are the systematic approaches developed for the selection of alternatives, based on the fuzzy group theory and hierarchical structure analysis. From the point of view of decision makers, generally intermittent judgments are more reliable than certain judgments and the fuzzy nature of the comparison process reveals that crisp judgments are insufficient to explain their preferences (Kahraman, Cebeci, & Ulukan, 2003). The first study with FAHP was carried out by Van Laarhoven and Pedrycz (1983). Since then, FAHP has been widely used for many different multi criteria comparison environments in the literature: technology selection problem (Chan, Chan, & Tang, 2007).
2000); facility selection problem (Kahraman, Ruan, & Doğan, 2003); comparison of catering companies (Kahraman, Cebeci, & Ruan, 2004); choice in optimum maintenance strategies (Wang, Chu, & Wu, 2007) and assessment of an IT department in manufacturing sector in Taiwan (Lee et al., 2008).

In the following, we briefly introduce some basic definitions of fuzzy concepts that are used in the proposed FAHP method and we also mention the methodology of FAHP used in this study for determining the weights of the criteria.

4.1.1. Fuzzy sets and fuzzy numbers

Under many conditions, exact data is inadequate for modeling real-life situations because human judgments and preferences are often ambiguous and cannot be estimated with exact numerical values. The fuzzy set theory first introduced by Zadeh (1965) is appropriate for dealing with uncertainty and imprecision associated with human beings’ subjective judgments that are often vague. One of the easier ways to clarify these subjective judgments is using linguistic variables. The concept of a linguistic variable is very useful in dealing with situations, which are too complex or not well defined to be reasonably described in conventional quantitative expressions (Zimmermann, 1991).

A fuzzy number is a special fuzzy set $A = \{ x \in \mathbb{R} | \mu_A(x) \}$, where $x$ takes its values on the real line $\mathbb{R}$, $\mu_A(x)$ is a continuous mapping from $\mathbb{R}$ to the closed interval $[0, 1]$. Triangular and trapezoidal fuzzy numbers are the most common used fuzzy numbers both in theory and practice. Triangular fuzzy numbers are more practical in application because of their calculation easiness and features. So, triangular fuzzy numbers are preferred for representing the linguistic variables in this study.

A triangular fuzzy number can be donated as $T = (l, m, u)$ and its membership function $\mu_T(x) : \mathbb{R} \rightarrow [0, 1]$ can be given as

$$\mu_T(x) = \begin{cases} 0, & x < l \text{ or } x > u \\ (x - l)/(m - l), & l \leq x \leq m \\ (u - x)/(u - m), & m \leq x \leq u \end{cases}$$ (12)

where $l \leq m \leq u$ and $l, m, u$ describe the smallest possible value, the most promising value, and the largest possible value of a fuzzy event, respectively. A triangular membership function $\mu_T(x)$ is shown in Fig. 2 (Deng, 1999).

Let $T_1 = (l_1, m_1, u_1)$, $T_2 = (l_2, m_2, u_2)$ be two triangular fuzzy numbers, the basic operations of triangular fuzzy numbers are defined as follows (Kaufmann & Gupta, 1991):

$$T_1 \oplus T_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$
$$T_1 \otimes T_2 = (l_1 m_2 + m_1 l_2, m_1 m_2, u_1 u_2)$$

$$\lambda \otimes T_1 = (\lambda l_1, \lambda m_1, \lambda u_1), \quad \lambda > 0, \quad \lambda \in \mathbb{R}$$

$$T_1^{-1} = (1/u_1, 1/m_1, 1/l_1)$$ (13)

To evaluate the importance of the VFP and AJP main-criteria and sub-criteria of these main-criteria, it is assumed that the expert group (decision makers) utilize the linguistic weighting set $W = \{ ALI; VSI; SSI; WLI; EI; WMI; SMIS; VSMI; AMI \}$, where ALI: absolutely less important, VSI: very strongly less important, SSI: strongly less important, WLI: weakly less important, EI: equally important, WMI: weakly more important, SMIS: strongly more important, VSMI: very strongly more important, AMI: absolutely more important.

The triangular fuzzy conversion scale given in Table 1 and the linguistic scale shown in Fig. 3 are used in our evaluation model.

To resolve the ambiguity frequently arising from human judgments and preferences, the fuzzy set theory has been incorporated into many MCDM approaches, including FAHP.

4.1.2. The methodology of FAHP

In this study, the weights of the financial performance criteria are obtained by using Chang’s (1992, 1996) extent FAHP method that is because of the computational easiness and efficiency. Let $X = \{ x_1, x_2, \ldots, x_n \}$ be an object set, and $U = \{ u_1, u_2, \ldots, u_m \}$ be a goal set. According to the method, 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:

$$M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m, \quad i = 1, 2, \ldots, n$$ (14)

where all the $M_{gi}^j$ ($j = 1, 2, \ldots, m$) are TFNs. The steps of Chang’s (1996) extent analysis 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 in Eq. (15):

$$S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[ \sum_{j=1}^{m} M_{gi}^j \right]^{-1}$$ (15)

To obtain $\sum_{j=1}^{m} M_{gi}^j$, perform the fuzzy addition operation of $m$ extent analysis values for a particular matrix as in Eq. (16):

$$\sum_{j=1}^{m} M_{gi}^j = \left( \sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right)$$ (16)

and to obtain $\left( \sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right)^{-1}$, the fuzzy addition operation of $M_{gi}^j$ ($j = 1, 2, \ldots, m$) values is performed as in Eq. (17):

$$\text{Table 1}
\begin{array}{|c|c|c|}
\hline
\text{Linguistic scale for importance and successes degrees} & \text{Triangular fuzzy scale} & \text{Triangular fuzzy reciprocal scale} \\
\hline
\text{Equally important/successful} & (1/2, 1, 3/2) & (2/3, 1, 2) \\
\text{Weakly more important/successful} & (1, 3/2, 2) & (1/2, 3/1, 1) \\
\text{Strongly more important/successful} & (3/2, 5/2, 2) & (2/5, 1/2, 3/2) \\
\text{Very strongly more important/ successful} & (2, 5/2, 3) & (1/3, 2/5, 1/2) \\
\text{Absolutely more important/ successful} & (5/2, 3, 7/2) & (2/7, 1/3, 2/5) \\
\hline
\end{array}$$

Fig. 2. A triangular membership function, $\mu_T(x)$.

Fig. 3. The linguistic scale of the triangular numbers for relative importance (RI).
\[
\sum_{i=1}^{n} \sum_{j=1}^{m} M'_{ij} = \left( \sum_{i=1}^{n} l_i \sum_{j=1}^{m} u_j \sum_{i=1}^{n} u_i \right)
\]

and then the inverse of the vector above is computed as in Eq. (18):

\[
\left[ \sum_{i=1}^{n} \sum_{j=1}^{m} M'_{ij} \right]^{-1} = \left( \frac{1}{\sum_{i=1}^{n} u_i} \frac{1}{\sum_{j=1}^{m} m_j} \frac{1}{\sum_{i=1}^{n} m_i} \right)
\]

Step 2. As \( M_1 \) and \( M_2 \) are two triangular fuzzy numbers, the degree of possibility of \( M_2 \geq M_1 \) is defined as

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

and can be equivalently expressed as follows:

\[
V(M_2 \geq M_1) = hgt(M_1 \cup M_2) = \mu_{M_2}(d)
\]

where \( d \) is the ordinate of the highest intersection point \( D \) between \( \mu_{M_1} \) and \( \mu_{M_2} \) (Fig. 4).

To compare \( M_2 \) and \( M_1 \), we need both 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 numbers \( M_i \) (\( i = 1, 2, 3, \ldots, k \)) can be defined by

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

Assume that

\[
d'(A_i) = \min V(S_i) = S_i
\]

For \( k = 1, 2, \ldots, n; k \neq i \). Then the weight vector is given by

\[
W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T
\]

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

Step 4. Via normalization, the normalized weight vectors are

\[
W = (d(A_1), d(A_2), \ldots, d(A_n))^T
\]

where \( W \) is a nonfuzzy number.

4.2. Ranking alternatives

In this study, two ranking MCDM methods TOPSIS and VIKOR are used to rank the companies as comparatively. In this section, these two methods are explained and compared to each other with respect to the procedural basics.

4.2.1. The TOPSIS method

TOPSIS (Technique for Order Performance by Similarity to Ideal Solution), one of the classical MCDM methods, was originally proposed by Hwang and Yoon (1981). According to this method, alternatives to be evaluated by \( n \) attributes in a MCDM problem are presented as points in an \( n \)-dimensional space. A basic assumption of TOPSIS is that each attribute has a tendency towards monotonically increasing or decreasing utility. In other words, TOPSIS is based on the concept that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative-ideal solution (NIS) for solving a multiple criteria decision-making problem (Benitez, Martin, & Roman, 2007). The TOPSIS method considers the distances to both the PIS and the NIS simultaneously by defining “relative closeness to ideal solution”. At the end, the ideal solution closest to the PIS and farthest to the NIS is obtained.

The algorithm of the TOPSIS method has mainly six steps given in the following:

\[
r_{ij} = \frac{w_i \cdot M_i - M_j}{\sqrt{\sum_{i=1}^{n} w_i^2}}, \quad j = 1, 2, \ldots, J; \quad i = 1, 2, \ldots, n
\]

Step 2. Weighted normalized decision matrix is obtained by multiplying normalized matrix with the weights of the criteria:

\[
v_{ij} = w_i \cdot r_{ij}, \quad j = 1, 2, \ldots, J; \quad i = 1, 2, \ldots, n
\]

Step 3. PIS (maximum values) and NIS (minimum values) are determined:

\[
A^+ = \{ v_1^+, v_2^+, \ldots, v_n^+ \}
\]

\[
A^- = \{ v_1^-, v_2^-, \ldots, v_n^- \}
\]

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

\[
d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{ij}^+)^2}, \quad j = 1, 2, \ldots, J
\]

\[
d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{ij}^-)^2}, \quad j = 1, 2, \ldots, J
\]

Step 5. The Closeness Coefficient of each alternative \( CC_i \) is calculated:

\[
CC_i = \frac{d_i^+}{d_i^+ + d_i^-}
\]

Step 6. At the end of the analysis, the ranking of alternatives is determined by comparing \( CC_i \) values.

4.2.2. The VIKOR method

VIKOR method known to be as a compromise ranking method is introduced one applicable technique to implement within the MCDM approaches. The foundation for compromise solution was established by Yu (1973) and Zeleny (1982). This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. It introduces the multi criteria ranking index based on the particular measure of “closeness” to the “ideal” solution (Opricovic, 1998). This method is based on an aggregating function representing closeness to the reference point(s). The VIKOR method introduces an aggregating function, representing the distance from the ideal solution. This ranking index is an aggregation of all criteria, the relative importance of the criteria, and a balance between total and individual satisfaction. This method
introduces different forms of aggregating function ($L_p$-metric) for ranking. The VIKOR method introduces $Q_j$ as a function of $L_1$ and $L_{\infty}$ and uses linear normalization to eliminate the units of criterion functions.

In this method, the various $J$ alternatives are denoted as $a_1, a_2, \ldots, a_J$. For an alternative $a_j$, the multiple attribute merit for compromising ranking was developed from the $L_p$-metric used in the compromise programming method (Zeleny, 1982)

$$L_{pj} = \left( \sum_{i=1}^{n} \left( \frac{w_i f_{ij} - f_{ij}}{f_{ij}^* - f_{ij}} \right)^p \right)^{1/p}, \quad 1 \leq p \leq \infty, \quad j = 1, 2, \ldots, J$$

(32)

$L_{1J}$ (as $S_j$ in Eq. (27)) and $L_{\infty J}$ (as $R_j$ in Eq. (28)) are used to formulate the ranking measures. The solution obtained by $\min S_j$ is with a maximum group utility (“majority” rule), and the solution obtained by $\min R_j$ is with a minimum individual regret of the “opponent”.

The main steps of the VIKOR method are described as follows:

1. Determine the best $f^*_j$ and the worst $f^*_j$ values of all criterion functions assuming that its function represents a benefit:

$$f^*_j = \max_i f_{ij}, \quad f^*_j = \min_i f_{ij}$$

(33)

2. Compute the values $S_j$ and $R_j$, $j = 1, 2, \ldots, J$, by the relations

$$S_j = \sum_{i=1}^{n} w_i (f^*_i - f_{ij})/(f^*_i - f^*_j)$$

(34)

$$R_j = \max_i [w_i (f^*_i - f_{ij})/(f^*_i - f^*_j)]$$

(35)

where $w_i$ are the weights of criteria, expressing their relative importance.

3. Compute the values $Q_j$, $j = 1, 2, \ldots, J$, by the relation

$$Q_j = \nu(S_j - S^*)/(S^* - S^* + (1 - \nu)(R_j - R^*)/(R^* - R^*)$$

(36)

where $S^* = \min S_j$, $S^* = \max S_j$, and $R^* = \min R_j$, $R^* = \max R_j$. $\nu$ is introduced as weight of the strategy of “the majority of criteria” (or “the maximum group utility”) and usually $\nu = 0.5$.

4. Rank the alternatives, sorting by the values $Q$, $S$, and $R$ in decreasing order. The results are three ranking lists.

5. Propose as a compromise solution, for given criteria weights, the alternative ($a^*$), which is the best ranked by the measure $Q$ if the following two conditions are satisfied:

**C1.** “Acceptable advantage”: $Q(a^*) - Q(a') > DQ$, where $a'$ is the alternative with second position in the ranking list by $Q$: $DQ = 1/(J - 1)$; $J$ is the number of alternatives.

**C2.** “Acceptable stability in decision making”: Alternative $a^*$ must also be the best ranked by $S$ or/and $R$. This compromise solution is stable within a decision making process, which could be: “voting by majority rule” (when $\nu > 0.5$ is needed), or “by consensus” $\nu \approx 0.5$, or “with veto” ($\nu < 0.5$). Here, $\nu$ is the weight of the decision making strategy “the majority of criteria” (or “the maximum group utility”).

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

- Alternatives $a'$ and $a^*$ if only the conditions C2 are not satisfied.
- Alternatives $a'$, $a^*$, \ldots, $a^{(k)}$ if the conditions C1 are not satisfied, $a^{(k)}$ is determined by the relation $Q(a^{(k)}) - Q(a') \approx DQ$, the positions of these alternatives are “in closeness”.

### 4.2.3. Comparison of the two ranking methods

TOPSIS and VIKOR are the two methods that are easy to apply in ranking alternatives in a MCDM environment. Opricovic and Tzeng (2003, 2004) discussed the differences of these two methods. The differences between these two methods are summarized in the following based on the main features of the methods.

The main procedural steps of both methods are

- A performance matrix obtained by the evaluation of all the alternatives in terms of each criterion is used.
- Normalization is used to eliminate the units of criterion values.
- An aggregating function is formulated.
- A ranking list is proposed based on the aggregation function.

Both methods are different in terms of the calculation procedures in normalization, aggregation steps, and ranking operation.

The main difference appears in the aggregation approaches of both methods. The VIKOR method introduces an aggregating function, representing the distance from the ideal solution. This ranking index is an aggregation of all criteria, the relative importance of the criteria, and a balance between total and individual satisfaction. The TOPSIS is based on aggregating function representing “closeness to ideal”. In TOPSIS, the chosen alternative should have the “shortest distance” from the positive ideal solution and the “farthest distance” from the negative ideal solution. The TOPSIS method introduces two reference points, but it does not consider the relative importance of the distances from these points.

These two MCDM methods use different kinds of normalization to eliminate the units of the criterion functions, whereas the VIKOR method uses linear normalization, the TOPSIS method uses vector normalization. The normalized value in the VIKOR method does not depend on the evaluation unit of criterion function, whereas the normalized values by vector normalization in the TOPSIS method may depend on the evaluation unit (Chu, Shyu, Tzeng, & Khosla, 2007).

Both methods provide a ranking list. The highest ranked alternative by VIKOR is the closest to the ideal solution. However, the highest ranked alternative by TOPSIS is the best in terms of the ranking index, which does not mean that it is always the closest to the ideal solution. In addition to ranking, the VIKOR method proposes a compromise solution with an advantage rate.

### 5. Application

The aim of this study is to evaluate the financial performance of the companies in the Turkish manufacturing sectors traded on ISE by using both AFP measures and VFP measures together in a fuzzy environment. Manufacturing industry of Turkey has seven sectors that are coded ISE Industrials. In Table 2, sectors descriptions, abbreviations of each sector and the number of the companies of each sector are given.

Manufacturing companies are subjected to evaluation by using the data sets of the year 2007. For this period of the research,
annual financial statements of companies which pass away independent external auditing are considered. The values of the measures created from the data set are calculated by using Finnet Excel Add-In programme based on ISE. Balance sheet values are used directly for calculation of AFP measures. On the contrary, some assumptions are allowed for calculating VFP measures in the study. Accordingly, the financial statements are adjusted to avoid inflation effect in terms of consumer price index (CPI). In calculating of EVA measure, depreciating assets market value is obtained from number of shares outstanding times generation as a risk free rate of interest. In calculating MVA, total companies in the related term. Treasury bill rates are taken into consideration as a risk free rate of interest. In calculating MVA, total market value is obtained from number of shares outstanding times share price. In calculating CFROI measure, depreciating assets comprise sum of gross plant inflation adjustment, constructions in progress, net present value of gross leased property and adjusted intangibles.

The hierarchical structure of the criteria is portrayed in Fig. 5. The decision problem consists of three levels: at the highest level, the objective of the problem is situated while in the second level, the main-criteria are listed, and in the last level, the sub-criteria of each main-criterion are listed.

The weights of the criteria are first determined by using FAHP. The pair-wise comparison scores have been carried out by four experts working in ISE. Fuzzy pair-wise comparisons matrix for the sub-criteria of the VFP main-criteria (Table 3) and the calculation of the weights are given as follows:

The obtained synthetic values are compared by using Eq. (20) and the following results are obtained:

The synthetic values for each criterion are first calculated by Eq. (15).

The synthetic values are obtained by using Eq. (20) and the following results are obtained:

The obtained synthetic values are compared by using Eq. (20) and the following results are obtained:

The obtained synthethic values are compared by using Eq. (20) and the following results are obtained:

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Later, the priority weights are calculated by using Eq. (22):

Weights vector is $W = (1, 0.5737, 0.3368, 0.2242)^T$. After the normalizational procedure, the normalized weight vector with respect to the VFP main-criteria is obtained as follows: $W = (0.4685, 0.2687, 0.1578, 0.1050)^T$.

Fuzzy pair-wise comparison matrices for the sub-criteria and main-criteria of the AFP are presented in Tables 4 and 5, respectively. The calculated importance weights of these criteria are given under the related tables.

For the consistency of the fuzzy pair-wise comparison matrices, we used defuzzification technique to convert the fuzzy numbers into crisp numbers. The most common used approaches for the defuzzification are Mean-of-Maximum, Center-of-Area, and Alphacut Method (Zhao & Govind, 1991). In this study, we utilized the Center-of-Area method owing to its calculation easiness.

As indicated before, two MCDM approaches, TOPSIS and VIKOR methods, are used to rank the companies of each sector in the Turkish manufacturing industry. In the first step of the algorithms, total values of each main-criterion are calculated by using their own sub-criteria. The calculation steps for the VFP and AFP main-criteria of the FOOD sector are given as an example in Tables 6 and 7, respectively.

After calculating the total values of the main-criteria, companies of the FOOD sector are ranked by using TOPSIS and VIKOR methods. These total values are the main input for both methods. Calculation steps of the TOPSIS method are given in Table 8.

Calculation steps of the VIKOR method are given Table 9.

While the alternatives are ranked by sorting $C_S$ values in a decreasing order in the TOPSIS method, the alternatives are ranked by sorting $S_P$, $R_P$, and $Q$ values in an increasing order in the VIKOR method. In Table 10, companies of the FOOD sector are ranked with respect to both methods.

As seen in Table 10, the best ranked company for the FOOD sector is KERVT company with respect to both methods. This company
is proposed as a compromise solution because the two conditions (C1 and C2) are satisfied. Given these results, KERV has an acceptable advantage; in other words $Q_{C1} - Q_{C2} = 0.1236 > DQ = 0.0833$ (in Table 10, it can be observed that the ratings of KERV and BANVT alternatives are not very close to each other). And, KERV is also stable within the decision-making process; in other words it is also the best ranked in $S_1$ and $R_1$. Because the two conditions are satisfied together, the alternative KERV is proposed as a compromise solution.

As seen in Table 11, the best ranked company for the PAPER sector is different companies with respect to both methods. While GENTS is the best ranked company in the TOPSIS method, KAPLM is the best ranked company in the VIKOR method. Given these results, KAPLM does not have an acceptable advantage; in other words $Q_{C1} - Q_{C2} = 0.0568 < DQ = 0.1250$. On the other hand, we observe that KAPLM is stable within the decision-making process; in other words it is also the best ranked in $S_1$ and $R_1$. Because C1 is not satisfied only, KAPLM, GENTS, KARTN companies are proposed as a set of compromise solution. This is the result of two inequities:

$$Q_{C1} - Q_{C2} = 0.0568 < DQ = 0.1250$$

$$Q_{C1} - Q_{C2} = 0.2870 > DQ = 0.1250$$
Given these results of the CHEM sector in Table 12, ECILC is the best ranked company in according to the TOPSIS method and BAG-FS is the best ranked company according to the VIKOR method. Six companies have different ranks with respect to both methods. In the VIKOR method, BAG-FS does not have an acceptable advantage; in other words \( \frac{Q^{0.5}}{C_1} - \frac{Q^{0.5}}{C_0} = 0.0320 > D_Q = 0.0833 \). On the other hand, we observe that BAG-FS is stable within the decision-making process; in other words it is the best ranked in \( S_j \) and \( R_j \). Because only \( C_1 \) is not satisfied, we propose companies BAG-FS, MRSHL and HEKTS as a set of compromise solutions. This is the result of two inequities:

\[ Q^{0.5}_{[3]} - Q^{0.5}_{[1]} = 0.0831 < D_Q = 0.0833 \]
\[ Q^{0.5}_{[4]} - Q^{0.5}_{[1]} = 0.1202 > D_Q = 0.0833 \]

As seen in Table 13, the best ranked company for the METAL sector is BRSAN with respect to both methods. Ranks of the companies are almost similar in both methods. Given these results, BRSAN does not have an acceptable advantage; in other words \( Q^{0.5}_{[2]} - Q^{0.5}_{[1]} = 0.0508 < D_Q = 0.1250 \). On the other hand, we observe that BRSAN is stable within the decision-making process; in other words it is also the best ranked in \( S_j \) and \( R_j \). Because only \( C_1 \) is not satisfied, we propose companies BRSAN, KRDMA, DMSAS and CEMTS as a set of compromise solution. This is the result of two inequities:

\[ Q^{0.5}_{[3]} - Q^{0.5}_{[1]} = 0.0854 < D_Q = 0.1250 \]
\[ Q^{0.5}_{[5]} - Q^{0.5}_{[1]} = 0.1534 > D_Q = 0.1250 \]
As seen in Table 14, the best ranked company for the METAL & MACH sector is FROTO for both methods. And also, ranks of the companies are almost similar in both methods. Given these results, FROTO does not have an acceptable advantage; in other words $Q_2 = 0.6051$, while $Q_1 = 0.5760$. On the other hand, we observe that FROTO is stable within the decision-making process; in other words it is also the best ranked in $S_j$. Because only $C_1$ is not satisfied, we propose FROTO and OTKAR companies as a set of compromise solutions. This is the result of only one inequity: $Q_3 = 0.1782 > Q_4 = 0.1534$.

As seen in Table 14, the best ranked company for the METAL & MACH sector is FROTO for both methods. And also, ranks of the companies are almost similar in both methods. Given these results, FROTO does not have an acceptable advantage; in other words $Q_2 = 0.6051 < Q_1 = 0.5760$. On the other hand, we observe that FROTO is stable within the decision-making process; in other words it is also the best ranked in $S_j$. Because only $C_1$ is not satisfied, we propose FROTO and OTKAR companies as a set of compromise solutions. This is the result of only one inequity: $Q_3 = 0.1782 > Q_4 = 0.1534$.

As seen in Table 15, the best ranked company for the NON-METAL sector is CIMSA with respect to both methods. This company is proposed as a compromise solution because the two conditions ($C_1$ and $C_2$) are satisfied.
has an acceptable advantage; in other words $Q_{2} - Q_{1} = 0.1195 \geq DQ = 0.0476$ (in Table 15, it can be observed that the ratings of CIMSA and ADANA are not very close to each other). And, it is observed that CIMSA is stable within the decision-making process; in other words it is also the best ranked in $S_j$ and $R_j$. As a conclusion, the alternative CIMSA is proposed as a compromise solution because the two conditions are satisfied. As seen in Table 16, the best ranked company for the TEXT sector is IDAS with respect to both methods. And also, ranks of the companies are almost similar in both methods. Given these results, IDAS does not have an acceptable advantage; in other words $Q_{2} - Q_{1} = 0.0274 \leq DQ = 0.1000$. On the other hand, we observe that IDAS is stable within the decision-making process; in other words it is also the best ranked in $S_j$ and $R_j$. Because only $C_1$ is not satisfied, IDAS and ALTIN are the proposed alternatives as a set of compromise solution. This is the result of only one inequity: $Q_{2} - Q_{1} = 0.1248 > DQ = 0.1000$.

Note that the value of the weight $v$ has a central role in the ranking of alternatives. A sensitivity analysis can be undertaken by setting $v$ systematically to some values between 0 and 1 and by tracking the changes in the ranking. The results of such an analysis are presented for each sector in the Turkish manufacturing industry in Table 17.

### 6. Conclusion

Financial ratios provide useful quantitative financial information to both investors and analysts so that they can evaluate the operation of a company and analyze its position within a sector over time. In this context, this study puts forth a fuzzy model proposal for the financial performance evaluation of the seven Turkish manufacturing sectors whose effective and productive performance is measured by using both traditional and modern financial ratios.

In the proposed method, FAHP has been utilized to determine the weights of the main-criteria and also sub-criteria. The two MCDM methods TOPSIS and VIKOR based on an aggregating function representing closeness to the reference point(s) have been used for ranking the companies in their own manufacturing sector comparatively.

According to the ranking results, the best company are the same with regard to both methods in five sectors that are FOOD, METAL, METAL & MACH, NONMETAL and TEXT. The best ranked company is different in the PAPER and CHEM sectors with respect to both methods. In the PAPER sector, the best ranked company according to the TOPSIS method is the second best company with respect to the VIKOR method. But in the CHEM sector, the best ranked

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**Table 15**

Ranking of the companies in the NONMETAL sector.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>VIKOR (for $v = 0.50$)</th>
<th>TOPSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$S$</td>
<td>Distance</td>
</tr>
<tr>
<td>--------------</td>
<td>-----</td>
<td>----------</td>
</tr>
<tr>
<td>ADANA</td>
<td>0.3121</td>
<td>2</td>
</tr>
<tr>
<td>AFYON</td>
<td>0.3281</td>
<td>3</td>
</tr>
<tr>
<td>AKCNS</td>
<td>0.5957</td>
<td>14</td>
</tr>
<tr>
<td>ANACM</td>
<td>0.8711</td>
<td>22</td>
</tr>
<tr>
<td>BOLUC</td>
<td>0.4900</td>
<td>9</td>
</tr>
<tr>
<td>BTCIM</td>
<td>0.5480</td>
<td>12</td>
</tr>
<tr>
<td>BUICM</td>
<td>0.5085</td>
<td>11</td>
</tr>
<tr>
<td>CIMSA</td>
<td>0.1800</td>
<td>1</td>
</tr>
<tr>
<td>CMETN</td>
<td>0.4846</td>
<td>8</td>
</tr>
<tr>
<td>CEMENT</td>
<td>0.5769</td>
<td>13</td>
</tr>
<tr>
<td>DENCIM</td>
<td>0.6534</td>
<td>16</td>
</tr>
<tr>
<td>ECYAP</td>
<td>0.8418</td>
<td>21</td>
</tr>
<tr>
<td>EGGER</td>
<td>0.7404</td>
<td>19</td>
</tr>
<tr>
<td>GOLTS</td>
<td>0.7077</td>
<td>18</td>
</tr>
<tr>
<td>HZIDR</td>
<td>0.4989</td>
<td>10</td>
</tr>
<tr>
<td>IZOCM</td>
<td>0.4217</td>
<td>6</td>
</tr>
<tr>
<td>KONYA</td>
<td>0.5999</td>
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</tr>
<tr>
<td>KUTPO</td>
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</tr>
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<td>MRDIN</td>
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<td>TRKCM</td>
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</tr>
<tr>
<td>UNYEC</td>
<td>0.3716</td>
<td>5</td>
</tr>
<tr>
<td>USAK</td>
<td>0.4612</td>
<td>7</td>
</tr>
</tbody>
</table>

**Table 16**

Ranking of the companies in the TEXT sector.

<table>
<thead>
<tr>
<th>Companies</th>
<th>VIKOR (for $v = 0.50$)</th>
<th>TOPSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$S$</td>
<td>Distance</td>
</tr>
<tr>
<td>AKALT</td>
<td>0.3704</td>
<td>5</td>
</tr>
<tr>
<td>AKIPD</td>
<td>0.5272</td>
<td>9</td>
</tr>
<tr>
<td>ALTIN</td>
<td>0.1314</td>
<td>2</td>
</tr>
<tr>
<td>ARSAN</td>
<td>0.9869</td>
<td>11</td>
</tr>
<tr>
<td>ATEKS</td>
<td>0.5313</td>
<td>10</td>
</tr>
<tr>
<td>BOSSA</td>
<td>0.2777</td>
<td>3</td>
</tr>
<tr>
<td>IDAS</td>
<td>0.1126</td>
<td>1</td>
</tr>
<tr>
<td>KORDS</td>
<td>0.5640</td>
<td>8</td>
</tr>
<tr>
<td>KRTEK</td>
<td>0.4140</td>
<td>6</td>
</tr>
<tr>
<td>MTEKS</td>
<td>0.4105</td>
<td>7</td>
</tr>
<tr>
<td>SKTAS</td>
<td>0.2732</td>
<td>4</td>
</tr>
</tbody>
</table>
company according to the TOPSIS method is the fifth best company with respect to the VIKOR method. And also, as the VIKOR method proposes a compromise solution with an advantage rate, we present compromise solution sets for each sector by using different decision making strategy weights between 0 and 1.

In today’s world economy, a company’s competitive advantage lies in the financial situations that are generally evaluated by the financial ratios. But, many studies in the literature involving MCDM procedures use only the traditional financial ratios. So, this study is different from other studies from the point of using not only the traditional AFP measures but also modern VFP measures together in a MCDM environment. Since this proposed study has quantitative financial performance measures, further study can include both quantitative and qualitative financial performance measures. In addition to the proposed methods in this study, some other MCDM methods such as ELECTRE; PROMETHEE and ORESTE can be used comparatively in a fuzzy environment.

**References**


**Table 17**

<table>
<thead>
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<th>Sector</th>
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Yurdakul, M., & Ye, Y. T. (2003). An illustrative study aimed to measure and rank performance of Turkish automotive companies using TOPSIS. *Journal of the Faculty of Engineering and Architecture of Cadi University, 19*(1), 1–18.


