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Performance Evaluation and Management of Indian Manufacturing Organizations Through Fuzzy Optimization Techniques

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Abstract: In a context of intense competition, evaluating financial performance is crucial for manufacturing sectors. As such, a precise and fitting performance review is essential. In the process of evaluation, financial performance indicators need to be carefully chosen because they show how competitive a business is. In this paper, the financial performances of the firms in the Indian manufacturing industry are evaluated using financial ratios, specifically accounting-based financial performance (AFP) measures and value-based financial performance (VFP) measures. These financial performances are assessed through multi-criteria decision-making (MCDM) techniques, specifically fuzzy multi-objective and optimization on the basis of ratio analysis (F-MOORA) and fuzzy step-wise weight assessment ratio (F-SWARA). First, the financial performance indicators' weights are determined by the F-SWARA approach, and then the firms' rankings are determined by the F-MOORA approach. By applying SWARA methodology in a fuzzy environment, the implications of the findings demonstrate that the factor named Return on Assets (ROA) contains the maximum weight and the factor named regret contains the lowest weight. By applying F-MOORA technique, it also demonstrates that company C1 is the best and company C3 is the worst.

Introduction

In the contemporary global economy, assessing a firm's financial performance is crucial for management, creditors, present and future investors, and other businesses operating within the same industry. Corporate performance evaluations are typically conducted in conjunction with financial assessments. Since the term "financial performance" can refer to various concepts, it may be advantageous for corporations to use financial ratios when evaluating performance. The income statement and balance sheet data are used to calculate financial ratios, which are important measurement instruments for assessing a firm's performance and financial standing.

The importance of financial ratios also highlights a company's strengths and weaknesses with regard to

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growth, profitability, and liquidity. The most widely used financial measures in performance evaluations are conventional financial indicators, most of which are connected to profitability. The firm's financial condition and ratings have essentially been assessed using traditional financial metrics called accounting-based financial performance (AFP) measures. These metrics offer insightful quantitative financial data to analysts and investors, enabling them to assess a firm's performance over time and assess its place in a certain industry.

Based on the information they give, AFP metrics can be categorized as growth, activity, financial leverage, profitability, liquidity, and ratios. For a long time, conventional AFP metrics have been chastised for not being sufficient in directing strategic choices. The 1990s saw the introduction of new metrics and analytical tools for gauging a business's performance. Traditional AFP measurements are receiving less attention as modern value-based financial performance (VFP) indicators emerge as viable options for manufacturing organizations looking to create value. Since value creation is what the shareholders anticipate receiving in exchange for their capital investment and assume risks, they have a direct stake in its success. The managers' and employees' immediate interests are also met by the strategic goal of increasing the corporation's standards.

Value creation in the context of a national economy refers to the effective use of that economy's potential as well as growth in GDP that supports social welfare. Since value creation is what the shareholders anticipate receiving in exchange for their capital investment and assume risks, they have a direct stake in its success. This study aims to rate the firms of the Indian manufacturing company by combining the AFP and VFP metrics into two evaluation methodologies. This work proposes two approaches: F-MOORA and F-SWARA. First, the weight of financial performance indicators is determined by the F-SWARA approach, and then the firms' rankings are determined by the F-MOORA approach. As human opinions and preferences are frequently imprecise and cannot be precisely quantified, precise data is frequently insufficient for modeling real-life scenarios.

When it comes to handling information-related ambiguity and imprecision, the fuzzy set theory makes sense. This idea is the best weapon for illuminating the vagueness of concepts connected to people's subjective, frequently imprecise judgments'. Using language factors is one of the simplest methods to make these subjective judgments' clearer. The idea of a linguistic variable comes in particularly handy when handling circumstances that are either overly complicated or poorly defined. Fuzzy numbers that are most frequently employed in both theory and practice are triangular and trapezoidal fuzzy numerals. Triangular fuzzy numerals have properties that make them easier to calculate and make them more useful in real-world applications. Therefore, triangle fuzzy numbers are chosen to represent the linguistic variables in this study. The purpose of this study is to determine the best and worst Indian manufacturing companies on the basis of identified financial evaluation measures through the fuzzy mathematical modeling, namely F-SWARA and F-MOORA, in terms of linguistic concepts by applying TrFNs in order to run the organizations efficiently.

This is how the paper is structured. Literature review on financial performance measures, the F-SWARA approach, and the F-MOORA technique with an emphasis on performance measurements is provided. The financial ratios utilized in the performance assessment of the firms—AFP and VFP—are outlined. We discuss the methodology of the F-SWARA and F-MOORA approaches. The financial performance assessment of the businesses in each of the seven Indian organizations is provided. The application's results are shown in the last section, along with recommendations for more study.

Literature Review

Using fuzzy numbers, which Zadeh (1965) proposed, many research in the financial performance literature concentrates on establishing the links between financial metrics and the impact of these measures on the performance of organizations. Regression models are frequently used in these studies to demonstrate how much financial metrics account for a company's performance. Performance evaluation is thought of as an MCDM problem, where the choice is made from a group of options that are described by qualities. Finding the best option with the maximum level of satisfaction for all pertinent criteria is the goal of the MCDM (Yang et al., 2007). A fuzzy MCDM approach was used by Wang (2008) to assess the financial performance of Taiwan's local carriers.

A method of balanced score-card (BSC) and FAHP was developed by Lee et al. (2008) for the assessment of an IT section. By combining the FAHP and TOPSIS approaches, Secme et al. (2009) developed a fuzzy model containing financial as well as non-financial performance factors of Turkish banking firms. Three criteria are used to evaluate commercial banks in that study: performance, non-performance, and financial performance. By combining the FAHP and TOPSIS approaches, Ertug˘rul and Karakas_og˘lu (2009) created a fuzzy methodology

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to assess the financial performance of Turkish cement corporations. Only a few of the conventional AFP indicators are taken into account when evaluating cement companies.

Getting an assessment of the financial performance of Taiwan container lines, Wang (2009) coupled fuzzy MCDM with grey analysis. Yalcin et al. (2012) suggested a novel way for evaluating the financial performance in Turkish corporation businesses by employing fuzzy MCDM in which accounting-based and value-based financial performance factors were studied. They constructed a hierarchy of evaluation criteria using fuzzy AHP and they employed VIKOR and TOPSIS as ranking methods. Yilmaz and Konyar (2013) assessed the financial performance of 9 hotels on the Istanbul Stock Exchange by TOPSIS. A fuzzy MCDM approach was analyzed by Mandic et al. (2014) to help in evaluating the financial performance of banks.

Between 2005 and 2010, research was conducted on Serbia's banking industry. Shen and Tzeng (2014) presented an integrated two-stage inference approach to forecast banks' financial success. Financial metrics are used by Marichova and Durisova (2015) to estimate the financial performance of businesses in IT companies. O'Neill et al. (2016) examine quality-based management strategies and how they affect a company's bottom line. During the global financial crisis, Khuan et al. (2017) assessed Malaysian property development enterprises for their operational strategies and financial performances.

The most popular technique for assessing a company's risk and profitability and assessing its financial status is to utilize financial ratios. Ratios, however, have little significance until they are compared to industry norms, standards, or specific competitors. Using F-AHP and F-TOPSIS model, they assessed the financial performance of Turkish airline businesses, as stated by Aldalou and Percin (2018). Using DEA method, Karimi & Barati (2018) assessed the financial performances of firms on the Tehran Stock Exchange. A thorough assessment of the financial performance of intermediary corporations using MCDM was first presented by Aras et al. (2018). A MCDM method was used by Pineda et al. (2018) to enhance the operational and financial performance of airlines. A work on the financial status of young CSOs in Turkey's TRB1 Region was conducted by Ayhan (2019).

Decision-making using numerous criteria was applied in financial modeling by De Almeida et al. (2020). An objective criterion proposal was used by Bayda & Elma (2021) to compare the weighting and MCDM approaches in financial performance measuring. Using information from financial markets, Bayda et al. (2022) investigated the unique capabilities of several MCDM under uncertainty. Agarwal et al. (2022) analyzed a study on benchmarking the interactions among green as well as sustainable vendor selection factors. Agarwal et al. (2023) developed a strategy for the selection of the best sustainable as well as resilient supplier through F-EDAS strategy. Again Agarwal et al. (2023) study a strategy for the selection of the best sustainable vendor through ARAS strategy. Işık et al. (2024) developed a consolidated MCDM structure for the overall performance assessment of listed insurance industries on the basis of ranking strategies. Mastilo et al. (2024) assessed the banking sector of Bosnia and Herzegovina by analyzing Financial Indicators by applying MEREC as well as MARCOS approaches.

Research Methodology

To evaluate the performance of Indian manufacturing companies, an extended and new version of the fuzzy MCDM technique, named F-SWARA and F-MOORA is used in this study. In many earlier studies, researchers applied the fuzzy set theory to obtain more realistic results in unpredictable conditions. Embedding Fuzzy with traditional MCDM techniques like SWRA and MOORA gives a robust mathematical structure which can investigate the indefinite conceptual situation, which can be carefully studied to solve the identified problem in this study.

This modeling language is well suited for conditions in a fuzzy environment and mathematically represented as:

Set U, is a non-empty universal fuzzy set. The set $A = < x, \mu_A(x) >$, the grade of membership of x in A is represented by $\mu_A(x): U \rightarrow [0,1]$.

The fuzzy set $B =< b_1, b_2, b_3 >$ on R is referred to as a TFN, whose membership function can be expressed as shown below in figure 1:

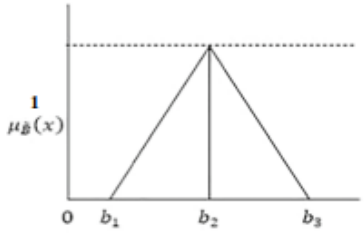

Fig. 1

This paper looks at the evaluation of the performance of the Indian manufacturing organizations on the basis of identified criteria for applying MCDM strategies called SWARA as well as MOORA in fuzzy surroundings where SWARA strategy is applicable to establishing the weightage of the factors and MOORA strategy is

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applicable to establish the best as well as worst company and also the gratings of the companies in probabilistic surroundings made by linguistic concepts by triangular fuzzy numbers deciding through resource persons.

Financial performance measures

The financial performance evaluation metrics have grown in diversity and scope in tandem with technological advancements and management perceptions of the organization. Performance measurements are a hybrid of conventional and contemporary financial ratios, referred to as VFP and AFP measures, respectively. Sub-measures of indicators are essential for assessing performance, particularly in the manufacturing sector. The following provides a quick explanation of each primary criterion's sub-criteria measures.

Financial performance measures

The expert group from ISE determined 4 traditional measures as the sub-criteria of the AFP main criterion in this study to estimate all the enterprises in the Turkish corporation. These metrics include price/earnings ratio (P/E), earnings per share (EPS), return on assets (ROA), and return on equity (ROE). The following is a brief explanation of each of these sub-criteria.

Return on Assets (ROA)

This metric compares a firm's net income for a given year to its average total assets for that same year. ROA is a profitability metric that is represented as a percentage for a business. This statistic is crucial for the manufacturing industries since it shows how well a company has generated earnings using all of its available assets. Put differently, return on assets (ROA) provides a handy means of contrasting a business's performance with that of its rivals.

ROA = Net Income Available to Common Stockholders/Total Assets

Return on equity (ROE)

It calculates the percentage of gain received from the investments made in the companies by common stockholders. ROE is a significant and frequently used financial statistic in companies. Theoretically, a business that wants to maximize shareholder wealth ought to aim to maximize this ratio. As a result, it is possible to argue that the purpose of this performance metric is to gauge the expected return on investors' firm shares.

ROE =Net Income Available to Common Stockholders/Stockholder’s Equity

Earnings per share (EPS)

EPS is a crucial metric that shows how strong a business is. Most people agree that the most crucial factor in figuring out a share's price is its earnings per share (EPS). It plays a significant role in the price-to-earnings valuation ratio computation as well. It is an important metric as the market responds to a firm's capacity to satisfy its profit forecasts.

EPS =Net Income Available to Shareholders / Number of Shares Outstanding

Price-earnings ratio (P/E)

How much investors are ready to pay for every dollar of current earnings is shown by the P/E ratio. What the merchandise is ready to pay for a corporation's earnings is the fundamental concept of the P/E ratio.

P/E = Market Price per Share / Earnings per Share

Modern value-based financial performance measures

The expert group identifies 4 contemporary metrics as the sub-criteria of the VFP main-criteria in this study, which is used to assess every firm in every Turkish corporation. Cash Flow Return on Investment (CFROI), Market Value Added (MVA), Economic Value Added (EVA), and Cash Value Added (CVA) are the metrics used to calculate these values. The following is a quick explanation of these sub-criteria measurements.

Economic Value Added (EVA)

Taking the price of capital into account when assessing performance evaluation is a crucial aspect of EVA. EVA is a residual income metric that emphasizes the need for a business to provide a sufficient return on its asset investment.

Market Value Added (MVA)

Maximizing the gap between firm's overall market worth and the amount of capital that investors have contributed to the firm is how shareholder wealth is maximized. This distinction is called MVA.

Total Market Value minus Total Capital Employed equals MVA.

Cash Flow Return on Investment (CFROI)

It calculates the actual cash return as a percentage of the capital invested in a corporation. The rate of return known as CFROI is what brings a company's gross cash investment. to equal with the present value of its future cash flows, including a "terminal value" from the release of non-depreciating assets.

CFROI is the same as Gross Investment / Cash Flows.

Cash Value Added (CVA)

The metric preserves the benefit of total capital costs while producing a profit figure that is even more in line with cash flow than the adjusted EVA. Value-based business management uses CVA to monitor economic performance and control through strategic and operational financial planning.

CVA = Cash Flows from operating - Depreciation - Capital Cost

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Methodology of F-SWARA approach

The traditional SWARA method for crisp values was initially put forth by Kersˇulienein et al. 2010. It is used to rank the criteria according to their weights, allowing the best option to be chosen. It also serves to assess the weights of the criterion. Using precise numerical data, purchasing managers express their preferences for certain criteria in this manner. However, this approach is not suitable for handling unclear environments. A revised version of the fuzzy SWARA approach is offered as a solution to this problem. The decision managers in the F-SWARA approach validate the fuzzy preference values of the criterion based on linguistic phrases expressed in terms of fuzzy triangular numbers. The F-SWARA approach does not require a pair-wise association of criteria, in contrast to the F-AHP method.

Step 1 Recognition of criteria - First, a long list of financial performance metrics is identified in this step based on the experts' discussion of their decreasing order of projected relevance.

Step 2 Define linguistic concepts (l_c)- At first, from the 2^{nd} measures, $(j-1)^{th}$measure is differentiated by j^{th} measure by linguistic concepts by applyingTrFNs decided by researchers, which means comparative importance of mean value.

Step 3 Finding fuzzy coefficient value (f_{cv}) –It is computed as:

$$f_{cv} = \begin{cases} 1\,, & whenj\ is\ 1 \\ l_c + 1\,, & whenj\ is\ greater\ than\ 1 \end{cases} \quad (1)$$

Step 4 Computing fuzzy re-calculated weights (f_{rw})–It is computed by:

$$f_{rw} = \begin{cases} 1\,, & whenj\ is\ 1 \\ \dfrac{f_{rw-1}}{f_{cv}}\,, & whenj\ is\ greater\ than\ 1 \end{cases} \quad (2)$$

Step 5 Computing fuzzy weights (w_f) - They are computed by:

$$w_f = \frac{f_{rw}}{\Sigma f_{rw}} \quad (3)$$

Where $w_f = (w_f^1, w_f^2, w_f^3)$

Step 6 Transforming fuzzy weights to crisp weights(w_c) – They are calculated as:

$$w_c = \frac{1}{3}(w_f^1 + w_f^2 + w_f^3) \quad (4)$$

Methodology of F-MOORA approach

Brauers and Zavadskas (2006) proposed the MOORA strategy for the first time. The three types of MOORA methods are Full Multiplicative Form, Reference Point Approach, and Ratio System. The finance managers and the expert group validate the fuzzy preference values of the criterion in the F-MOORA approach based on linguistic phrases that are articulated in terms of fuzzy triangular numbers. The following are the steps in the F-MOORA method.

Step 1 - Establishing a group of experts, confirming the firms, and identifying the limited financial performance measures – It is the initial step in identifying the team of experts, companies and financial performance measures.

Step 2 - Confirming linguistic concepts for estimating the weights of measures and the performance ratings of companies - The significant weights of financial performance measures and performance fuzzy rating of the companies are expressed by linguistic concepts in the form of TrFNs through the experiences of the experts.

Step 3–Forming decision matrix - This is formed by the experiences of researchers using linguistic terms through TrFNs.

Step 4–Changing fuzzy to crisp matrix by ranking function – A fuzzy decision matrix is changed to a crisp matrix through ranking function. In a ranking function, Liou & Wang (1992), a fuzzy numeral is mapped to a real numeral in such a way that $\Re : F(\mathbb{R}) \to \mathbb{R}$, where F(R) be a fuzzy set. For two triangular fuzzy numerals, m = (α, β, γ) and n, [1] proposed a ranking function as:

i. $\tilde{m} \precsim \tilde{n}$ iff $\mathcal{R}(\tilde{m}) \leq \mathcal{R}(\tilde{n})$,
ii. $\tilde{m} \approx \tilde{n}$ iff $\mathcal{R}(\tilde{m}) = \mathcal{R}(\tilde{n})$,
iii. $\tilde{m} \succsim \tilde{n}$ iff $\mathcal{R}(\tilde{m}) \geq \mathcal{R}(\tilde{n})$

where $\mathcal{R} = \frac{\alpha+2\beta+\gamma}{4}$ (5)

Step 5-Developing normalized decision matrix (a_{ij}^*)- It is determined as:

$$a_{ij}^* = \frac{a_{ij}}{\sqrt{\Sigma a_{ij}^2}} \quad (6)$$

Step 6–Developing weighted-normalized decision matrix (v_{ij})- It is determined as:

$$v_{ij} = w_j * a_{ij}^* \quad (7)$$

Step 7-Final preference values (p_i^*) - In this step, the final preference values are estimated as:

$$p_i^* = \sum_{j=1}^{l} v_{ij} - \sum_{l+1}^{n} v_{ij} \text{ q} \quad (8)$$

Where $j = 1, 2, \ldots, l$ represents the beneficial attributes while $j = l+1, l+2, \ldots, n$ represents the non-beneficial attributes.

Step 8-Estimating ranking of the alternatives(r_a) - Alternatives are ranked by final preference values. If the final preference values of the alternatives are maximum, then that alternative is ranked 1.

$$r_a = max\,(p_i^*) \quad (9)$$

Numerical Analysis

In this part, we identified a total of eight financial performance measures from the literature review, six

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companies, namely C1 – C6 of Indian manufacturing industries and three experts. Financial performance measures include - Cash Value Added (CVA), Market Value Added (MVA), Return on assets (ROA), Economic Value Added (EVA), Return on equity (ROE), Earnings per share (EPS), Cash Flow Return on Investment (CFROI), Price earnings ratio (P/E), Economic opportunity loss (EOL) and regret. All criteria except

Table 1. Linguistic concepts of measures.

Linguistic Concepts	TrFNs
EL: Extremely low	(0.0, 0.0, 0.1)
VL: Very Low	(0.0, 0.1, 0.3)
L: Low	(0.1, 0.3, 0.5)
M: Medium	(0.3, 0.5, 0.7)
H: High	(0.5, 0.7, 0.9)
VH: Very High	(0.7, 0.9, 1.0)
EH: Extremely High	(0.9, 1.0, 1.0)

Table 2. Linguistic concepts of fuzzy ratings of companies.

Linguistic Concepts	Fuzzy Numbers
VL: Very Low	1,1,3
L: Low	1,3,5
AVG: Average	3,5,7
H: High	5,7,9
VH: Very High	7,9,9

Table 3. Estimating f_{cv} and f_{rw}.

Financial performance measures	l_c	f_{cv}	f_{rw}
ROA		(1, 1, 1)	(1, 1, 1)
ROE	(0.9, 1, 1)	(1.9, 2, 2)	(0.52, 0.51, 0.51)
EPS	(0.9, 1, 1)	(1.9, 2, 2)	(0.28,0.25,0.26)
P/E	(0.7, 0.9, 1)	(1.7, 1.9, 2)	(0.17,0.14,0.13)
EVA	(0.7, 0.9, 1)	(1.7, 1.9, 2)	(0.08,0.07,0.07)
MVA	(0.5, 0.7, 0.9)	(1.5, 1.7, 1.9)	(0.06,0.05,0.04)
CFROI	(0.5, 0.7, 0.9)	(1.5, 1.7, 1.9)	(0.05,0.03,0.03)
CVA	(0.3, 0.5, 0.7)	(1.3, 1.5, 1.7)	(0.04,0.01,0.02)
EOL	(0.3, 0.5, 0.7)	(1.3, 1.5, 1.7)	(0.03,0.006,0.006)
Regret	(0.1, 0.3, 0.5)	(1.1, 1.3, 1.5)	(0.001,0.004,0.003)

Table 4. Finding w_f and w_c.

Financial performance measures	w_f	w_c
ROA	(0.45,0.49,0.51)	0.48
ROE	(0.24,0.25,0.24)	0.25
EPS	(0.13,0.12,0.13)	0.12
P/E	(0.08,0.07,0.07)	0.07
EVA	(0.05,0.04,0.04)	0.04
MVA	(0.04,0.03,0.02)	0.03
CFROI	(0.03,0.008,0.008)	0.012
CVA	(0.02,0.005,0.004)	0.006
EOL	(0.008,0.002,0.003)	0.004
Regret	(0.0004,0.0019,0.0014)	0.0012

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EOL and regret are beneficial criteria. Linguistic concepts of attributes and fuzzy ratings of the criteria and companies are determined by the judgments of researchers in the form of TrFNs which are represented in following tables 1and 2.

Estimating f_{cv} as well asf_{rw} through eq. (1) and (2), respectively, which depicts Table 3.

Evaluating the fuzzy and crisp weights of all the measures through eq. (3) and (4) respectively which depicts Table 4.

Linguistic variables of all the companies assessment by all the experts are shown in the Tables 5, 6 and 7.

Now, constructing the fuzzy decision matrix assessed by all the experts by TrFNs as shown in the Tables 8, 9 and 10.

Table 5. Linguistic variables of company's assessment by first expert.

	ROA	ROE	EPS	P/E	EVA	MVA	CFROI	CVA	EOL	Regret
C1	VH	H	A	VH	L	H	H	L	A	VH
C2	H	VH	L	A	VH	A	L	VH	H	A
C3	L	A	VH	H	A	L	VH	L	A	H
C4	A	L	H	L	H	VH	A	L	VH	A
C5	VH	H	L	A	L	VH	H	VH	L	A
C6	H	A	A	H	H	H	L	VH	A	L

Table 6. Linguistic variables of company's assessment by second expert.

	ROA	ROE	EPS	P/E	EVA	MVA	CFROI	CVA	EOL	Regret
C1	H	VH	H	L	VH	A	L	H	VH	A
C2	VH	A	L	A	H	L	VH	H	L	A
C3	L	H	A	H	VH	A	L	A	H	VH
C4	A	L	VH	VH	H	H	A	L	H	H
C5	VH	H	H	A	L	H	A	VH	L	A
C6	A	L	VH	H	VH	L	H	H	A	L

Table 7. Linguistic variables of company's assessment by the third expert.

	ROA	ROE	EPS	P/E	EVA	MVA	CFROI	CVA	EOL	Regret
C1	VH	H	A	L	VH	L	A	H	VH	A
C2	A	L	L	VH	L	H	VH	A	L	H
C3	L	A	VH	H	A	L	H	VH	H	A
C4	H	VH	A	L	VH	H	L	H	A	H
C5	H	H	L	VH	A	L	VH	H	L	VH
C6	VH	A	L	H	VH	A	H	VH	H	L

Table 8. Fuzzy decision matrix assessment by first expert.

	ROA	ROE	EPS	P/E	EVA	MVA	CFROI	CVA	EOL	Regret
C1	7,9,9	5,7,9	3,5,7	7,9,9	1,3,5	5,7,9	5,7,9	1,3,5	3,5,7	7,9,9
C2	5,7,9	7,9,9	1,3,5	3,5,7	7,9,9	3,5,7	1,3,5	7,9,9	5,7,9	3,5,7
C3	1,3,5	3,5,7	7,9,9	5,7,9	3,5,7	1,3,5	7,9,9	1,3,5	3,5,7	5,7,9
C4	3,5,7	1,3,5	5,7,9	1,3,5	5,7,9	7,9,9	3,5,7	1,3,5	7,9,9	3,5,7
C5	7,9,9	5,7,9	1,3,5	3,5,7	1,3,5	7,9,9	5,7,9	7,9,9	1,3,5	3,5,7
C6	5,7,9	3,5,7	3,5,7	5,7,9	7,9,9	5,7,9	1,3,5	7,9,9	3,5,7	1,3,5

Table 9. Fuzzy decision matrix assessment by second expert.

	ROA	ROE	EPS	P/E	EVA	MVA	CFROI	CVA	EOL	Regret
SS1	5,7,9	7,9,9	5,7,9	1,3,5	7,9,9	3,5,7	1,3,5	5,7,9	7,9,9	3,5,7
SS2	7,9,9	3,5,7	1,3,5	3,5,7	5,7,9	1,3,5	7,9,9	5,7,9	1,3,5	3,5,7
SS3	1,3,5	5,7,9	3,5,7	5,7,9	7,9,9	3,5,7	1,3,5	3,5,7	5,7,9	7,9,9
SS4	3,5,7	1,3,5	7,9,9	7,9,9	5,7,9	5,7,9	3,5,7	1,3,5	5,7,9	5,7,9
SS5	7,9,9	5,7,9	5,7,9	3,5,7	1,3,5	5,7,9	3,5,7	7,9,9	1,3,5	3,5,7
SS6	3,5,7	1,3,5	7,9,9	5,7,9	7,9,9	1,3,5	5,7,9	5,7,9	3,5,7	1,3,5

Table 10. Fuzzy decision matrix assessment by the third expert.

	ROA	ROE	EPS	P/E	EVA	MVA	CFROI	CVA	EOL	Regret
C1	7,9,9	5,7,9	3,5,7	1,3,5	7,9,9	1,3,5	3,5,7	5,7,9	7,9,9	3,5,7
C2	3,5,7	1,3,5	1,3,5	7,9,9	1,3,5	5,7,9	7,9,9	3,5,7	1,3,5	5,7,9
C3	1,3,5	3,5,7	7,9,9	5,7,9	3,5,7	1,3,5	5,7,9	7,9,9	5,7,9	3,5,7
C4	5,7,9	7,9,9	3,5,7	1,3,5	7,9,9	5,7,9	1,3,5	5,7,9	3,5,7	5,7,9
C5	5,7,9	5,7,9	1,3,5	7,9,9	3,5,7	1,3,5	7,9,9	5,7,9	1,3,5	7,9,9
C6	7,9,9	3,5,7	1,3,5	5,7,9	7,9,9	3,5,7	5,7,9	7,9,9	5,7,9	1,3,5

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Developing a combined fuzzy decision matrix by the assessment of researchers by linguistic concepts through TrFNs for deciding the fuzzy performance ratings of companies, as depicted in Table 11.

Now, constructing a combined fuzzy decision matrix into a crisp matrix through ranking function by using the eq. (5) which depicts Table 12.

Developing normalized decision matrix through equation (6) for financial performance measures, which depicts Table 13.

Table 11. Combined Fuzzy decision matrix assessed by all the experts.

	ROA	ROE	EPS	P/E	EVA	MVA	CFROI	CVA	EOL	Regret
C1	6.3,8.3,9	5.7,7.7,9	3.7,5.7,7.7	3,5,6.3	5,7,7.7	3,5,7	3,5,7	3.7,5.7,7.7	5.7,7.7,8.3	4.3,6.3,7.7
C2	5,7,8.3	3.7,5.7,7	1,3,5	4.3,8,7.7	4.3,6.3,7.7	3,5,7	5,7,7.7	5,7,8.3	2.3,4.3,6.3	3.7,5.7,7.7
C3	1,3,5	3.7,5.7,7.7	5.7,7.7,8.3	5,7,9	4.3,6.3,7.7	1.7,3.7,5.7	4.3,6.3,7.7	3.7,5.7,7	4.3,6.3,8.3	5,7,8.3
C4	3.7,5.7,7.7	3,5,6.3	5,7,8.3	3,5,6.3	5.7,7.7,9	5.7,7.7,9	2.3,4.3,6.3	2.3,4.3,6.3	5,7,8.3	4.3,6.3,8.3
C5	6.3,8.3,9	5,7,9	2.3,4.3,6.3	4.3,6.3,7.7	1.7,3.7,5.7	4.3,6.3,7.7	5,7,8.3	6.3,8.3,9	1,3,5	4.3,6.3,7.7
C6	5,7,8.3	2.3,4.3,6.3	3.7,5.7,7	5,7,9	7,9,9	3,5,7	3.7,5.7,8.3	6.3,8.3,9	3.7,5.7,7.7	1,3,5

Table 12. Combined crisp decision matrix.

	ROA	ROE	EPS	P/E	EVA	MVA	CFROI	CVA	EOL	Regret
C1	7.975	7.525	5.700	4.825	6.675	5.000	5.000	5.700	7.350	6.150
C2	6.825	5.525	3.000	7.000	6.150	5.000	6.675	6.825	4.300	5.700
C3	3.000	5.700	7.350	7.000	6.150	3.700	6.150	5.525	6.300	6.825
C4	5.700	4.825	6.825	4.825	7.525	7.525	4.300	4.300	6.825	6.300
C5	7.975	7.000	4.300	6.150	3.700	6.150	6.825	7.975	3.000	6.150
C6	6.825	4.300	5.525	7.000	8.500	5.000	5.850	7.975	5.700	3.000

Table 13. Normalized decision matrix.

	ROA	ROE	EPS	P/E	EVA	MVA	CFROI	CVA	EOL	Regret
C1	3.93	3.90	2.34	1.53	2.75	1.84	1.73	2.03	3.81	2.65
C2	2.87	2.10	0.65	3.22	2.33	1.84	3.10	2.91	1.30	2.27
C3	0.55	2.24	3.90	3.22	2.33	1.01	2.63	1.91	2.80	3.26
C4	2.00	1.60	3.38	1.53	3.49	4.18	1.28	1.15	3.29	2.78
C5	3.93	3.37	1.33	2.48	0.84	2.79	3.24	3.98	0.63	2.65
C6	2.87	1.27	2.20	3.22	4.45	1.84	2.38	3.98	2.29	0.63

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Developing a weighted normalized decision matrix through equation (7), which depicts Table 14.

Now, estimating the final preference values and ranking of the companies through equations (9) and (10) respectively and is shown in Table 15.

Table 14. Weighted- Normalized decision matrix.

	ROA	ROE	EPS	P/E	EVA	MVA	CFROI	CVA	EOL	Regret
C1	1.88	0.93	0.28	0.10	0.08	0.03	0.02	0.01	0.02	0.003
C2	1.37	0.50	0.07	0.22	0.06	0.03	0.03	0.02	0.005	0.002
C3	0.26	0.53	0.46	0.22	0.06	0.02	0.03	0.01	0.01	0.004
C4	0.96	0.38	0.40	0.10	0.10	0.08	0.01	0.006	0.01	0.003
C5	1.88	0.80	0.15	0.17	0.02	0.05	0.04	0.02	0.002	0.003
C6	1.37	0.30	0.26	0.22	0.13	0.03	0.03	0.02	0.009	0.0007

Table 15. Estimation of final preference values and ranking of companies.

Companies	Final preference values	Ranking of companies
C1	3.307	1
C2	2.293	4
C3	1.576	6
C4	2.023	5
C5	3.125	2
C6	2.350	3

Finally, Table 16 shows the ranking of the companies - SS1>SS5>SS3>SS2> SS4 > SS3.

Conclusion, Limitations of the study and Future scope

Financial ratios give analysts and investors relevant quantitative financial data that they may use to assess a firm's performance over time and examine its place in a sector. Within this framework, the paper proposes a fuzzy strategy for evaluating the financial performance of the Turkish industrial corporations, where conventional as well as current financial criteria are used to determine effective and productive performance. The suggested approach uses a new fuzzy multi-criteria optimization technique (F-MOORA) to rank the firms of Turkish corporations and to determine the weights of the financial performance measures.

The main benefit of using MCDM approaches is that they are readily accessible to all users. However, the main limitation of MCDM techniques is that the users must be professionals, scholars, and outstanding investigators. This technique uses fuzzy theory to address the problems of uncertainties, ambiguities, obscurities, vagueness, etc., in DM problems. However, fuzzy theory's primary limitation is that it can only be applied in fuzzy environments. The recommended technique requires less processing time than earlier MCDM techniques. Because of this, DM finds this method to be beneficial and applicable to various business operations.

A company's competitive advantage in the global economy of today is derived from its financial circumstances, which are typically assessed using financial ratios. However, a large number of MCDM procedure-related research in the literature exclusively make use of conventional financial ratios. Thus, this study differs from others in that it employs contemporary VFP measures in addition to the conventional AFP measures inside an MCDM setting. Further research can incorporate both quantitative and qualitative financial performance measurements, as the presented study includes quantitative financial performance measures. Many MCDM techniques, like ELECTRE, PROMETHEE, TOPSIS, SWARA, etc., may be applied comparably in fuzzy surroundings.

The conclusion of this study shows that the company which has the highest final preference value is given the first rank whereas the company that has the lowest final preference value is given the last rank. This paper also concludes that the first company is best and the third company is worst and also determines the order of the ranking of the companies by taking the final preference values of the companies by implementing the techniques of SWARA and MOORA in a fuzzy environment. In future cases, the fuzzy SWARA and fuzzy MOORA

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approaches can be applied to other business evaluation problems in different domains related to both service and manufacturing organizations.

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Conflict of Interest

The authors declare no conflict of interest.

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