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A Hybrid Fuzzy MCDM Approach for Security Analysis and Portfolio Optimization

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Abstract
This study evaluates the key financial criteria influencing investment decisions in the Indian stock market using the Fuzzy Analytic Hierarchy Process (FAHP). Data were collected from the top 10 companies listed on the Bombay Stock Exchange (BSE), and expert judgments were obtained from two highly experienced professionals: an investor and a professor of finance, each with more than 30 years of expertise. Six financial criteria were considered: Return on Equity (ROE), Earnings Per Share (EPS), Price-to-Earnings (P/E) Ratio, Debt-to-Equity (D/E) Ratio, Current Ratio, and Return on Assets (ROA). The FAHP model identified ROE as the most significant factor, followed by EPS, P/E Ratio, D/E Ratio, and ROA, while the Current Ratio ranked lowest. The findings highlight that profitability-related measures dominate investor preferences, whereas liquidity indicators exert minimal influence. This research provides valuable insights for investors by emphasizing the prioritization of profitability and growth metrics over short-term solvency in portfolio selection.
Keywords: Fuzzy Analytic Hierarchy Process (FAHP); Investment Decision-Making; Financial Criteria,FMCDM.

1.INTRODUCTION

An active and well-functioning capital market is widely recognized as a hallmark of economic development at both national and international levels. Vibrant markets not only enhance financial integration but also facilitate capital formation, which in turn contributes to the growth and prosperity of industries across sectors. Investor participation plays a crucial role in this process, as their willingness to take an active role in trading fosters liquidity, efficiency, and market stability. To maximize returns, investors generally prefer to select stocks of companies that demonstrate strong financial performance and upward stock price trends. However, because financial markets are inherently uncertain, investors face challenges in predicting future returns with certainty. Consequently, portfolio diversification becomes an essential strategy to minimize the risk of losses while ensuring sustainable growth (Secme et al., 2009). Portfolio selection has long been regarded as a central issue in finance, as it represents a classic case of decision-making under risk. Since the future returns of assets are not known at the time of investment, investors must rely on ex-ante models to guide their decisions. The performance of such decisions can only be evaluated once the uncertainty surrounding asset returns is resolved. Thus, portfolio selection models serve as critical decision-making tools, enabling investors to evaluate trade-offs between risk and return in advance (Roman & Mitra, 2009). The foundation of modern portfolio theory (MPT) was laid by Markowitz (1952), who introduced the mean-variance framework. In this approach, portfolio risk is

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measured by the variance and covariance of asset returns, leading to a quadratic programming formulation for constructing efficient portfolios. The Markowitz model was later extended by Sharpe (1966), Lintner (1965), and Mossin (1966), which collectively gave rise to the Capital Asset Pricing Model (CAPM). These developments firmly established the mean-variance approach as a cornerstone of portfolio management, guiding investors and fund managers in their pursuit of efficient portfolios that maximize diversification benefits. Despite its popularity, traditional portfolio selection models face limitations when applied to real-world scenarios. Investors often consider multiple qualitative and quantitative factors—such as firm size, financial ratios, stock market conditions, and managerial performance—when evaluating stocks. These factors are often conflicting, interdependent, and subject to uncertainty. The task of identifying, comparing, and weighting such criteria in stock selection is both complex and computationally demanding. To address this challenge, researchers have increasingly turned to multi-criteria decision-making (MCDM) methods, which enable systematic evaluation of alternatives under multiple attributes. In particular, the integration of fuzzy logic into MCDM provides a powerful framework for handling uncertainty, vagueness, and imprecision in financial decision-making. A hybrid fuzzy decision-making approach, therefore, offers a robust methodology for portfolio selection by combining quantitative rigor with qualitative judgment, ultimately assisting investors in constructing optimal portfolios under uncertainty.

1.1. LITERATURE REVIEW

Since its inception, the fuzzy Analytic Hierarchy Process (FAHP) has become one of the most widely adopted fuzzy multi-criteria decision-making (MCDM) methods, addressing the limitations of Saaty's crisp AHP in handling vagueness and uncertainty in expert judgments. Early contributions, such as Chang's (1996) extent analysis method based on triangular fuzzy numbers, provided the foundation for practical FAHP applications that could convert subjective preferences into decision weights. During the following decades, FAHP gained increasing attention across diverse domains, with Kahraman (2008) presenting comprehensive theoretical advancements and applications in engineering, management, and finance. At the same time, methodological critiques, such as those of Wang and Chin (2008), highlighted issues with the robustness of fuzzy pairwise comparison matrices, encouraging refinements in weighting procedures and consistency checks. In the financial domain, FAHP began to gain traction in the late 2000s. Tiryaki and Ahlatcıoğlu (2009) demonstrated one of the first FAHP-based portfolio selection models, showing its potential to incorporate investor preferences and qualitative judgments into asset ranking. Similarly, Roman and Mitra (2009) emphasized the importance of multi-criteria approaches in portfolio selection under uncertainty, reinforcing FAHP's relevance for financial decision-making. Building on this foundation, subsequent research explored hybrid models, where FAHP was combined with other MCDM techniques such as TOPSIS, GRA, and VIKOR. These hybrid frameworks allowed FAHP to generate criteria weights, followed by ranking alternatives using distance- or relation-based methods. Such combinations proved especially effective in evaluating stocks and mutual funds, where both quantitative ratios and qualitative indicators must be integrated (Paul et al., 2021; Senfi, 2024).

At the same time, extensions of FAHP into richer fuzzy set environments further expanded its methodological capabilities. Intuitionistic FAHP (Yu et al., 2021), fuzzy ANP (Rahiminezhad Galankashi et al., 2020), and more recent innovations such as Pythagorean (Milošević, 2023; Başaran, 2023), spherical (Mathew, 2020), and Fermatean fuzzy AHP approaches have enhanced the flexibility of decision models, offering better representation of uncertainty and hesitation in expert judgments. Comprehensive bibliometric analyses, such as Castelló-Sirvent et al. (2022), confirm that FAHP-related publications have grown exponentially, diversifying into finance, sustainability, and supply chain management. Beyond FAHP, other fuzzy MCDM frameworks also support financial decision-making. Liu et al. (2012) developed a fuzzy portfolio selection model incorporating return, transaction cost, risk, and skewness, simulating real-world transactions to provide investors with robust alternatives. Shamsuzzaman et al. (2013) applied fuzzy MCDM in an industrial context by ranking coals based on calorific value and chemical composition, while Gupta et al. (2013) introduced a hybrid portfolio optimization model integrating both financial and ethical criteria using AHP and fuzzy MCDM. These studies collectively emphasize the value of fuzzy-based frameworks in addressing complex, uncertain, and multi-dimensional decision problems, while also recognizing the role of structured expert consensus methods, such as Delphi, to enhance judgment reliability.

1.2.Research Gap

Although FAHP and fuzzy MCDM techniques have been extensively applied in finance, portfolio management, and other decision-making domains, several critical gaps remain. Most existing studies rely on hypothetical or simulated datasets, with limited validation against actual financial market benchmarks, which raises concerns about their practical applicability for investors. Furthermore, while quantitative factors such as financial ratios are well represented, qualitative and behavioral dimensions—including managerial expertise, investor sentiment, and ethical considerations—are often underexplored in FAHP-based models. Another limitation lies in the static nature of most frameworks, which do not adequately reflect the dynamic and volatile conditions of real financial markets. Methodological challenges such as sensitivity to defuzzification techniques and the persistence of rank reversal also reduce the robustness of existing approaches. Finally, despite the rapid progress in artificial intelligence and data analytics, the integration of FAHP with machine learning, big data, and predictive modeling remains relatively limited. These gaps highlight the need for advanced hybrid approaches that combine FAHP with other fuzzy MCDM tools and emerging technologies to provide more reliable, adaptive, and comprehensive decision-support systems for portfolio selection and financial evaluation.

2.Criteria Selection

Return on Equity (ROE):

ROE, or Return on Equity, is a financial ratio that measures a company's profitability by showing how much profit it generates with the money invested by its shareholders. Calculated as Net Income / Shareholders' Equity, a higher ROE generally indicates that a company is more efficient and successful at using its equity capital to make money. Investors often use ROE to gauge a company's financial performance, compare its efficiency against competitors, and identify good investment opportunities.

Return on Equity (ROE)=Net income ÷ Average Total Equity

.Earnings Per Share (EPS):

EPS stands for **Earnings Per Share**, a crucial financial metric that shows how much profit a company allocates to each outstanding share of its common stock. It's a key indicator of a company's profitability and financial health, helping investors assess its value and compare it to others in the same industry. To calculate EPS, you divide a company's net income (minus preferred stock dividends) by the average number of outstanding shares.

Earnings per share (EPS) measures a company's profitability on a per-share basis for its common stockholders, calculated using the formula:

EPS = (Net Income – Preferred Dividends) ÷ Number of Outstanding Shares.

A higher EPS indicates strong profitability and efficient use of shareholder funds, making it a key metric for investors to assess a company's financial health and investment potential.

Price-to-Earnings (P/E) ratio:

The Price-to-Earnings (P/E) ratio is a valuation metric in the share market that shows how much investors are willing to pay for each rupee of a company's earnings. It helps determine if a stock is overvalued or undervalued by comparing its current stock price to its earnings per share (EPS).

The formula is P/E Ratio = Market Price per Share ÷ Earnings per Share (EPS)

Debt-to-Equity (D/E) ratio:

The Debt-to-Equity (D/E) ratio is a financial metric in the stock market that shows a company's leverage by dividing its total liabilities (debt) by its total shareholder equity. This ratio indicates the extent to which a company relies on borrowed funds versus its own capital. A higher D/E ratio suggests greater reliance on debt, implying higher financial risk for the company and its investors, while a lower ratio signifies a stronger financial position and lower risk.

Current ratio:

In the share market, the current ratio is a liquidity metric that measures a company's ability to pay off its short-term liabilities (due within one year) with its current assets (convertible to cash within a year). It is calculated by dividing current assets by current liabilities. A ratio greater than 1 suggests a company can meet its short-term obligations, while a ratio less than 1 indicates potential liquidity issues. Investors use this ratio to assess a company's short-term financial health and stability.

Current Ratio = Current Assets / Current Liabilities

Return on Assets (ROA):
In the share market, the **Return on Assets (ROA)** is a financial ratio that measures a company's profitability and efficiency in using its assets to generate profit. It is calculated as **Net Income / Average Total Assets**. A higher ROA percentage indicates that the company is using its assets more effectively to produce earnings, which is favorable for investors assessing the company's operational effectiveness and future growth potential.

2.1. Fuzzy Analytic Hierarchy Process (Fuzzy AHP)
The Analytic Hierarchy Process (AHP), introduced by Thomas L. Saaty in 1980, simplifies complex decision-making by structuring it into a hierarchical model and employing pairwise comparisons to establish priority scales. To address the uncertainty in judgments, this method has been enhanced with Triangular Fuzzy Numbers (TFNs), allowing for a more flexible and nuanced evaluation.
1. Developing a fuzzy comparison matrix
First the scale of linguistics is determined. The scale used is the TFN scale from one to nine are shows in Table 1.

Table 1. Scale of Interest

Scale of Interest	Linguistic Variable	Membership Function
1	Equally important	(1,1,1)
3	Weakly important	(2,3,4)
5	Strongly more important	(4,5,6)
7	Very strongly important	(6,7,8)
9	Extremely important	(8,9,10)

Then, using the TFN to make pair-wise comparison matrix for the main criteria and sub-criteria.
Equation (1) shows the form of fuzzy comparison matrix.

$$\mathcal{\bar{A}} = \begin{bmatrix} 1 & \cdots & \overline{a_{1n}} \\ \vdots & \ddots & \vdots \\ \overline{a_{n1}} & \cdots & 1 \end{bmatrix} \tag{1}$$

2. Define Fuzzy Geometric Mean
The fuzzy geometric mean is then calculated using Equation (2)[13]:

$$\overline{x_i} = \left(\bar{a}_{(i1)} \otimes \bar{a}_{(i2)} \otimes \ldots \otimes \bar{a}_{(in)}\right)^{\frac{1}{n}} \tag{2}$$

Where $\tilde{a}_{in}$ is a value of fuzzy comparison matrix from criteria I to n. Result from the fuzzy geometric mean will be referred to later as local fuzzy number.

3. Calculate the weight of fuzzy of each dimension
The next step is to calculate the global fuzzy number for each evaluation dimension with Equation (3).

$$\widetilde{w}_i = \tilde{x}_1 \otimes (\tilde{x}_1 \oplus \tilde{x}_1 \oplus \ldots \oplus \tilde{x}_1)^{-1} \tag{3}$$

4. Define the best non fuzzy performance (BNP)
The global fuzzy number is then converted to crisp weight value using the Centre of Area (COA) method to find the value of best BNP from the fuzzy weight in each dimension, calculated using Equation (4).

$$BNP_{wi} = \frac{[(u_{wi} - l_{wi}) + (m_{wi} - l_{wi})]}{3} + l_{wi} \tag{4}$$

2.2. Case study
In this study, data were collected from the top 10 companies listed on the Bombay Stock Exchange (BSE), India (https://www.bseindia.com/). Expert opinions were obtained from two professionals: (i) an experienced investor and (ii) a professor of finance. Both experts possess more than 30 years of experience in the field of investments, ensuring credibility in the evaluation process. The study considered six key financial criteria:C1 – Return on Equity (ROE), C2 – Earnings Per Share (EPS), C3 – Price-to-Earnings (P/E) Ratio, C4 – Debt-to-Equity (D/E) Ratio, C5 – Current Ratio, and C6 – Return on Assets (ROA). The Fuzzy Analytic Hierarchy Process (FAHP) was then employed to determine the relative importance weights of these criteria, with the results presented in Table 1

Table 1: Determining the weights of the criteria by FAHP Approach

Criteria	C_1	C_2	C_3	C_4	C_5	C_6
Fuzzy Weights	0.2302	0.2248	0.2090	0.1901	0.1463	0.2026
Rank	1	2	3	4	6	5

2.3. RESULTS AND DISCUSSION

As per the proposed model, C1 – Return on Equity (ROE) emerged as the most significant criterion, securing the first rank. This finding highlights the critical role of ROE in investment decision-making, as it directly reflects a company's efficiency in generating profits from shareholders' equity. A higher ROE often signals strong financial performance and effective management strategies, which align with investor preferences for maximizing returns. Following ROE, C2 – Earnings Per Share (EPS), C3 – Price-to-Earnings (P/E) Ratio, C4 – Debt-to-Equity (D/E) Ratio, and C6 – Return on Assets (ROA) secured the second, third, fourth, and fifth ranks, respectively. EPS ranking second emphasizes its importance as a direct indicator of profitability on a per-share basis, making it a critical metric for investors evaluating stock value. The third-ranked P/E ratio reflects the balance between market valuation and earnings potential, suggesting that investors consider both profitability and valuation when making decisions. The D/E ratio's fourth position highlights the moderate importance of financial leverage, where a balanced debt structure supports growth while avoiding excessive risk. ROA, ranked fifth, underscores the efficiency of asset utilization but appears to hold relatively lower influence compared to equity-based returns (ROE). Lastly, C5 – Current Ratio secured the lowest rank, indicating that liquidity considerations are relatively less critical in the context of long-term investment decisions. While the Current Ratio is an essential measure of short-term financial health, its lower importance suggests that investors prioritize profitability and growth indicators over liquidity when evaluating potential investments. Overall, the results demonstrate that profitability-related criteria (ROE, EPS, P/E) dominate investor decision-making, while liquidity measures play a less influential role. This hierarchy of importance reflects a rational investment perspective, where returns and valuation drive stock selection more strongly than short-term solvency.

3.CONCLUSION

The study concludes that Return on Equity (ROE) plays the most decisive role in investment decision-making among BSE-listed companies, as it reflects a firm's ability to generate shareholder value effectively. Other profitability-based measures, including Earnings Per Share (EPS) and Price-to-Earnings (P/E) Ratio, also carry significant weight, indicating that investors prioritize returns and valuation metrics when evaluating stocks. In contrast, Current Ratio, a liquidity measure, was ranked least important, suggesting that short-term solvency is not a primary concern for long-term investors. These findings reaffirm the rational investment perspective, where profitability and sustainable growth are the driving forces behind stock selection. The study further demonstrates the usefulness of FAHP in systematically ranking financial criteria, thereby offering a structured decision-support framework for both novice and experienced investors.

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