İSTANBUL UNIVERSITY PRESS

Journal of Data Analytics and Artificial Intelligence Applications, D3AI 1, 1 (January 2025): 36–60

https://doi.org/10.26650/d3ai.1607081

Submitted: 25.12.2024
Revision Requested: 03.01.2025
Last Revision Received: 22.01.2025
Accepted: 23.01.2025
Published Online 27.01.2025

Journal of Data Analytics and Artificial Intelligence Applications

Research Article

Open Access

Financial Performance Evaluation of Companies Listed in Corporate Governance and Sustainability Indices: Application of the IVSF-RBNAR Method

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Abstract

Companies strive to improve their financial conditions not only to gain a competitive advantage but also to be listed on corporate governance and sustainability indices. Companies listed in the Corporate Governance Index are understood to have high levels of corporate governance success, whereas those listed in the Sustainability 25 Index are recognised for being long-term environmentally sustainable organisations. It is evident that companies listed in both indices not only implement successful governance practices but also adopt sustainability principles. The primary motivation of this research is to evaluate the financial performance of companies listed on both indices. Accordingly, the main objective of this study is to develop a method for calculating the financial performance of these companies and to demonstrate its applicability. In this study, which is approached as a decision problem using the multi-criterion decision-making (MCDM) approach, the IVSF-RBNAR (Interval-Valued Spherical Fuzzy - Reference-Based Normalised Assessment Ranking) method is proposed for calculating financial performance. This method allows criterion weighting based on expert opinions and performance ranking based on reference distance. In the application phase of this study, the financial performance levels of the ten companies listed in The Corporate Governance Index and The Sustainability 25 Index were determined by considering seven financial ratio indicators. As a result, Doğan Companies Group Holding Inc. was identified as having the highest financial performance. The most significant financial ratio was determined to be Return on Assets (ROA). The study also presents research implications and suggests future research directions.

Keywords Financial Performance Analysis · Corporate Governance Index · Sustainability 25 Index · Interval-Valued Spherical Fuzzy Sets · Reference-Based Normalised Assessment Ranking Method

Author Note This research was presented as a Turkish abstract at the VII. Congress on Critical Debates in Social Sciences held at İzmir Democracy University on November 22, 2024.

Citation: Karahan Kara, Galip Cihan Yalçın, and Hamide Özyürek. 2025. Financial performance evaluation of companies listed in corporate governance and sustainability indices: application of the IVSF-RBNAR method. *Journal of Data Analytics and Artificial Intelligence Applications* 1, 1 (January 2025), 36-60. https://doi.org/10.26650/d3ai.1607081

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1. Introduction

Corporate governance and sustainability are critical factors that determine the long-term success of companies and form the foundation of modern business practices [1]. Corporate governance consists of a set of principles and procedures that regulate a company's management structure to ensure transparency, accountability and the protection of stakeholder rights. In contrast, sustainability is an approach that comprehensively addresses environmental, social, and governance (ESG) parameters [2]. The interaction between these two concepts ensures that businesses are managed not only according to financial performance but also in consideration of their societal responsibilities. Consequently, companies adhering to both corporate governance and sustainability principles can achieve sustainable success in their internal management processes and in their relationships with external stakeholders.

Corporate governance and sustainability have become not only ethical obligations but also key areas that define a company's strategic competitive advantages and help it achieve sustainable growth objectives [3]. In this context, corporate governance and sustainability indices have emerged as important tools for measuring and evaluating the level of implementation in these areas. These indices, which are particularly critical for investors, provide a comprehensive assessment of a company's corporate governance practices and sustainability performance, enabling investment decisions to be based on a more informed and sound foundation [4].

In Türkiye, the BIST Corporate Governance Index and the BIST Sustainability Index are important indicators used to identify companies that demonstrate high performance in corporate governance and sustainability. The Sustainability Index is a tool that measures companies' ESG performance. This index objectively evaluates how well companies adhere to sustainability principles and practices in this area. It assesses sustainability practices based on various criteria, including environmental factors (such as carbon footprint, energy consumption, and water usage), social factors (such as labour rights, occupational health and safety, and community relations), and governance factors (such as ethical standards, corporate governance practices, and transparency) [5].

The Sustainability Index provides investors and other stakeholders comprehensive information about companies' sustainability performance. This enables investors to make investments in companies that align with sustainability goals. The index encourages companies to act responsibly towards the environment and society, enhancing their long-term success and reputation. Sustainability indices strengthen companies' competitive advantages by increasing transparency and accountability. They promote sustainable investments and encourage companies to adopt more sustainable business practices. Launched on November 21, 2022, the BIST Sustainability 25 Index comprises companies with high sustainability performance as well as large and liquid companies. This index is an important indicator that brings together companies in Türkiye based on sustainability principles (It identifies and evaluates companies that adopt best practices in sustainability [6]. Commitment to sustainability principles also influences a company's financial performance. While measuring companies' financial performance, the index also reveals how well these companies align with their sustainability goals. It supports companies' strategic environmental, social, and governance decisions, helping them better plan their sustainability objectives to achieve long-term success.

The Corporate Governance Index is a tool that objectively measures the extent to which companies adhere to corporate governance principles. This index provides an indicator of companies' corporate governance performance. Since the index assesses corporate governance practices based on specific criteria (such as shareholders, transparency, stakeholders, and board of directors), it allows for the analysis of how successful companies are in meeting these criteria [7]. An analysis of corporate governance practices enhances the trust of investors and other stakeholders in companies. By highlighting well-managed companies, the index offers investors safer investment options. The Corporate Governance Index serves as an appropriate benchmark for understanding the relationship between financial performance and corporate governance practices.

The index provides investors and companies with insights into areas for improvement in corporate governance practices. This helps in making strategic decisions. The Corporate Governance Index is a comprehensive measurement tool that evaluates companies' corporate governance levels across multiple criteria. This enables a more detailed analysis of company management quality.

Companies included in these indices have a broad impact on the business world, not only through their financial success but also by fulfilling their environmental and social responsibilities. Therefore, companies' performance in these indices goes beyond financial indicators, highlighting their potential for sustainable growth and their contributions to society.

The importance of corporate governance and sustainability indices in the business world and financial analysis lies in the fact that these indices provide a comprehensive evaluation that reflects not only a company's corporate governance practices but also its capacity for long-term value creation [8]. Analysing the performance of companies included in these indices is crucial because it helps to understand not only financial outcomes but also the impact on companies' strategies for sustainable growth and risk management.

The relationship between corporate governance and sustainability is becoming increasingly important. Good corporate governance supports a company's long-term sustainability, while strong practices in both corporate governance and sustainability create trust among investors and stakeholders, positively impacting a company's overall performance. In this context, examining the performance of companies included in the Corporate Governance Index and the Sustainability Index offers a comprehensive approach to understanding how companies are managed in terms of both financial and social/environmental sustainability. Corporate governance principles and sustainability practices are critical factors that influence investors' decisions, and companies with high scores are perceived as more transparent, ethical, and trustworthy. This enhances investor confidence and supports the company's long-term success.

The Corporate Governance Index and the Sustainability Index are important tools that objectively demonstrate companies' performance in terms of transparency and accountability. Companies included in these indices are subject to greater scrutiny and evaluation, both in terms of their internal governance mechanisms and in terms of their external environmental impact and social responsibility [9]. This allows for more reliable analysis of performance. Companies that exhibit strong performance in both corporate governance and sustainability are more likely to achieve long-term success and not just short-term gains. Well-managed companies that focus on sustainability principles gain a stronger competitive advantage in their markets, improve operational efficiency, and enhance their social prestige by fulfilling their social responsibilities. These factors directly influence companies' financial performance, contributing to more sustainable long-term success.

Companies included in the Corporate Governance Index and the Sustainability Index not only achieve financial goals but also prioritise fulfilling their environmental and social responsibilities. These companies emphasise the importance of environmental and social contributions while achieving financial success in alignment with societal values.

This study adopts a multi-criterion decision-making (MCDM) approach to identify the financial performance levels of selected companies as a decision-making problem. The research also incorporates expert opinions into the analysis. The primary motivation of this study is to propose a method for evaluating the financial performance of companies in decision-making models and to demonstrate its applicability.

In this context, the IVSF-RBNAR (*Interval-Valued Spherical Fuzzy - Reference-Based Normalised Assessment Ranking*) Method is proposed and applied. In this method, expert opinions are collected using linguistic expressions, which are then transformed into IVSF numbers [10]. The influence of experts on the decision-making process is assessed using IVSF sets, and the weights of the criteria are determined using the IVSWAM (*Interval-Valued Spherical Weighted Arithmetic Mean*) aggregation operator [10]. The ranking of companies' performance is performed using the RBNAR method [11]. The primary reason for choosing this methodology is its ability to rank alternatives based on their distances to reference points, providing a robust framework for performance evaluation. This study highlights the effectiveness of the IVSF-RBNAR method in addressing the challenges of decision-making in corporate financial performance analysis.

The primary objectives of this research are as follows:

- *Financial Performance Assessment*: To calculate the financial performance of companies listed on the corporate governance and sustainability index using financial ratio values derived from their financial reports for 2022.
- *Identification and Analysis*: To identify companies included in both indices and analyse their financial reports to compute relevant financial ratio metrics.
- *Decision-Making Problem*: This study treats financial performance evaluation as a decision-making problem by applying an MCDM approach.
- *Methodology Application*: To apply the IVSF-RBNAR Method for financial performance assessment. This involves: (i) Utilising expert opinions to determine the importance of criteria. (ii) Employing linguistic expressions to assess expert expertise and calculate their weights. (iii) Calculating criteria weights using the IVSWAM aggregation operator. (iv) The financial performance of companies is ranked based on their distance from the reference points using the RBNAR method.
- *Case Study Implementation*: To implement the IVSF-RBNAR method on a sample of 10 companies listed in the indices, involving: 7 experts, 7 criteria, and 10 alternatives (companies).

This research makes the following key contributions to the field of financial performance assessment and decision-making methodologies:

- *Methodological Advancement*: Introduces and demonstrates the applicability of the IVSF-RBNAR Method for financial performance evaluation by integrating IVSF and the RBNAR approach.
- *Expert-driven decision-making: This approach develops* a robust framework to incorporate expert opinions into the financial performance evaluation process. This includes: (i) The use of linguistic expressions to assess and quantify the expertise of decision-makers. (ii) The application of the IVSWAM aggregation operator to calculate the importance weights of criteria based on expert inputs.

- *Corporate Financial Analysis*: Provides a structured approach for analysing the financial performance of companies listed on the corporate governance and sustainability index using financial ratios derived from company reports.
- *Identification of Key Performance Drivers*: Highlights Return on Assets (ROA) as the most critical criterion for evaluating financial performance, providing actionable insights for stakeholders.
- *Best-Performing Company Recognition*: Identifies Doğan Companies Group Holding Inc. as the company with the highest financial performance among the evaluated entities.
- *Support for Decision-Making Models*: The IVSF-RBNAR method is validated as a reliable and effective tool for ranking corporate financial performance, making a valuable contribution to decision-making processes in corporate governance and sustainability contexts.

This study is organised into seven sections: *Section 2-Literature Review*: Provides an overview of relevant studies and theoretical foundations related to financial performance evaluation, corporate governance and sustainability indices. *Section 3 – Methodology*: The methodological framework is outlined, detailing the IVSF-RBNAR method, expert judgement integration, and criterion weighting processes. *Section 4 - Application*: This section demonstrates the practical implementation of the proposed methodology, including data collection, calculations, and performance rankings for the selected companies. *Section 5 – Results*: This section presents the findings of the study, highlighting company rankings, key criteria, and the significance of the applied method. *Section 6-Research Implications*: This section discusses the theoretical, practical, and methodological contributions of the study to financial performance evaluation and decision-making processes. *Section 7 - Conclusion*: The study's key outcomes, limitations, and recommendations for future research.

2. Literature Review

Financial analysis is a fundamental tool for understanding the dynamics of financial markets and making informed decisions. As markets become increasingly complex and interconnected, the ability to accurately assess market trends, forecast future movements, and effectively analyse investment opportunities is critical for investors, policymakers, and businesses. Accurate financial analysis enables stakeholders to minimise risks, optimise returns, and allocate resources more efficiently, thus supporting global economic stability and contributing to sustainable growth.

In this context, financial ratios play a paramount role. Financial ratios provide critical indicators for understanding a company's financial health, performance, and efficiency. These ratios allow investors and analysts to assess a company's profitability, debt levels, and operational efficiency. In particular, key metrics, such as profitability ratios, offer valuable insights into company financial performance. These indicators enable in-depth analysis of financial statements, helping decision-makers to take more accurate and strategic actions. Additionally, the use of financial ratios in combination allows for multiple perspectives to be evaluated, making the decision-making process more robust and reliable.

The application of advanced analytical methods, such as MCDM, further enhances financial analysis by evaluating market factors and performance indicators more comprehensively. These methods do not rely solely on traditional financial metrics; instead, they consider other factors in the market, enabling the generation of more accurate and predictable results. Consequently, the adoption of more sophisticated multi-criteria decision models has increased in financial research, making financial decision-making processes more reliable and effective.

Building upon the significance of financial ratios and advanced analytical techniques, the integration of MCDM methods has emerged as a critical component of modern financial market analysis. Over recent years, academic and practical research has increasingly focused on harnessing these methods to optimise decision-making processes, empowering investors, financial analysts, and decision-makers to make more informed, precise, and effective choices across various indices and sectors. The application of MCDM methods allows for a more comprehensive evaluation of complex financial data, facilitating the consideration of multiple criteria, and enhancing the quality of financial decisions. This section provides an overview of key studies in the literature, focusing on the methods used and their impact on sectoral and financial decision-making. Kara et al. [11] conducted a performance analysis of the technology sector on the Istanbul Stock Exchange, utilising SVN-CIMAS-CRITIC-RBNAR (*Single-Valued Neutrosophic - Criteria Importance Assessment - Criteria Importance Through Intercriteria Correlation - Reference-Based Normalisation Alternative Ranking*) methods. This study aimed to develop decision support mechanisms for investments in the technology sector. Kaya et al. [12] examined the sustainability index using a combination of FUCOM (*Full Consistency Method*), GRA (*Grey Relational Analysis*), MABAC (*Multi-Attributive Border Approximation Area Comparison*), and TOPSIS techniques. *For Order Performance By Similarity To Ideal Solution* method, evaluating the impact of sustainability factors on sectoral performance. Isik et al. [13] employed the DEMATEL (*Decision-Making Trial and Evaluation Laboratory*), CRITIC, EDAS (*Evaluation Based on Distance from Average Solution*), and WASPAS (*Weighted Aggregated Sum Product Assessment*) methods to analyse the food and beverage sector on the Istanbul Stock Exchange, providing insights into the opportunities and challenges within the sector. Alsanousi et al. [14] analysed five sectors of the Saudi Arabian stock market in 2022 using BWM and TOPSIS methods, highlighting the effectiveness of these techniques in sectoral performance analysis. Biswas [15] focused on the energy sector by using the ERUNS (*Evaluation Based on Relative Utility and Nonlinear Standardisation*) methodology to evaluate energy sector performance and provide recommendations for efficient resource use. Elma [16] examined the Bosa İstanbul Sustainability Index on the Istanbul Stock Exchange using various methods, including FUCA (*Faire Un Choix Adéqua*), VIKOR (*VIekriterijumsko KOmpromisno Rangiranje*), TOPSIS, and others, offering insights into sustainability factors and their influence on financial markets. Işık et al. [17] studied the insurance sector, applying Pythagorean fuzzy AHP (*Analytic Hierarchy Process*) and MAIRCA (*MultiAtributive Ideal-Real Comparative Analysis*) methods to assess risks and opportunities within the sector.

Hoang et al. [18] explored the performance of electronic enterprises globally using the spherical fuzzy AHP and WASPAS methods. This study aims to provide strategic recommendations for firms in the electronics sector. Nguyen et al. [19] analysed the retail sector in Vietnam using Pythagorean fuzzy AHP and CoCoSo (*Combined Compromise Solution*) methods to uncover key decision-making factors. Kara et al. [20] conducted a study on the BIST Sustainability Index, employing MEREC (*Method Based on The Removal Effects Of Criteria*) - RBNAR methods to evaluate sector performance. Güçlü and Muzac [21] focused on the iron and steel sector in Türkiye, using the Extended Grey MULTIMOORA (*Multi-Objective Optimisation by Ratio Analysis Plus Full Multiplicative Form*) method to analyse sectoral risks and opportunities.

Yüksel and Uncu [22] investigated the railway transportation sector in Türkiye using the EDAS method and provided recommendations for increasing sector efficiency. Lam et al. [23] utilised Fuzzy TOPSIS methods to analyse the performance of firms on the Dow Jones Stock Exchange in the United States and identify the key factors influencing investment decisions. Miguez et al. [24] used AHP and TOPSIS methods to study the tourism sector in Spain and develop decision support tools for the tourism industry. Makki and Alqahtani [25] examined the energy sector in Saudi Arabia using AHP and TOPSIS methods to evaluate sector performance over the period 2019-2021.

Liew et al. [26] employed the entropy-DEMATEL-TOPSIS methods to analyse firms listed on the Dow Jones Stock Exchange, providing valuable insights into their future performance. Ghosh and Bhattacharya [27] used MEREC and Grey-based CoCoSo methods to investigate the hospitality and tourism sectors in India, offering strategic decision-making support to firms in these industries. Bae et al. [28] utilised Fuzzy AHP and TOPSIS methods to analyse the airline sector in the United States, assisting industry stakeholders in making more informed decisions. Katrancı et al. [47] utilised the Indifference Threshold-Based Attribute Ratio Analysis (ITARA) and the Cost Estimation, Benchmarking, and Risk Assessment (COBRA) methods to evaluate the financial performance of 25 companies listed on Borsa Istanbul. These studies highlight the applicability of various MCDM methods across different sectors and their contribution to improving decision-making in financial markets. The integration of different MCDM techniques allows for a more in-depth analysis of sectoral dynamics, leading to more informed and strategic decision-making. Overall, the literature provides significant insights into the decision-making processes within financial markets, enhancing the quality and efficiency of decision support systems. Table 1 presents a summary of the literature review, showcasing key studies relevant to the stock exchange, sector/industry, methods, and years.

Table 1. Literature review of financial performance analysis using MCDM

Authors	Stock Exchange (SE)	Sector/Industry	Years	Methods
Kara et al. [11]	İstanbul SE	Technology	2023	SVN-CIMAS-CRITIC-RBNAR
Kaya et al. [12]	İstanbul SE	Sustainability index	2021	FUCOM-GRA-MABAC-MOOSRA-OCRA-TOPSIS-TODIM-VIKOR
Isik et al. [13]	İstanbul SE	Food/Beverage	2021	DEMATEL-CRITIC-EDAS-WASPAS-TOPSIS
Alsanousi et al. [14]	Saudi Stock Market	5 sectors	2022	BWM and TOPSIS
Biswas et al. [15]	-	Energy	-	ERUNS
Elma [16]	İstanbul SE	BIST Sustainability Index	2022	FUCA, VIKOR, TOPSIS, SAW, CODAS, RAFSI and GRA
Işık et al. [17]	-	Insurance	-	Pythagorean fuzzy AHP and MAIRCA
Hoang et al. [18]	-	10 electronic enterprises	-	Spherical fuzzy AHP and WASPAS
Nguyen et al. [19]	-	Retailing industry	-	Pythagorean fuzzy AHP and CoCoSo
Kara et al. [20]	İstanbul SE	BIST Sustainability Index	2022	MEREC-RBNAR
Güçlü and Muzac [21]	İstanbul SE	Iron and Steel	-	Extended Grey MULTIMOORA
Yüksel and Uncu [22]	-	Railway Transportation	2015-2021	EDAS
Lam et al. [23]	Dow Jones, Inc.	-	-	Fuzzy TOPSIS
Miguez et al. [24]	-	Tourism	2019	AHP- TOPSIS

Authors	Stock Exchange (SE)	Sector/Industry	Years	Methods
Makki and Alqahtani [25]	Saudi	Energy	2019-2021	AHP-TOPSIS
Liew et al. [26]	Dow Jones, Inc.	-	2015-2020	Entropy-DEMATEL-TOPSIS
Ghosh and Bhattacharya [27]	Indian	hospitality and tourism	2019-2021	MEREC-Grey CoCoSo
Bae et al. [28]	-	Airline	2018	Fuzzy AHP TOPSIS

3. Methodological Framework

In this study, the IVSF-RBNAR method is proposed and applied to calculate companies' financial performance using the MCDM approach. This method comprises three key stages: *Stage 1*: Expert weights are determined by considering the expertise levels of the specialists consulted for criteria weighting. *Stage 2*: Weights of criteria are identified using IVSF sets and the IVSFWAM aggregation operator. *Stage 3*: The financial performance of the companies is determined using the RBNAR method. The stages of this hybrid method are sequentially interconnected. The decision-maker weights obtained in Stage 1 are utilised in Stage 2. Similarly, the criterion weights calculated in Stage 2 are employed in Stage 3. The methodology of the study is illustrated in Figure 1. In the methodology section, basic IVSF set calculations are provided. The steps of the IVSF-RBNAR method are then demonstrated in detail.

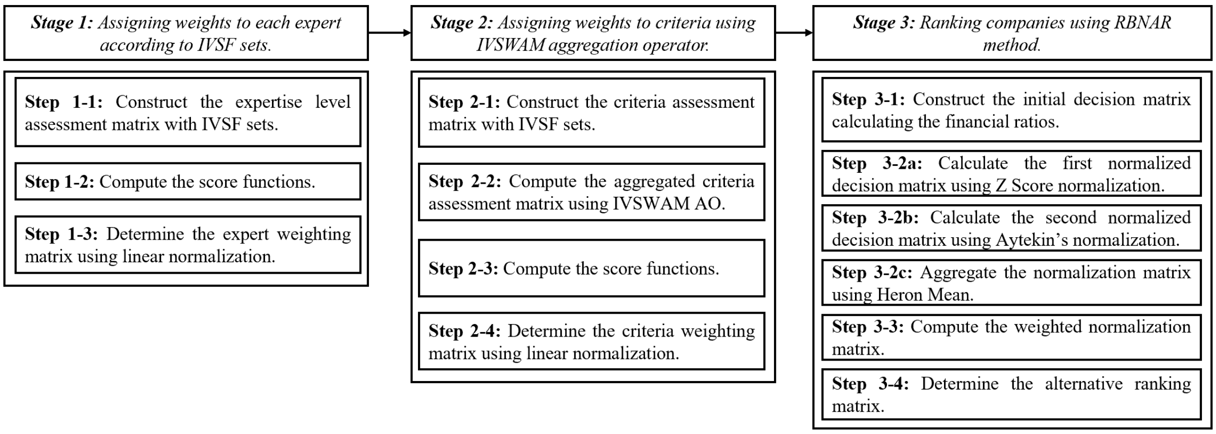

Figure 1. Methodology framework

3.1. Fundamentals of Interval Valued Spherical Fuzzy (IVSF) Sets

Definition 1. In the specified domain of discourse, denoted as $\mathcal{L}$, the symbol $\tilde{\mathcal{K}}$ as introduced $\tilde{\mathcal{K}} = \left\{\left\langle \ell\left(\chi^l_{\mathfrak{Y}}(\ell), \chi^u_{\mathfrak{Y}}(\ell)\right), \left(\phi^l_{\mathfrak{Y}}(\ell), \phi^u_{\mathfrak{Y}}(\ell)\right), \left(\varphi^l_{\mathfrak{Y}}(\ell), \varphi^u_{\mathfrak{Y}}(\ell)\right) \mid \ell \in \mathcal{L}\right\rangle\right\}$, represents the presence of IVSF sets operating within the broader framework of set $\mathcal{L}$ [10]. Here, the constraints are $0 \leq \chi^l_{\mathfrak{Y}}(\ell) \leq \chi^u_{\mathfrak{Y}}(\ell) \leq 1, 0 \leq \phi^l_{\mathfrak{Y}}(\ell) \leq \phi^u_{\mathfrak{Y}}(\ell) \leq 1$, and $0 \leq \varphi^l_{\mathfrak{Y}}(\ell) \leq \varphi^u_{\mathfrak{Y}}(\ell) \leq 1$.

Within the given context, the functions $\chi^l_{\mathfrak{Y}}(\ell),\ \phi^l_{\mathfrak{Y}}(\ell), and\ \varphi^l_{\mathfrak{Y}}(\ell)$ are interpreted as abstract representations of the lower degree of membership, the lower degree of non-membership, and the lower degree of hesitancy, respectively. The functions $\chi^u_{\mathfrak{Y}}(\ell),\ \phi^u_{\mathfrak{Y}}(\ell), and\ \varphi^u_{\mathfrak{Y}}(\ell)$ represent abstract concepts corresponding to the upper degree of membership, non-membership, and hesitancy, respectively. These functions are formally defined such that the inequality $0 \leq \left(\chi^u_{\mathfrak{Y}}(\ell)\right)^2 + \left(\phi^u_{\mathfrak{Y}}(\ell)\right)^2 + \left(\varphi^u_{\mathfrak{Y}}(\ell)\right)^2 \leq 1$ holds for all elements ℓ belonging to the set $\mathcal{L}$.

Definition 2. Two IVSF sets, specifically denoted as $\tilde{\mathcal{K}}_1$ and $\tilde{\mathcal{K}}_2$, are constructed within the universal set $\mathcal{L}$ and are defined by their respective components as follows: $\tilde{\mathcal{K}}_1 = \left(\left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell), \chi^u_{\tilde{\mathcal{K}}_1}(\ell)\right), \left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell), \phi^u_{\tilde{\mathcal{K}}_1}(\ell)\right), \left(\varphi^l_{\tilde{\mathcal{K}}_1}(\ell), \varphi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)\right)$ and $\tilde{\mathcal{K}}_2 = (\left(\chi^l_{\tilde{\mathcal{K}}_2}(\ell), \chi^u_{\tilde{\mathcal{K}}_2}(\ell)\right), \left(\phi^l_{\tilde{\mathcal{K}}_2}(\ell), \phi^u_{\tilde{\mathcal{K}}_2}(\ell)\right), \left(\varphi^l_{\tilde{\mathcal{K}}_2}(\ell), \varphi^u_{\tilde{\mathcal{K}}_2}(\ell)\right))$. The principles governing the interactions among these three IVSF sets are outlined as follows [10]:

$$\tilde{\mathcal{K}}_1 \oplus \tilde{\mathcal{K}}_2 = \left\{ \begin{pmatrix} \left(\left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 + \left(\chi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)^2 - \left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 \left(\chi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)^{\frac{1}{2}} \\ \left(\left(\chi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 + \left(\chi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)^2 - \left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 \left(\chi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)^{\frac{1}{2}} \\ \left(\left(\left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)\left(\phi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)\right), \left(\left(\phi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)\left(\phi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)\right)\right) \\ \left(\left(\left(1-\left(\chi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)\left(\varphi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right) + \left(\left(1-\left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)\left(\varphi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right) - \left(\left(\varphi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\left(\varphi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)\right)^{\frac{1}{2}} \\ \left(\left(\left(1-\left(\chi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)\left(\varphi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right) + \left(\left(1-\left(\chi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)\left(\varphi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right) - \left(\left(\varphi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\left(\varphi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)\right)^{\frac{1}{2}} \end{pmatrix} \mid \ell in \mathcal{L} \right\},$$

$$\tilde{\mathcal{K}}_1 \otimes \tilde{\mathcal{K}}_2 = \left\{ \begin{pmatrix} \left(\left(\left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)\left(\chi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)\right), \left(\left(\chi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)\left(\chi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)\right)\right) \\ \left(\left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 + \left(\phi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)^2 - \left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 \left(\phi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)^{\frac{1}{2}} \\ \left(\left(\phi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 + \left(\phi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)^2 - \left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 \left(\phi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)^{\frac{1}{2}} \\ \left(\left(\left(1-\left(\phi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)\left(\varphi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right) + \left(\left(1-\left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)\left(\varphi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right) - \left(\left(\varphi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\left(\varphi^l_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)\right)^{\frac{1}{2}} \\ \left(\left(\left(1-\left(\phi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)\left(\varphi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right) + \left(\left(1-\left(\phi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)\left(\varphi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right) - \left(\left(\varphi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\left(\varphi^u_{\tilde{\mathcal{K}}_2}(\ell)\right)^2\right)\right)^{\frac{1}{2}} \end{pmatrix} \mid \ell in \mathcal{L} \right\},$$

$$\Theta\tilde{\mathcal{K}}_1 = \left\{ \begin{pmatrix} \left(1 - \left(1 - \left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta}\right)^{\frac{1}{2}} \\ \left(1 - \left(1 - \left(\chi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta}\right)^{\frac{1}{2}} \\ \left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^{\Theta} \\ \left(\phi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^{\Theta} \\ \left(\left(1 - \left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta} - \left(1 - \left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 - \left(\varphi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta}\right)^{\frac{1}{2}} \\ \left(\left(1 - \left(\chi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta} - \left(1 - \left(\chi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 - \left(\varphi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta}\right)^{\frac{1}{2}} \end{pmatrix} \mid \ell in \mathcal{L} \right\} for \Theta > 0,$$

$$\tilde{\mathcal{K}}_1^{\Theta} = \left\{ \left(\begin{array}{c} \left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^{\Theta} \\ \left(\chi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^{\Theta} \\ \left(1-\left(1-\left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta}\right)^{\frac{1}{2}} \\ \left(1-\left(1-\left(\phi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta}\right)^{\frac{1}{2}} \\ \left(\left(1-\left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta} - \left(1-\left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2-\left(\varphi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta}\right)^{\frac{1}{2}} \\ \left(\left(1-\left(\phi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta} - \left(1-\left(\phi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2-\left(\varphi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2\right)^{\Theta}\right)^{\frac{1}{2}} \end{array} \right) \mid \ell in \mathcal{L} \right\} for \Theta > 0.$$

Definition 2 is expected to adhere to the following criteria [10]:

(i) $\tilde{\mathcal{K}}_1 \oplus \tilde{\mathfrak{V}}_2 = \tilde{\mathfrak{V}}_2 \oplus \tilde{\mathcal{K}}_1$,

(ii) $\tilde{\mathcal{K}}_1 \bigotimes \tilde{\mathcal{K}}_2 = \tilde{\mathcal{K}}_2 \bigotimes \tilde{\mathcal{K}}_1$,

(iii) $\Theta(\tilde{\mathcal{K}}_1 \oplus \tilde{\mathcal{K}}_2) = \Theta\tilde{\mathcal{K}}_2 \oplus \Theta\tilde{\mathfrak{V}}_2 for \Theta > 0$,

(iv) $(\tilde{\mathcal{K}}_1 \bigotimes \tilde{\mathcal{K}}_2)^{\Theta} = \tilde{\mathcal{K}}_1^{\Theta} \bigotimes \tilde{\mathcal{K}}_2^{\Theta}\ for \Theta > 0$,

(v) $\Theta_1\tilde{\mathcal{K}}_1 \oplus \Theta_2\tilde{\mathcal{K}}_1 = (\Theta_1+\Theta_2)\tilde{\mathcal{K}}_1 for \Theta_1, \Theta_2 > 0$,

(vi) $\tilde{\mathcal{K}}_1^{\Theta_1} \bigotimes \tilde{\mathcal{K}}_1^{\Theta_2} = \tilde{\mathcal{K}}_1^{(\Theta_1+\Theta_2)} for \Theta_1, \Theta_2 > 0$.

Definition 3. In scenario in which $\tilde{\mathcal{K}}_1 = \left(\left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell), \chi^u_{\tilde{\mathcal{K}}_1}(\ell)\right), \left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell), \phi^u_{\tilde{\mathcal{K}}_1}(\ell)\right), \left(\varphi^l_{\tilde{\mathcal{K}}_1}(\ell), \varphi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)\right)$ presents an IVSF numbers within the set $\mathcal{L}$, the score function, denoted as $S(\tilde{\mathcal{K}}_1)$, is computed using Eq. (1).

$$S(\tilde{\mathcal{K}}_1) = \frac{\left(\chi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 + \left(\chi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 - \left(\phi^l_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 - \left(\phi^u_{\tilde{\mathcal{K}}_1}(\ell)\right)^2 - \left(\frac{\varphi^l_{\tilde{\mathcal{K}}_1}(\ell)}{2}\right)^2 - \left(\frac{\varphi^u_{\tilde{\mathcal{K}}_1}(\ell)}{2}\right)^2}{2} + 1; \qquad (1)$$

$$S(\tilde{\mathcal{K}}_1) \in [0, 2]$$

Definition 4. Consider $\tilde{\mathcal{K}}_a = \left(\left(\chi^l_{\tilde{\mathcal{K}}_a}(\ell), \chi^u_{\tilde{\mathcal{K}}_a}(\ell)\right), \left(\phi^l_{\tilde{\mathcal{K}}_a}(\ell), \phi^u_{\tilde{\mathcal{K}}_a}(\ell)\right), \left(\varphi^l_{\tilde{\mathcal{K}}_a}(\ell), \varphi^u_{\tilde{\mathcal{K}}_a}(\ell)\right)\right)$ presents an IVSF sets $(\tilde{\mathcal{K}}_a = (\tilde{\mathcal{K}}_1, \tilde{\mathcal{K}}_2, ..., \tilde{\mathcal{K}}_A))$. The formulation of the IVSWAM aggregation operator is shown in Eq. (2):

$IVSWAM\ (\tilde{\mathcal{K}}_1, \tilde{\mathcal{K}}_2, ..., \tilde{\mathcal{K}}_A) = \oplus_{a=1}^{A} \Theta_a \tilde{\mathcal{K}}_a =$

$$\left\{\left\langle\begin{pmatrix}\left(1-\prod_{a=1}^{A}\left(1-\left(\chi^{l}_{\widetilde{\mathcal{K}}_a}(\ell)\right)^2\right)^{\Theta_a}\right)^{\frac{1}{2}}\\ \left(1-\prod_{a=1}^{A}\left(1-\left(\chi^{u}_{\widetilde{\mathcal{K}}_a}(\ell)\right)^2\right)^{\Theta_a}\right)^{\frac{1}{2}}\\ \prod_{a=1}^{A}\left(\phi^{l}_{\widetilde{\mathcal{K}}_a}(\ell)\right)^{\Theta_a}\\ \prod_{a=1}^{A}\left(\phi^{u}_{\widetilde{\mathcal{K}}_a}(\ell)\right)^{\Theta_a}\\ \left(\prod_{a=1}^{A}\left(1-\left(\chi^{l}_{\widetilde{\mathcal{K}}_a}(\ell)\right)^2\right)^{\Theta_a}-\prod_{a=1}^{A}\left(1-\left(\chi^{l}_{\widetilde{\mathcal{K}}_a}(\ell)\right)^2-\left(\varphi^{l}_{\widetilde{\mathcal{K}}_a}(\ell)\right)^2\right)^{\Theta_a}\right)^{\frac{1}{2}}\\ \left(\prod_{a=1}^{A}\left(1-\left(\chi^{u}_{\widetilde{\mathcal{K}}_a}(\ell)\right)^2\right)^{\Theta_a}-\prod_{a=1}^{A}\left(1-\left(\chi^{u}_{\widetilde{\mathcal{K}}_a}(\ell)\right)^2-\left(\varphi^{u}_{\widetilde{\mathcal{K}}_a}(\ell)\right)^2\right)^{\Theta_a}\right)^{\frac{1}{2}}\end{pmatrix}\right\rangle \mid \ell\in\mathcal{L}\right\}. \tag{2}$$

here, we introduce the associated weight vector $\Theta_a = (\Theta_1, \Theta_2, ..., \Theta_A)$ where $\sum_{a=1}^{A} \Theta_a = 1$ and $\Theta \in [0,1]$.

3.2. The IVSF-RBNAR Method using IVSWAM Aggregation operator

The IVSF-RBNAR method is used to evaluate financial performance. Let consider $B = \{B_1, B_2, ..., B_z, ..., B_Z\}$ $(z = 1,2,...,Z)$ presents companies, $C = \{C_1, C_2, ..., C_v, ..., C_V\}$ $(v = 1,2,...,V)$ presents criteria, $E = \{E_1, E_2, ..., E_f, ..., E_F\}$ $(f = 1,2,...,F)$ represent the decision makers. The procedural steps of the IVSF-RBNAR method are as follows:

***Stage 1: assign** weights to each expert according to IVSF sets.*

Step 1-1: Expertise level is determined using linguistic variables (LVs), as shown in Table 2. These LVs are then converted into IVSF sets, resulting in IVSF sets representing the priorities of each expert.

Table 2. Linguistic variables representing the expertise level for experts [29]

Expertise Level	Interval Valued Spherical Fuzzy Numbers
Extremely Important (EI)	⟨ (0.75, 0.85); (0.10, 0.15); (0.05, 0.10) ⟩
Critical (VI)	⟨ (0.65, 0.75); (0.15, 0.20); (0.10, 0.15) ⟩
Important (I)	⟨ (0.55, 0.65); (0.20, 0.25); (0.15, 0.20) ⟩
Moderately Important (MI)	⟨ (0.45, 0.55); (0.25, 0.30); (0.20, 0.25) ⟩

Step 1-2: The score functions $(S(E_f))$ are calculated using Eq. (3):

$$S(E_f) = \frac{\left(\chi^{l}_{E_f}(\ell)\right)^2 + \left(\chi^{u}_{E_f}(\ell)\right)^2 - \left(\phi^{l}_{E_f}(\ell)\right)^2 - \left(\phi^{u}_{E_f}(\ell)\right)^2 - \left(\frac{\varphi^{l}_{E_f}(\ell)}{2}\right)^2 - \left(\frac{\varphi^{u}_{E_f}(\ell)}{2}\right)^2}{2} + 1; \tag{3}$$
$$S(E_f) \in [0,2].$$

Step 1-3: By employing linear normalisation shown in Eq. (4), the expert weighting matrix $\left(w = [w_f]_F\right)$ can be calculated.

$$w_f = \frac{S(E_f)}{\sum_{f=1}^{F} S(E_f)}; (f = 1,2,...,F). \tag{4}$$

Herein, $w_f = (w_1, w_2, ..., w_f, ..., w_F)$ for $w_f\, \epsilon[0,1]$ with the $\sum_{f=1}^{F} w_f = 1$.

***Stage 2: Assign** weights to criteria using IVSWAM.*

Step 2-1: Each expert (E_f) evaluates each criterion (C_v) using LVs shown in Table 3. Subsequently, LVs are converted to IVSF numbers. Thus, the criterion assessment matrix $\left(\tilde{P} = [\tilde{P}_{vf}]_{VF}\right)$ can be determined. Wherein, $\tilde{P}_{vf} = \left\langle \left(\left(\chi^l_{\tilde{P}_{vf}}(\ell), \chi^u_{\tilde{P}_{vf}}(\ell) \right), \left(\phi^l_{\tilde{P}_{vf}}(\ell), \phi^u_{\tilde{P}_{vf}}(\ell) \right), \left(\varphi^l_{\tilde{P}_{vf}}(\ell), \varphi^u_{\tilde{P}_{vf}}(\ell) \right) \right) \right\rangle$, where $(v = 1, 2, ..., V; f = 1, 2, ..., F)$.

Table 3. Linguistic variables for evaluating criteria [29]

Linguistic variables for evaluating the criteria	Interval Valued Spherical Fuzzy Numbers
Extremely satisfied (ES)	⟨ (0.80, 0.90), (0.10, 0.20), (0.05, 0.15) ⟩
Very satisfied (VS)	⟨ (0.70, 0.80), (0.20, 0.30), (0.15, 0.25) ⟩
Satisfied (S)	⟨ (0.60, 0.70), (0.30, 0.40), (0.25, 0.35) ⟩
Moderate (M)	⟨ (0.45, 0.55), (0.40, 0.50), (0.35, 0.45) ⟩
Dissatisfied (D)	⟨ (0.30, 0.40), (0.60, 0.70), (0.25, 0.35) ⟩
Very dissatisfied (SLI)	⟨ (0.20, 0.30), (0.70, 0.80), (0.15, 0.25) ⟩
Extremely dissatisfied (LI)	⟨ (0.10, 0.20), (0.80, 0.90), (0.05, 0.15) ⟩

Step 2-2: Employing the IVSWAM aggregation operator shown in Eq. (5), experts' assessments can be aggregated. Then, aggregated criterion assessment matrix $\left(\tilde{P} = [\tilde{P}_v]_V\right)$ can be determined.

$$IVSWAM\left(\tilde{P}_1, \tilde{P}_2, ..., \tilde{P}_F\right) = \oplus_{f=1}^{F} w_f \tilde{P}_{vf} =$$

$$\left\{ \left(\begin{array}{c} \left(1 - \prod_{f=1}^{F}\left(1 - \left(\chi^l_{\tilde{P}_{vf}}(\ell)\right)^2\right)^{w_f}\right)^{\frac{1}{2}} \\ \left(1 - \prod_{f=1}^{F}\left(1 - \left(\chi^u_{\tilde{P}_{vf}}(\ell)\right)^2\right)^{w_f}\right)^{\frac{1}{2}} \\ \prod_{f=1}^{F}\left(\phi^l_{\tilde{P}_{vf}}(\ell)\right)^{w_f} \\ \prod_{f=1}^{F}\left(\phi^u_{\tilde{P}_{vf}}(\ell)\right)^{w_f} \\ \left(\prod_{f=1}^{F}\left(1 - \left(\chi^l_{\tilde{P}_{vf}}(\ell)\right)^2\right)^{w_f} - \prod_{f=1}^{F}\left(1 - \left(\chi^l_{\tilde{P}_{vf}}(\ell)\right)^2 - \left(\varphi^l_{\tilde{P}_{vf}}(\ell)\right)^2\right)^{w_f}\right)^{\frac{1}{2}} \\ \left(\prod_{f=1}^{F}\left(1 - \left(\chi^u_{\tilde{P}_{vf}}(\ell)\right)^2\right)^{w_f} - \prod_{f=1}^{F}\left(1 - \left(\chi^u_{\tilde{P}_{vf}}(\ell)\right)^2 - \left(\varphi^u_{\tilde{P}_{vf}}(\ell)\right)^2\right)^{w_f}\right)^{\frac{1}{2}} \end{array} \right) \middle| \ \ell \in \mathcal{L} \right\}. \tag{5}$$

Step 2-3: The score functions $(S(\tilde{P}_v))$ are calculated using Eq. (6):

$$S(\tilde{P}_v) = \frac{\left(\chi^l_{\tilde{P}_v}(\ell)\right)^2 + \left(\chi^u_{\tilde{P}_v}(\ell)\right)^2 - \left(\phi^l_{\tilde{P}_v}(\ell)\right)^2 - \left(\phi^u_{\tilde{P}_v}(\ell)\right)^2 - \left(\frac{\varphi^l_{\tilde{P}_v}(\ell)}{2}\right)^2 - \left(\frac{\varphi^u_{\tilde{P}_v}(\ell)}{2}\right)^2}{2} + 1; \tag{6}$$

$$S(\tilde{P}_v) \in [0, 2].$$

Step 2-4: By employing linear normalisation shown in Eq. (7), the criteria weighting matrix $(\omega = [\omega_v]_V)$ can be calculated.

$$\omega_v = \frac{S(\tilde{P}_v)}{\sum_{v=1}^{V} S(\tilde{P}_v)}; (v = 1, 2, ..., V). \tag{7}$$

Herein, $\omega_v = (\omega_1, \omega_2, ..., \omega_v, ..., \omega_V)$ for $\omega_v \, \epsilon \, [0,1]$ with the $\sum_{v=1}^{V} \omega_v = 1$.

***Stage 3**: Ranking companies using the RBNAR method* [10].

Step 3-1: Using the financial documents of the companies, financial ratio values can be calculated. Then, the initial matrix $\left(H_{zv} = [H_{zv}]_{ZxV}\right)$ for assessing the financial performance of companies can be constructed using these financial ratio values.

Step 3-2a: Using the Z-score reference-based normalisation [30] shown in Eq. (8), the first normalised decision matrix $\left(M_{zv} = [M_{zv}]_{ZxV}\right)$ can be calculated.

$$M_{zv} = e^{\left(\frac{H_{zv}-R_v}{-2(\sigma_v)^2}\right)}; (z = 1,2,...,Z; v = 1,2,...,V). \tag{8}$$

Herein, σ_v is represent the standard deviation of each criterion and R_v presents the reference value for each criterion.

Step 3-2b: Using Aytekin's reference-based normalisation [31], as shown in Eq. (9), the second normalised decision matrix $\left(T_{zv} = [T_{zv}]_{ZxV}\right)$ can be calculated.

$$T_{zv} = 1 - \frac{|M_{zv} - R_v|}{|R_v| + 10^{\delta}}; (z = 1,2,...,Z; v = 1,2,...,V). \tag{9}$$

Wherein, δ is determined for a positive parameter.

Step 3-2c: Using the Heron mean [32], as shown in Eq. (10), the aggregated normalised decision matrix $\left(N_{zv} = [N_{zv}]_{ZxV}\right)$ can be calculated.

$$N_{zv} = \left(\alpha\sqrt{M_{zv}T_{zv}} + (1-\alpha)\frac{M_{zv}+T_{zv}}{2}\right); (z = 1,2,...,Z; v = 1,2,...,V). \tag{10}$$

Herein,$\alpha \, \epsilon \, [0,1]$ is trade of parameter for evaluating the significance level of normalisation.

Step 3-3: Using Eq. (11), the weighted normalised decision matrix $\left(S_{zv} = [S_{zv}]_{ZxV}\right)$ can be calculated.

$$S_{zv} = (\omega_v N_{zv}); (z = 1,2,...,Z; v = 1,2,...,V). \tag{11}$$

Herein, $\omega_v = (\omega_1, \omega_2, ..., \omega_v, ..., \omega_V)$ for $\omega_v \, \epsilon \, [0,1]$ with the $\sum_{v=1}^{V} \omega_v = 1$.

Step 3-4: Using Eq. (12), the financial performance ranking matrix $\left(R_z = [R_z]_Z\right)$ can be calculated.

$$R_z = \sum_{z=1}^{Z} S_{zv}; (z = 1,2,...,Z; v = 1,2,...,V). \tag{12}$$

The alternative with the highest R_z value is recognised as exhibiting the best financial performance.

4. Application

The objective of this study is to determine the financial performance of 10 companies listed on the *Borsa Istanbul Corporate Governance Index* and the *BIST Sustainability 25 Index*. In this regard, the balance sheets and income statements for these companies for 2022 were examined, and financial ratios were calculated for each company. Subsequently, an initial decision matrix was developed. The companies included in the study are detailed in the following subsection.

4.1. Elements of the Decision Model

4.1.1. Identification of Expert Group

This model requires expert opinion to determine significant levels of financial performance. The expert group was selected from individuals with knowledge and experience in evaluating financial ratios. Seven experts have been identified for this application: The first expert is an academic in accounting and finance. The second expert is a CFO of a company in the energy production sector. The third and fourth experts are academics in finance. The fifth and sixth experts are academic researchers in accounting and finance. The seventh expert is a professor specialising in accounting and finance. The professional titles of these experts are presented in Table 4.

Table 4. The expert group

Notation	Experts	Professions
E_1	1st Expert	Professor conducting accounting and finance research
E_2	2nd Expert	Chief financial officer with 14 years of experience.
E_3	3rd Expert	Professor conducting finance research
E_4	4th Expert	Professor conducting finance research
E_5	5th Expert	Professor conducting accounting and finance research
E_6	6th Expert	Professor conducting accounting and finance research
E_7	7th Expert	Professor conducting accounting and finance research

4.1.2. Financial Ratios as Criteria

In this study, financial ratios calculated from balance sheet and income statement data, which are commonly used in the literature, were selected as criteria in the MCDM model, and companies' performance was analysed based on these criteria, including the following financial ratios. Return on Equity (ROE) [33,34], Return on Assets (ROA) [35], Receivable Turnover Ratio [36], Leverage Ratio [37,38], Operating Profit Margin [39], Net Profit Margin [40], Profit Margin Before Tax [41,42]:

Return on Equity (ROE) (C_1): This ratio indicates the profit generated by a company from its equity. Equity refers to the company's own capital, that is, the capital provided by its owners or shareholders, independent of external debt. This ratio measures how efficiently the company uses its capital. A high return on equity suggests that the company is generating strong profits from its current capital and that management is effective [14,43].

Return on Assets (ROA) (C_2): This ratio measures how much profit a company generates from all its assets. Total assets represent the value of the resources owned by the company, including cash, receivables, machinery, and facilities. This ratio indicates how efficiently a company uses its assets to generate profit. A high ratio suggests that a company is effectively managing its assets and utilising them profitably [44].

Receivable Turnover Ratio (C_3): This ratio indicates how quickly a company collects receivables from its customers. This ratio is particularly important for understanding working capital management. A high receivables turnover ratio suggests that the company collects receivables efficiently, which in turn indicates a healthy cash flow. A low ratio, on the other hand, suggests that receivables are not being collected in a timely manner, which may put strain on the company's cash flow [45].

Leverage Ratio (C_4): This ratio indicates how much debt a company uses to finance its operations. This ratio measures the extent of the company's debt burden and the proportion of external financing (liabilities) relative to its total assets. A high leverage ratio suggests that the company is largely financed by debt, indicating higher financial risk. Conversely, a low ratio indicates that a company relies more on equity for financing, implying lower borrowing risks.

Operating Profit Margin (C_5): This ratio of a company's profit from core business activities to its sales revenue. This ratio indicates the profit generated by the company from its primary operations. A high operating profit margin suggests that the company generates strong profits from sales and manages its costs effectively. A low margin, on the other hand, may indicate high costs or insufficiently profitable sales.

Net Profit Margin (C_6): This margin indicates the proportion of net profit generated by a company from sales revenue. This ratio measures the amount of profit the company retains after all costs, including production costs, operating expenses, and taxes, are deducted. A high net profit margin indicates that the company is effectively managing its costs and operating profitable operations. A low ratio, on the other hand, may indicate that the company is struggling to generate sufficient profit from sales or that its costs are too high [46].

Profit Margin Before Tax (C_7): This ratio evaluates a company's operational profitability by comparing its profits to revenues. A higher ratio indicates greater profitability, whereas a lower ratio suggests lower efficiency in converting revenue into profit, making it a key indicator for assessing financial performance [42].

In this decision model, seven financial ratios (Return on Equity, Return on Assets, Receivables Turnover Ratio, Leverage Ratio, Operating Profit Margin, Profit Margin Before Tax, Net Profit Margin) were utilised to assess the financial performance of companies listed on the Borsa Istanbul Corporate Governance Index and the Sustainability 25 Index. The selected financial ratios provide insights into companies' profitability, efficiency, leverage, and turnover. The financial ratios considered as criteria in the decision model are presented in Table 5.

Table 5. Computation of criteria and source reports

Financial Rations (Criteria)	Equations	References
Return on equity (C_1)	$\frac{Net\ Income}{Total\ Equity}$	Alghafes et al. [33] Hao et al. [34].
Return on assets (C_2)	$\frac{Net\ Income}{Total\ Assets}$	Jin [35].
Receivables turnover ratio (C_3)	$\frac{Net\ Credit\ Sales}{Avarage\ Account\ Receiveble}$	Zhang et al. [36].
Leverage ratio (C_4)	$\frac{Total\ Debt}{Total\ Assets}$	Ma et al. [37] Wang et al. [38].
Operating profit margin (C_5)	$\frac{Operating\ Income}{Net\ Sales}$	Menezes et al. [39].
Profit margin before taxes (C_6)	$\frac{Before\ tax\ profit}{Net\ Sales}$	Aprima et al. [41] Indrati and Magfiroh [42].
Net profit margin (C_7)	$\frac{Net\ income}{Net\ Sales}$	Katenova and Qudrat-Ullah [40].

4.1.3. Companies as Alternatives

The codes and notations for the 10 companies included in this case study are presented in Table 6. These companies constitute alternatives in the initial decision matrix. The aim is to determine and rank these companies' financial performance using the IVSF-RBNAR Method using IVSWAM Aggregation operator method.

Table 6. Companies listed in Sustainability Index and Corporate Governance Index

Codes	Codes	Companies
B_1	ARCLK	Arçelik Inc.
B_2	DOAS	Doğuş Automotive Services and Trade Inc.

Codes	Codes	Companies
B_3	DOHOL	Doğan Companies Group, Inc.
B_4	ENJSA	Enerjisa Energy, Inc.
B_5	ENKAI	ENKA Construction and Industry Inc.
B_6	MGROS	Migros Trade Inc.
B_7	PGSUS	Pegasus Air Transportation, Inc.
B_8	SISE	Şişecam Inc.
B_9	TOASA	Tofaş Inc.
B_{10}	TTRAK	TürkTraktör Inc.

4.2. Financial Performance Evaluation of Companies using the IVSF-RBNAR Method

In this application, the IVSF-RBNAR method was used to evaluate the financial performance of the companies. Each step presented in the methodology section was applied. These steps were presented as follows:

Step 1-1: Using Table 2, each expert was evaluated based on their expertise level with LVs. The LVs are listed in Table 7. The LVs were then transformed into IVSF numbers. Thus, the expert assessment matrix was obtained, as shown in Table 7.

Table 7. The expert's assessment matrix

Experts	**LVs**	**Interval Valued Spherical Fuzzy Numbers**
First Expert (E_1)	Very Important (VI)	(0.65, 0.75); (0.15, 0.20); (0.10, 0.15)
Second Expert (E_2)	Very Important (VI)	(0.65, 0.75); (0.15, 0.20); (0.10, 0.15)
Third Expert (E_3)	Extremely Important (EI)	(0.75, 0.85); (0.10, 0.15); (0.05, 0.10)
Fourth Expert (E_4)	Moderately Important (MI)	(0.45, 0.55); (0.25, 0.30); (0.20, 0.25)
Fifth Expert (E_5)	Moderately Important (MI)	(0.45, 0.55); (0.25, 0.30); (0.20, 0.25)
Sixth Expert (E_6)	Very Important (VI)	(0.65, 0.75); (0.15, 0.20); (0.10, 0.15)
Seventh Expert (E_7)	Important (I)	(0.55, 0.65); (0.20, 0.25); (0.15, 0.20)

Step 1-2: Using the score function shown in Eq. (3), the crisp values $(S(E_f))$ were calculated (Table 8).

Step 1-3: By employing linear normalisation shown in Eq. (4), the expert weighting matrix $\left(w = [w_f]_F\right)$ was calculated, and it is presented in Table 8.

Table 8. The crisp values $(S(E_f))$ and experts weighting matrix $\left(w = [w_f]_F\right)$

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
$S(E_f)$	0.3988	0.3988	0.5888	0.0638	0.0638	0.3988	0.2238
w_f	0.1867	0.1867	0.2756	0.0298	0.0298	0.1867	0.1047

Step 2-1: Using Table 3, each expert evaluated each criterion with LVs. The LVs are listed in Table 9. The LVs were then converted to IVSF numbers. Thus, the criterion assessment matrix $\left(\tilde{P} = [\tilde{P}_{vf}]_{VF}\right)$ was obtained.

Table 9. The criterion assessment matrix $\left(\tilde{P} = [\tilde{P}_{vf}]_{VF}\right)$ with LVs

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
E_1	S	VS	ED	ED	VS	M	S
E_2	S	ES	M	VS	VS	VS	ES
E_3	ES	ES	M	M	S	S	ES
E_4	ES	S	VD	M	D	D	VS
E_5	S	M	ED	VD	D	VD	D
E_6	ES	ES	D	M	VS	S	S
E_7	VS	VS	M	S	VS	S	ES

Step 2-2: Employing the IVSWAM aggregation operator shown in Eq. (5), criterion assessments were aggregated. Aggregated criterion assessment matrix $\left(\tilde{P} = [\tilde{P}_v]_V\right)$ presented in Table 10.

Table 10. The aggregated criterion assessment matrix $\left(\tilde{P} = [\tilde{P}_v]_V\right)$ with IVSF numbers.

	$\chi^{l}_{P_v}(\ell)$	$\chi^{u}_{P_v}(\ell)$	$\phi^{l}_{P_v}(\ell)$	$\phi^{u}_{P_v}(\ell)$	$\varphi^{l}_{P_v}(\ell)$	$\varphi^{u}_{P_v}(\ell)$
C_1	0.7274	0.8352	0.1675	0.2760	0.1509	0.2303
C_2	0.7648	0.8689	0.1318	0.2362	0.1033	0.1880
C_3	0.3724	0.4690	0.5097	0.6132	0.3060	0.4012
C_4	0.4994	0.6014	0.3947	0.5025	0.2768	0.3688
C_5	0.6618	0.7637	0.2388	0.3416	0.1846	0.2821
C_6	0.5884	0.6905	0.3073	0.4103	0.2525	0.3474
C_7	0.7324	0.8410	0.1623	0.2722	0.1440	0.2220

Step 2-3: Using the score function shown in Eq. (6), the crisp values $(S(\tilde{P}_v))$ were calculated and shown in Table 11.

Step 2-4: By employing linear normalisation shown in Eq. (7), the criteria weighting matrix $\left(\omega = [\omega_v]_V\right)$ was calculated, as presented in Table 11.

Table 11. The crisp values $(S(\tilde{P}_v))$ and criteria weighting matrix $\left(\omega = [\omega_v]_V\right)$.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
$S(\tilde{P}_v)$	1.5518	1.6276	0.8296	1.0748	1.4095	1.2571	1.5629
ω_v	0.1666	0.1748	0.0891	0.1154	0.1513	0.1350	0.1678

Step 3-1: Using the financial documents of the companies, financial ratio values were calculated. Then, the initial matrix $\left(H_{zv} = [H_{zv}]_{ZxV}\right)$ for assessing the financial performance of the companies is generated using these financial ratio values. The results are shown in Table 12.

Table 12. The initial matrix $\left(H_{zv} = [H_{zv}]_{ZxV}\right)$ for assessing the financial performance of companies.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
B_1	0.17425	0.03572	4.64947	0.79503	6.78801	3.14976	3.52689
B_2	0.67040	0.37977	21.54510	0.43351	16.94003	18.21443	16.77606
B_3	0.29468	0.16400	13.24248	0.44344	15.17245	15.10367	15.09882
B_4	0.67207	0.24495	14.99938	0.63553	9.88526	5.26545	17.16786
B_5	0.01728	0.01318	12.97293	0.23706	19.81762	6.11524	3.42145
B_6	0.63080	0.07083	224.00984	0.88772	3.65765	2.56134	3.46277
B_7	0.39347	0.07411	56.51585	0.81165	22.64211	15.48936	16.61544
B_8	0.21165	0.12281	6.56989	0.41976	18.26967	20.72589	21.11541
B_9	0.75680	0.21206	5.93222	0.71979	13.62395	13.06306	13.06300
B_{10}	0.81661	0.21535	12.97215	0.73628	13.82471	13.11421	13.60691

Step 3-2a: Using the Z-score reference-based normalisation shown in Eq. (8), the first normalised decision matrix $\left(M_{zv} = [M_{zv}]_{ZxV}\right)$ was calculated by employing the reference value matrix. The first normalised decision matrix and reference values are given in Table 13.

Table 13. The first normalised matrix $\left(M_{zv} = [M_{zv}]_{ZxV}\right)$ and reference values.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
B_1	0.67877	0.65194	0.95008	0.77919	0.28698	0.25928	0.22752
B_2	0.67091	0.10449	0.99764	0.61983	0.98991	0.79760	0.95361
B_3	0.90380	0.97769	0.98169	0.64783	0.98768	0.98129	0.99868
B_4	0.66733	0.64889	0.98630	0.99932	0.57347	0.41962	0.93446
B_5	0.35383	0.53123	0.98093	0.16653	0.81965	0.49421	0.22126
B_6	0.75377	0.82837	0.01321	0.52317	0.10768	0.22256	0.22370
B_7	0.99535	0.84294	0.90322	0.73551	0.54013	0.96834	0.96058
B_8	0.75676	0.98839	0.95841	0.58098	0.93452	0.57105	0.62306
B_9	0.48539	0.81559	0.95573	0.93865	0.91549	0.99291	0.96666
B_{10}	0.36687	0.80019	0.98092	0.91064	0.92815	0.99381	0.98444
Reference R_v	0.4205	0.1400	26.1715	0.6434	16.1006	13.8392	14.7634

Step 3-2b: Using Aytekin's reference-based normalisation shown in Eq. (9), the second normalised decision matrix $\left(T_{zv} = [T_{zv}]_{ZxV}\right)$ was calculated (Table 14).

Table 14. The second normalised matrix $\left(T_{zv} = [T_{zv}]_{ZxV}\right)$.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
B_1	0.9999998	0.9999999	0.9999785	0.9999998	0.9999907	0.9999893	0.9999888
B_2	0.9999998	0.9999998	0.9999954	0.9999998	0.9999992	0.9999956	0.9999980
B_3	0.9999999	1.0000000	0.9999871	0.9999998	0.9999991	0.9999987	0.9999997
B_4	0.9999997	0.9999999	0.9999888	1.0000000	0.9999938	0.9999914	0.9999976
B_5	0.9999996	0.9999999	0.9999868	0.9999996	0.9999963	0.9999923	0.9999887
B_6	0.9999998	0.9999999	0.9998022	0.9999998	0.9999876	0.9999887	0.9999887
B_7	1.0000000	0.9999999	0.9999697	0.9999998	0.9999935	0.9999983	0.9999981
B_8	0.9999998	1.0000000	0.9999804	0.9999998	0.9999978	0.9999931	0.9999936
B_9	0.9999997	0.9999999	0.9999798	0.9999999	0.9999975	0.9999992	0.9999983
B_{10}	0.9999996	0.9999999	0.9999868	0.9999999	0.9999977	0.9999993	0.9999988

Step 3-2c: Using the Heron mean in Eq. (10), the aggregated normalised decision matrix $\left(N_{zv} = [N_{zv}]_{ZxV}\right)$ was calculated $(\alpha = 0.5)$ and shown in Table 15.

Table 15. The aggregated normalised matrix $\left(N_{zv} = [N_{zv}]_{ZxV}\right)$

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
B_1	0.83163	0.81670	0.97487	0.88615	0.58960	0.56941	0.54537
B_2	0.82727	0.43775	0.99882	0.79860	0.99495	0.89594	0.97667
B_3	0.95129	0.98882	0.99082	0.81440	0.99383	0.99062	0.99934
B_4	0.82528	0.81499	0.99313	0.99966	0.77200	0.67879	0.96695
B_5	0.63588	0.74723	0.99043	0.49567	0.90758	0.72505	0.54050
B_6	0.87254	0.91216	0.31071	0.74245	0.44099	0.54152	0.54240
B_7	0.99767	0.91980	0.95098	0.86268	0.75249	0.98411	0.98019
B_8	0.87415	0.99418	0.97909	0.77635	0.96698	0.77060	0.80043
B_9	0.71970	0.90545	0.97773	0.96908	0.95728	0.99645	0.98326
B_{10}	0.64457	0.89732	0.99043	0.95480	0.96374	0.99690	0.99220

Step 3-3: Using Eq. (11), the weighted aggregated normalised decision matrix $\left(S_{zv} = [S_{zv}]_{ZxV}\right)$ was calculated, as shown in Table 16.

Table 16. The weighted aggregated normalised matrix $\left(S_{zv} = [S_{zv}]_{ZxV}\right)$

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
B_1	0.1385648	0.1427276	0.0868375	0.1022693	0.0892319	0.0768576	0.0915217
B_2	0.1378386	0.0765012	0.0889704	0.0921654	0.1505796	0.1209319	0.1638993
B_3	0.1585025	0.1728066	0.0882580	0.0939879	0.1504102	0.1337115	0.1677042
B_4	0.1375071	0.1424285	0.0884640	0.1153691	0.1168380	0.0916218	0.1622684
B_5	0.1059487	0.1305875	0.0882238	0.0572049	0.1373577	0.0978656	0.0907041
B_6	0.1453817	0.1594111	0.0276770	0.0856844	0.0667406	0.0730925	0.0910236
B_7	0.1662305	0.1607446	0.0847093	0.0995607	0.1138858	0.1328321	0.1644903

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
B_8	0.1456494	0.1737450	0.0872131	0.0895974	0.1463471	0.1040134	0.1343245
B_9	0.1199149	0.1582376	0.0870920	0.1118401	0.1448788	0.1344983	0.1650056
B_{10}	0.1073964	0.1568162	0.0882237	0.1101914	0.1458567	0.1345593	0.1665064

Step 3-4: Using Eq. (12), the financial performance ranking matrix $\left(R_z = [R_z]_Z\right)$ was calculated, as shown in Table 17.

Table 17. The financial performance ranking matrix $\left(R_z = [R_z]_Z\right)$

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
R_z	0.7280	0.8309	0.9654	0.8545	0.7079	0.6490	0.9225	0.8809	0.9215	0.9096
Rank	8th	7th	1st	6th	9th	10th	2nd	5th	3rd	4th

5. Results

This study employs the IVSF-RBNAR method to evaluate the financial performance of companies listed under corporate governance and the Sustainability 25 Index. The research yields three primary findings: *(i)* expert weightings, *(ii)* criteria weightings, and *(iii)* companies' financial performance and rankings. The results of the analysis are summarised as follows:

- *Expert Contributions*: The influence of experts on the decision-making process is ranked as follows: " $E_3 > E_1 = E_2 = E_6 > E_7 > E_4 = E_5$". Accordingly, the third expert was identified as the most influential contributor to the decision-making process.
- *Criteria Weightings*: The criteria's impact on the decision-making process is ranked as follows: "Return on assets (C_2) > Net profit margin (C_7) > Return on equity (C_1) > Operating profit margin (C_5) > Profit margin before tax (C_6) > Leverage ratio (C_4) > Receivables turnover ratio (C_3)". Among these, Return on Assets (ROA) emerged as the most significant criterion for evaluating companies' financial performance, while the receivables turnover ratio had the least impact.
- *Company Rankings*: The financial performance rankings of the companies are as follows: "DOHOL (B_3) > PGSUS (B_7) > TOASA (B_9) > TTRAK (B_{10}) > SISE (B_8) > ENJSA (B_4) > DOAS (B_2) > ARCLK (B_1) > ENKAI (B_5) > MGROS (B_6) ". Among the evaluated firms, Doğan Companies Group Holding Inc. was identified as having the highest financial performance, whereas Migros Trade Inc. demonstrated the lowest financial performance.

In conclusion, the IVSF-RBNAR method effectively supports the analysis of corporate financial performance. These results underscore the applicability and robustness of the methodology for evaluating financial performance within the framework of corporate governance and sustainability indices.

6. Research Implications

This study has several significant implications for academic research, corporate decision-making, and methodological advancements in financial performance evaluation:

- *Advancement in Financial Performance Evaluation*: Demonstrates the utility of the IVSF-RBNAR Method as a novel approach for assessing and ranking financial performance based on financial ratios. This framework provides a robust framework for future performance analysis studies.

- *Integration of Expert Judgments*: Highlights the importance of incorporating expert opinions into decision-making processes. The use of linguistic expressions and IVSF sets to quantify expert expertise ensures a nuanced understanding of decision-makers' contributions.
- *Enhanced Decision-Making Methodologies*: This study validates the integration of the IVSWAM aggregation operator and RBNAR method for calculating criteria weights and ranking companies, paving the way for their application in other multi-criteria decision-making contexts.
- *Key Financial Metrics*: Identifies Return on Assets (ROA) as the most critical financial metric, emphasising its importance for corporate governance and sustainability-focused performance evaluations.
- *Empirical Validation of Methodology*: Provides a practical application of the IVSF-RBNAR method to evaluate the financial performance of 10 companies listed in the Corporate Governance Index and the Sustainability Index, offering a replicable model for similar studies.
- *Corporate Governance and Sustainability*: Offers insights into the financial health of companies adhering to corporate governance and sustainability principles and contributes to the literature on the financial implications of these frameworks.
- *Decision Support for Stakeholders*: Supports stakeholders in identifying high-performing companies, as evidenced by the identification of Doğan Companies Group Holding Inc. as the top performer. This will facilitate informed decision-making in investment and policy development.

Methodological Applicability: Confirms the suitability of the IVSF-RBNAR method for financial performance ranking, encouraging its adoption and adaptation in diverse decision-making scenarios within corporate finance and beyond.

7. Conclusion

This study evaluates the financial performance of companies listed in the Corporate Governance Index and the Sustainability Index using financial ratios and an MCDM approach. By employing the IVSF-RBNAR Method, the research effectively integrated expert judgments and linguistic expressions to determine criterion importance and rank companies based on their financial performance. The analysis highlighted the significance of incorporating both qualitative and quantitative data to create a comprehensive decision-making framework, demonstrating the method's applicability in corporate financial evaluation.

The findings reveal that Doğan Companies Group Holding Inc. achieved the highest financial performance among the 10 analysed companies, while Return on Assets (ROA) emerged as the most critical criterion influencing corporate performance. The use of the IVSWAM aggregation operator for criteria weighting and the RBNAR method for performance ranking proved effective in terms of delivering accurate and meaningful results. These insights contribute to the understanding of financial performance dynamics, offering a valuable tool for stakeholders to assess companies based on their adherence to corporate governance and sustainability principles.

This study underscores the potential of the IVSF-RBNAR method as a robust approach for financial performance assessment, but it also acknowledges its limitations, including the reliance on expert judgments and the relatively small sample size. Future research should expand on this framework by incorporating additional criteria, exploring larger datasets, and integrating advanced computational techniques to further refine the methodology. Ultimately, this research provides a foundation for enhancing decision-making processes in corporate finance and governance.

7.1. Research limitations

Although this study provides valuable insights into the financial performance evaluation of companies listed in the Corporate Governance Index and the Sustainability Index, it is not without limitations. These include:

- *Sample Size*: The research focuses on a limited sample of 10 companies, which may not fully capture the broader diversity of firms in the indices or general corporate practices.
- *Criteria Selection*: The evaluation relies on seven financial criteria, potentially omitting other significant financial or non-financial factors that could influence corporate performance.
- *Expert Dependency*: The methodology relies heavily on expert judgments for weighting criteria and assessing importance, which may introduce subjectivity despite efforts to standardise inputs using IVSF sets.
- *Context-Specific Findings*: The findings, including the identification of Doğan Companies Group Holding Inc. as the best-performing company, may not generalise to other indices, industries, or geographical contexts.
- *Linguistic Expression Limitations*: The use of linguistic expressions to represent expert assessments, while innovative, may lead to loss of precision or inconsistencies in interpretation.
- *Focus on Financial Ratios*: By prioritising financial ratios, this study does not account for qualitative factors such as corporate governance practices, environmental sustainability, or social impact, which are crucial for holistic performance evaluation.
- *Methodological Constraints*: Although the IVSF-RBNAR method has been validated in this context, its applicability and reliability in different decision-making scenarios or larger datasets remain to be tested.

These limitations provide avenues for future research to refine the methodology, expand the scope of the analysis, and incorporate additional dimensions to ensure a more comprehensive evaluation.

7.2. Future Research Suggestions

Building on the findings and limitations of this study, the following recommendations are proposed for future research:

- *Expanding the Sample Size*: Future studies could include a larger number of companies across various indices, industries, or geographic regions to enhance the generalizability of the findings.
- *Incorporating Additional Criteria*: The inclusion of both financial and non-financial criteria, such as environmental sustainability metrics, governance quality, and social responsibility indicators, would provide a more comprehensive evaluation framework.
- *Longitudinal Analysis*: Conducting a longitudinal study to track changes in financial performance over time would offer deeper insights into trends and temporal dynamics.
- *Automation and Standardisation*: Developing automated tools to process linguistic expressions and calculate IVSF values could minimize subjectivity and improve the reproducibility of results.
- *Methodological Comparisons*: Comparing the IVSF-RBNAR method with other MCDM approaches will help validate its effectiveness and identify scenarios where it performs optimally.

- *Dynamic Expert Weighting*: Exploring dynamic or adaptive weighting mechanisms that adjust expert influence based on past performance or domain relevance can enhance decision-making processes.
- *Integration with Machine Learning*: Combining the IVSF-RBNAR method with machine learning techniques can improve predictions and automate the performance ranking process.

These directions can extend the scope and impact of financial performance evaluation research and contribute to more robust and versatile decision-making models.

Peer Review: Externally peer-reviewed.
Author Contributions: Conception/Design of Study- K.K., G.C.Y., H.Ö.; Data Acquisition – K.K., G.C.Y., H.Ö.; Data Analysis/Interpretation- K.K., G.C.Y., H.Ö.; Drafting Manuscript- K.K., G.C.Y., H.Ö.; Critical Revision of Manuscript- K.K., G.C.Y., H.Ö.; Final Approval and Accountability- K.K., G.C.Y., H.Ö.; Supervision- K.K., G.C.Y., H.Ö.
Conflict of Interest: The authors have no conflict of interest to declare.
Grant Support: The authors declared that this study has received no financial support.

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