Financial Innovation

RESEARCH

Open Access

Determining the financial performance of the firms in the Borsa Istanbul sustainability index: integrating multi criteria decision making methods with simulation

Ahmet Kaya[1], Dragan Pamucar[2,3,4*], Hasan Emin Gürler[5] and Mehmet Ozcalici[6]

*Correspondence:
dragan.pamucar@va.mod.gov.rs

[1] Department of Banking-Finance, Applied Sciences Faculty, Akdeniz University, Antalya, Turkey
[2] Faculty of Organizational Sciences, University of Belgrade, Belgrade, Serbia
[3] College of Engineering, Yuan Ze University, Taoyuan, Taiwan
[4] Department of Computer Science and Mathematics, Lebanese American University, Byblos, Lebanon
[5] Department of International Trade and Logistics, Applied Sciences Faculty, Akdeniz University, Antalya, Turkey
[6] Department of International Trade and Logistics, Faculty of Economics and Administrative Sciences, Kilis 7 Aralık University, Kilis, Turkey

Abstract

Regardless of the industry in which a company operates, evaluating corporate performance is one of the most critical and vital processes; the most essential and prominent performance evaluation is related to financial performance. Appropriate performance analysis is complex and critical for decision-makers in different financial performance factors; thus, a methodological framework is needed to solve such complex decision problems. Therefore, this research aims to rank the companies included in the sustainability index (excluding banks) in Turkey by considering their financial performance. The criteria weights were determined using the full consistency method (FUCOM) by considering the evaluations of four experts. The firms were ranked using nine multi-criteria decision-making methods. The consensus among the nine rankings was ensured with the Copeland technique. The decision matrix includes financial ratios and the stock market performance of the firms; 100,000 FUCOM weights were created with random evaluations to validate the results. The results indicate that the most crucial criterion is the current ratio by considering expert evaluations. Weight simulation indicates that alternative 16 (alternative 21) is superior (inferior) to the other alternatives, even though the weights are determined with random evaluations. Ranking with expert evaluations is similar to the mean of the weight simulation results. The results demonstrate that the proposed framework can be performed as a basis for financial performance ranking.

Keywords: Financial performance, BIST sustainability index, Simulation, MCDM techniques

Introduction

In recent years, companies have widely used financial performance as an essential indicator of management performance (Cheng et al. 2012). Company managers must measure the financial performance of their companies (Tsolas 2020), and recently, it has become more critical to measure the financial performance of companies, especially in the financial sector (Yalçın and Bayrakdaroğlu 2012). In today's competitive environment, reliable and accurate determination of a company's financial performance is crucial for managers, creditors, current/potential investors, and companies operating in the same sector (Farrokh et al. 2016; Alossta et al. 2021). The financial performance evaluation of listed companies is critical for both shareholders and investors (Dong et al. 2018), especially with economic globalization and financial innovation; therefore, evaluating the financial performance of companies is a valuable research topic for investors and researchers (Inani and Gupta 2017; Muhammad et al. 2021).

Companies must be ranked by their financial performance to know their position against their competitors. Owing to these performance evaluations, companies can determine the strategies needed to increase their financial performance (Lam et al. 2021). Since the financial performance evaluation includes many evaluation criteria, it is considered a kind of multi-criteria decision-making (MCDM) problem (Dong et al. 2018; Yalçın and Ünlü 2018). MCDM analysis determines the best alternative by considering more than one criterion or factor that affects the other options (Lam et al. 2021). MCDM methods, widely used in business and engineering, enable decision-makers to make more rational and effective decisions regarding alternatives (Deng et al. 2011). Nonetheless, financial ratios are generally used as evaluation criteria, as they can fully reflect the information regarding the companies' financial status (Dong et al. 2018), revealing financial strengths and weaknesses (Lam et al. 2021). Over the years, many studies have shown the effectiveness of financial ratios in performance measurements (Yalcin et al. 2012).

The criteria weights that directly affect the results of MCDM methods can be determined subjectively and objectively, and expert opinions generally determine subjective weights. In contrast, objective weights are mainly determined according to the data set's essential characteristics; however, it is crucial to objectively determine the weights of the criteria to create more accurate rankings.

This research aims to rank the companies included in the 2021 sustainability index in Turkey by considering their financial performance. The dataset was collected from two different sources, and the criteria weights were determined with the full consistency method (FUCOM). Four experts completed surveys and created four different weight sets, with the arithmetic average of the four weight sets calculated to obtain a single weight set. There are 22 firms in the Borsa Istanbul (BIST) sustainability index (excluding banks since their financial statements differ from other firms). There are nine criteria, including the stock market performance of the firms. The dimensions of the decision matrix are 22 by 9 for 2021. Nine techniques were employed to evaluate the alternatives: combined compromise solution (CoCoSo), grey relational analysis (GRA), multi-attributive border approximation area comparison (MABAC), multi-attribute ideal real comparative analysis (MAIRCA), multi-objective optimization based on simple ratio analysis (MOOSRA), operational competitiveness ratings (OCRA), the technique for order of preference by similarity to ideal solution (TOPSIS), the Portuguese acronym for interactive MCDM (TODIM), and multi-criteria optimization and compromise solution Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR). Although significant efforts have been made to develop many multi-criteria techniques, no comprehensive methodology exists, and no single method appears to be better than its counterparts (Saaty and Ergu 2016; Varmazyar et al. 2016); each technique has its superiority in identifying the weights of factors. According to Kou et al. (2021a), a hybrid approach involves utilizing various MCDM models to assign weights to criteria and rank alternatives. As a result, hybrid methods enhance the objectivity of these outcomes.

In this research, a consensus among the different MCDM techniques is ensured with the Copeland technique. Kou et al. (2014) state that a ranking obtained through the consensus of several MCDM methods is considered more reliable than a ranking produced by only one MCDM method; thus, a single score (and rank) is calculated for each alternative. If the two alternative scores differ significantly (in other words, if the difference between them is high), it is possible to say that the alternative with high scores is superior to the alternative with low scores. Conversely, if the difference between the scores is insignificant, it is difficult to determine whether there is a practical difference between the alternatives. Practical significant differences are always an issue of judgment and interpretation for the decision-maker; however, the discipline of statistics can guide the issue of statistically significant differences (Rosenbloom 1997). This study created 100,000 FUCOM weight sets of random values to examine the alternatives' statistical superiority (or inferiority). The alternative that exhibits statistical superiority is determined using 100,000 scores.

The proposed framework presents a comprehensive and reliable performance evaluation tool to help determine financial performance rankings. This paper's objectives can be summarized as follows.

- This study aims to realize a sustainability performance evaluation of companies using the stock market return and financial ratios of the companies listed in the BIST sustainability index. The companies' stock market and financial performances were then integrated into a single decision matrix.
- We created a weight set using the FUCOM technique with four experts.
- This work applied nine MCDM techniques (CoCoSo, GRA, MABAC, MAIRCA, MOOSRA, OCRA, TOPSIS, TODIM, and VIKOR) to evaluate the alternatives.
- Using the Copeland technique, we ensured the consensus among the ranking results of various MCDM tools.
- A weight simulation process was applied to determine the statistically superior alternatives.
- The proposed methodology was repeated in the years 2019 and 2020.

This study is structured as follows. After this introduction, the second section presents a review of the related literature and discusses the importance of evaluating financial performance and the studies in which financial performance is determined using MCDM techniques. The third section is dedicated to the methodology, where the research flowchart, performance indicators, and MCDM techniques are presented. In addition, the analysis and processes to be carried out at each stage of the proposed framework are presented. The results are given in the fourth section, and the results are discussed in the fifth section with managerial emphasis. Finally, the sixth section is dedicated to the conclusion and directions for future research.

Literature review

Performance evaluation investigates whether the company's goals and objectives have been achieved (Chang and Tsai 2016) and whether resources have been allocated efficiently. It is applied for operational control purposes in the short-term and strategic management and planning purposes in the long-term (Wu et al. 2009). In a competitive environment, companies generally aim to compete in the international market and be at the top of the sector in which they operate. Financial performance evaluation is one of the most important indicators of whether these targets have been achieved. At this point, analyzing companies' financial ratios effectively reveals their strengths and weaknesses (Abdel-Basset et al. 2020). Financial performance is performed for stakeholders, including company owners, managers, investors, competitors, and creditors (Bağcı and Yerdelen Kaygın 2020).

Different methods have been used to determine the financial performance of companies. In financial performance evaluation, discriminant analysis (Mihalovic 2015; Keskin et al. 2020a), a balanced scorecard (Davis and Albright 2004; Cohen et al. 2008; Knápková et al. 2014), Generalized Method of Moments (GMM) analysis (Kılıç et al. 2022), and data envelopment analysis (Dekker and Post 2001) have been used. MCDM is another method frequently used in financial performance evaluation (Ersoy 2021; Dukić et al. 2022). Most financial performance evaluations are considered MCDM problems (Abdel-Basset et al. 2020). The use of MCDM in measuring companies' financial performance has become widespread since the 1980s (Erdoğan et al. 2016). Researchers have used it since the early 2000s as it helps financial information users make more accurate decisions, especially in a complex environment where the number of criteria related to financial performance is high (Baydaş and Elma 2021). MCDM methods are essential in solving multidimensional and complex problems (Lee et al. 2012). The most important feature distinguishing MCDM from other methods is that it provides a suitable framework for the decision-maker in case of many alternatives and conflicting criteria (Ersoy 2021).

Financial ratios generally determine the financial performance of companies. Using financial ratios in performance evaluation has a long history, and there has been a significant increase in these ratios in recent years (Alimohammadlou and Bonyani 2017). Financial ratios are essential evaluation tools to understand the profitability of companies and analyze their financial situation (Aldalou and Perçin 2020; Bakır et al. 2021); however, having financial data alone is not enough to evaluate financial performance. Furthermore, financial statements offer only a momentary glimpse into a company's financial position from the previous year and fail to depict its current operational state (Kou et al. 2021b). For this reason, firms and information users use financial ratios as data and calculate financial performance through statistical and econometric models, including regression analysis, correlation analysis, time series analysis, and MCDM methods (Bağcı and Yerdelen Kaygın 2020; Osintsev et al. 2021; Narang et al. 2022). However, with too many ratios or criteria, MCDM methods have proven to be quite successful in determining financial performance (Visalakshmi et al. 2015). Nonetheless, considering stock market indicators, such as stock returns and financial ratios, in evaluating financial performance is beneficial for users of financial information, as it can assist them in their decisions (Jokić et al. 2021).

Many studies use MCDM methods in financial performance evaluation, as shown in Table 1. These studies primarily aim to rank the alternatives according to financial performance criteria and identify the companies with the highest performance.

Table 1 shows that different MCDM methods rank firms according to their financial performance. It has been understood that various methods are increasingly preferred in ordering alternatives. As shown, most of the studies use more than one method together, and the criteria weights are determined mainly by the fuzzy AHP, entropy, and AHP methods.

There are studies in which companies' financial performances included in the BIST sustainability index are determined using different methods. For example, Ates (2020) investigated the effect of sustainability performance on financial performance using regression models. Similarly, Akben-Selcuk (2019) used regression models and examined the impact of corporate social responsibility on financial performance. Using the Hirose method, Karaömer and Oypan (2020) determined the financial performance of six banks in the BIST sustainability index. Acar and Temiz (2018) and Çimen (2019), investigated the effect of the sustainability index on firm performance by conducting an event study analysis. Using Mann–Whitney U, Kruskal–Wallis methods, and panel data analysis, Dinçer and Altınay (2020) examined the effect of disclosures in sustainability reports on financial performance. Using discriminant analysis, Keskin et al. (2020b) investigated the impact of sustainability on financial performance. In addition, Şahin et al. (2017) used a T-test analysis and examined the effect of sustainability on the financial performance of 15 firms in the BIST sustainability index.

The literature review revealed that FUCOM was not frequently used in determining the weights of the criteria in an MCDM framework to evaluate the performance of the companies in an emerging economy like Turkey. Furthermore, weight simulation was not employed with the FUCOM technique. The fact that the alternative evaluation was not conducted with random weight sets is an essential gap in the literature because, together with the simulation study, it is possible to determine the statistically superior (or inferior) alternative.

Methodology

This research determined firms' financial performances using four different MCDM methods. Previous that determined companies' financial performances used more than one financial performance indicator to make closer and more accurate assessments. In this context, the companies are ranked according to their financial performance using eight financial ratios and stock returns. According to Baydas and Pamučar, stock return is a significant financial indicator for research that determines financial performance together with MCDM methods (Baydas and Pamučar 2022). Table 2 shows the financial performance indicators and MCDM methods used in the research.

This study used 11 MCDM techniques together. The FUCOM technique is used to determine the order of importance of the criteria, nine techniques are used to rank the alternatives, and finally, one technique is used to reach a consensus among the nine rankings. In addition, random weight sets are created to provide a statistical interpretation of the results. Repeating the analysis with random weight sets has the following benefits:

- It can be determined whether the evaluations made by the experts are an extreme value. If random assessments are generated, some weights should occur very few times, and others should occur more frequently. In other words, a distribution of the weight of a criterion will appear. If the experts' assessments are at the extremes of this distribution, it can be stated that the experts made an extreme value assessment; therefore, concerns about the health of the assessment may arise. Conversely, if the

Table 1 Summary of related studies

Study	Weight determination	MCDM method	Number of alternatives	Number of performance indicators	Years
Wang (2008)	–	Fuzzy TOPSIS	3	21	2001–2005
Wu et al. (2009)	Fuzzy AHP	SAW, TOPSIS, VIKOR	3	23	
Chen et al. (2011)	–	DEMATEL, ANP	–	15	2009
Kung et al. (2011)	Fuzzy AHP	Fuzzy TOPSIS	5	7	–
Baležentis et al. (2012)	–	Fuzzy VIKOR, Fuzzy TOPSIS, Fuzzy ARAS	11	6	2007–2010
Ignatius et al. (2012)	–	PROMETHEE II	8	7	2009–2010
Lee et al. (2012)	Entropy	GRA	4	25	1999–2009
Yalcin et al. (2012)	Fuzzy AHP	TOPSIS, VIKOR	13	8	2007
Yalçın and Bayrakdaroğlu (2012)	Fuzzy AHP	Fuzzy AHP, VIKOR	17	7	1998–2011
Esbouei et al. (2014)	Fuzzy ANP	Fuzzy VIKOR	143	11	2002–2011
Ghadikolaei et al. (2014)	Fuzzy AHP	Fuzzy VIKOR, ARAS-F, Fuzzy COPRAS	6	11	2002–2011
Shen and Tzeng (2015)	DEMATEL-based ANP	VIKOR	34	25	2008–2011
Islamoglu et al. (2015)	Entropy	TOPSIS	25	16	2011–2014
Visalakshmi et al. (2015)	DEMATEL	TOPSIS	14	16	2008–2012
Wanke et al. (2016)	–	Fuzzy AHP, TOPSIS, ANN	88	25	2010–2013
Chang and Tsai (2016)	AHP	VIKOR	7	25	2007–2008
Erdoğan et al. (2016)	Buckley's Column Geometric Mean	TOPSIS, VIKOR, ELECTRE	21	8	2011–2014
Farrokh et al. (2016)	Fuzzy AHP	VIKOR, TOPSIS	8	12	–
Alimohammadlou and Bonyani (2017)	BWM	PROMETHEE II	14	5	2011–2015
Inani and Gupta (2017)	Equal weighting	TOPSIS	9	10	2011–2015
Ic et al. (2020)	AHP	Regression-AHP, VIKOR	5	9	2007–2011
Ayçin and Güçlü (2020)	Entropy	MAIRCA	17	8	2018
Abdel-Basset et al. (2020)	AHP	VIKOR, TOPSIS	10	20	–
Aldalou and Perçin (2020)	Fuzzy Shannon's Entropy	Fuzzy EDAS	21	18	2015–2017
Bağcı and Yerdelen Kaygın (2020)	Entropy	ARAS, WASPAS	43	5	2000–2017
Grida et al. (2020)	BWM	VIKOR	5	23	–
Biswas et al. (2020), Akbulut and Hepşen (2021)	Entropy	CoCoSo	27	10	2015–2019
Armağan et al. (2021)	SECA	SECA	12	5	2020
Baydaş and Elma (2021)	Hybrid, Entropy, Equal weighting	TOPSIS, WSA, PRO-METHEE	131	7	2014–2018
Bektaş (2021)	Entropy	MAIRCA	6	6	2018–2019
Kumaran (2021)	Objective weight-ing	VIKOR	18	6	2012–2018
Lam et al. (2021)	Entropy weighting	Fuzzy VIKOR	20	6	2015–2019

Table 1 (continued)

Study	Weight determination	MCDM method	Number of alternatives	Number of performance indicators	Years
Ersoy (2021)	Improved entropy	VIKOR	15	9	2017–2018
Pala (2021)	Correlation Coefficient and Standart Deviation	CoCoSo	9	8	2019–2020
Topal (2021)	Entropy	CoCoSo	10	8	2019
Iç et al. (2022)	AHP	AHP and Design of Experiments	18	44	2002–2016
Baydas and Pamucar (2022)	Equal weighting	PROMETHEE, FUCA, TOPSIS, SAW, CODAS, COPRAS, MOORA	24	7	2019–2021

AHP Analytical Hierarchy Process, *ANP* Analytical Network Process, *ARAS* Additive Ratio Assessment, *BWM* Best–Worst Method, *CODAS* Combinative Distance-Based Assessment, *COPRAS* Complex Proportional Assessment, *DEMATEL* Decision Making Trial and Evaluation Laboratory, *EDAS* Evaluation Based on distance from average solution, *FUCA* Faire un choix Adequat, *PROMETHEE* Preference Ranking Organization Method for Enrichment of Evaluations, *SECA* Simultaneous Evaluation of Criteria and Alternatives

Table 2 Indicators and methods

Weight determination	Performance indicators	MCDM tools
FUCOM (Fully Consistency Method)	Current Ratio, Acid-Test Ratio, Debt Ratio, Asset Turnover, Stock Turnover, EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortization), Net Profit Margin, Return On Equity, Stock Return	CoCoSo, GRA, MABAC, MAIRCA MOOSRA, OCRA, TOPSIS, TODIM, VIKOR Integration with Copeland

experts' evaluations are close to the mean in this distribution, it may be concluded that their evaluation is reasonable.

- Evaluations made by experts and simulation results with random weights can be compared. According to Xiao et al. (2023), the growing complexity of discrete event dynamic systems has increased the usage of simulation for their evaluation. In this way, the number of evaluations made by the experts in the interquartile range in random evaluations can be calculated, and the consistency of the evaluations can be revealed. If most of the alternatives are in the interquartile range according to the experts' evaluations, it is possible to ensure that their evaluations are not outliers.
- A table can be created regarding how many sets of weights an alternative is ranked first, second, third, and so on. Such a table reveals that the alternative is ranked higher not only in one weight set but also in more than one weight set. In other words, even if the weights are determined randomly, it will be possible to determine that an alternative is a superior (or inferior) alternative.
- With random evaluations, the statistical superiority of the alternatives over each other can be revealed; thus, for example, we can determine the number of total sets of weights between differently ranked alternatives. These numbers can be determined for each pairwise comparison.
- Since the calculation is made with a large number of weight sets, it can be statistically determined whether there is a difference between the group means with the help of

ANOVA analysis. As a continuation, post hoc analysis can be performed to determine which groups have a statistical difference between their means; thus, it will be possible to compare distribution means and perform statistical analysis instead of comparing with a single ranking.

Figure 1 shows the four methodological steps of the research as follows:

Step 1 Creating the decision matrix.

First, a decision matrix was created based on performance indicators. Next, nine indicators were used to determine financial performance.

Step 2 Determination of criterion weights.

The criteria weights were determined using the FUCOM method. This method was preferred because it integrates valuable expert judgments in decision-making. Therefore, the weights of all the criteria were determined according to this method. Four expert evaluations were collected at this stage, and the average of the weight sets was employed as the final weight set.

Step 3 Calculating and ranking the scores of the alternatives

Nine MCDM techniques were selected as ranking methods, and calculation steps were performed on the MATLAB platform; each method may produce different ranking results when more than one MCDM method is used. In such cases, integration methods are used to integrate different results and obtain a result. This step aims to integrate the different results suggested by each MCDM method using the Copeland method.

Step 4 Testing the validity of the results

In this step, a weight simulation was performed. Expert opinions were simulated with the help of random evaluations; 100,000 random evaluations were carried out, and as a result, 100,000 weight sets were created. Then, nine techniques were run for each weight set, and finally, the results were combined with the Copeland technique. As a result, 100,000 rankings emerged, allowing statistical evaluation of the results.

The purpose of weight simulation is to examine the system behavior in the case of many random weight sets. In the weight simulation, instead of only converging a single

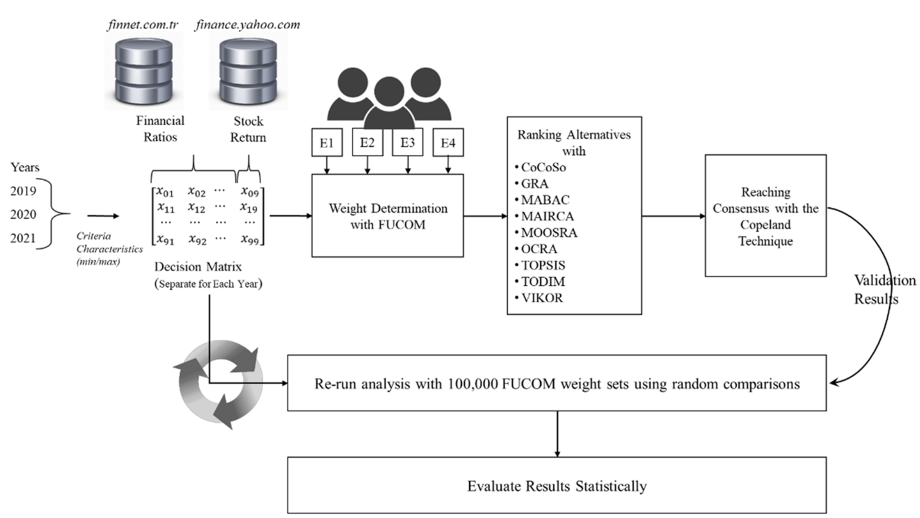

Fig. 1 Flowchart of the research

ranking, the superiority of the alternatives over each other is statistically examined; thus, for example, instead of concluding that "the first alternative is superior to the second alternative," it is possible to comment that "90% of the 10,000 weights are ranked in a higher position."

Financial performance indicators

The study used MCDM methods to reveal companies' financial performances; several indicators were also used to achieve this aim. These indicators are current ratio, acid-test ratio, debt ratio, asset turnover, stock turnover, Earnings before Interest Taxes, Depreciation, and Amortization (EBITDA), net profit margin, return on equity (ROE), and stock return. Additionally, the debt ratio is a cost variable, whereas other variables are benefit variables. The justification for selecting these performance indicators can be explained as follows. ROE is the most essential and well-known ratio used in financial performance evaluation. Stock return is a significant financial indicator for research in which financial performance is determined together with MCDM methods. Furthermore, the current and acid-test ratios are the most popular ratios used to determine the future risks of the firm as well as its financial performance (Baydas and Pamučar 2022). The current ratio is a vital liquidity ratio commonly used by financial analysts and investors (Ghosh and Bhattacharya 2022). Moreover, Bhadu et al. stated that the current ratio is a crucial measure of the financial performance of firms (Bhadu et al. 2021). EBITDA is vital in determining shareholder returns for the relevant period (Buračas et al. 2015). In this respect, this ratio allows an understanding of the relationship between financial performance and the relevant stakeholders (Puška et al. 2023). The net profit margin is the most critical indicator of the firm's financial and operational performance (Estiasih and Putra 2021). Aytekin stated that the current ratio, acid-test ratio, net profit margin, ROE, debt ratio, asset turnover, and stock turnover are the most used ratios in the literature to determine financial performance with MCDM methods (Aytekin 2019). The literature maintains two fundamental views on evaluating financial performance: traditional and modern. According to the traditional view, the stock return and the debt ratio are essential determinants of financial performance (Tavana et al. 2015), while stock turnover is an actual indicator of production performance (Bhadu et al. 2021). Explanatory information regarding these indicators is given below.

Current ratio

The current ratio is an essential indicator of short-term financial stability. The ratio allows the firm to compare its current assets with its current liabilities; therefore, the rate is expected to be high. A high current ratio guarantees that creditors meet short-term obligations (Bhadu et al. 2021).

Acid-test ratio

The acid-test ratio is calculated by dividing the current liabilities by the value resulting from deducting the stocks from the total current assets; stocks are not considered as their liquidity ratios are low (Akyüz and Bilgiç 2016).

Debt (leverage) ratio

The debt ratio is the ratio of total liabilities to total assets and is mainly used for information about long-term debts (Shaverdi et al. 2016). Furthermore, this ratio reveals the ratio of assets acquired by the firm using debt (Abdel-Basset et al. 2020).

Asset turnover

This ratio reveals the efficiency of the total resources the firm uses to make sales (Ertuğrul and Karakaşoğlu 2009). It also refers to the ability of the firm's assets to be used to sell or generate profits (Abdel-Basset et al. 2020).

Stock turnover

The inventory turnover rate expresses the efficient and effective use of company stocks, and this rate can be measured monthly. A low inventory turnover rate indicates that the firm is overstocked or has excessive previous inventory (Roy and Shaw 2021).

Earnings before interest taxes, depreciation, and amortization (EBITDA)

This ratio is calculated by accounting for the operating profit, ignoring the interest, tax, and depreciation amounts, which indicates the firm's ability to generate cash (Açıkgöz 2020).

Net profit margin

This ratio shows the firm's amount in stock after all expenditures, including legal payments. In addition, this profitability ratio provides users with information about the company's commercial activities (Roy and Shaw 2021).

Return on equity (ROE)

ROE shows the actual expenditure costs incurred against the expenditures made. This ratio is affected by the amount of debt businesses use to finance their assets. A high ratio indicates that the use of equity is efficient, and investors can obtain higher returns (Shaverdi et al. 2016). Table 3 shows the performance indicators, the formulas of the indicators, and references.

Table 3 Performance indicators, formulas, and references

Indicators	Code	Min/Max	Formulas	References
Current ratio	C1	Max	Current assets/Current liabilities	Wu et al. (2022)
Acid-Test ratio	C2	Max	(Current assets–Inventories)/Current liabilities	Akyüz and Bilgiç (2016)
Debt ratio	C3	Min	Total Debts/Total Assets	Abdel-Basset et al. (2020)
Asset turnover	C4	Max	Net Sales Revenue/Average Total Assets	Abdel-Basset et al. (2020)
Stock Turnover	C5	Max	Stock holding period = Avg. level of stock × 12 / Annual Sales (Turn Over)	Roy and Shaw (2021)
Ebitda	C6	Max	Operating profit + Depreciation + Amortization	Öztürk (2017)
Net profit margin	C7	Max	Earnings After Taxes / Sales	Moghimi and Anvari (2014)
Return on equity	C8	Max	Net income / Average shareholders' equity	Wu et al. (2022)
Stock Return	C9	Max	$R_t = (P_{(t)} - P_{(t-1)})/P_{(t-1)}$	Baydas and Pamucar (2022)

MCDM tools

MCDM methods facilitate decision-makers' work; they can be used in many areas requiring important decisions (Abdelli et al. 2020). These practical decision-making tools are used to evaluate and rank the alternatives for the decision. Each method has different basic features, advantages, and disadvantages (Chowdhury and Paul 2020; Badi et al. 2022); therefore, more than one method can solve the same problem and make more accurate decisions (Lee and Chang 2018). Although the number of MCDM methods has significantly increased in recent years, it is difficult to determine which methods are more appropriate and correct for any decision problem (Peng et al. 2011; Kiptum et al. 2022).

This study used CoCoSo, GRA, MABAC, MAIRCA, MOOSRA, OCRA, TOPSIS, TODIM, and VIKOR techniques to rank the alternatives. The calculation steps of the techniques are similar. For example, each technique requires a decision matrix, criteria of benefit or cost, and weight values data (Some techniques also have additional parameters). The decision matrix is normalized according to the benefit or cost criteria, and then the calculations continue with the help of different formulas in each technique. These nine techniques were chosen because of this similarity, and the practical aspects of each technique (additional reasons for inclusion in the analysis) are presented below.

Fully consistency method (FUCOM)

FUCOM is a comparison-based MCDM method that accepts the deviation from maximum consistency and pairwise comparison principles as basic assumptions (Feizi et al. 2021). This method determines criteria weights by subjective judgments; decision-makers rank the criteria according to their preferences and make pairwise comparisons of the criteria they rank. The most crucial difference between other subjective methods is that FUCOM shows minor deviations from the optimal values in the criterion weights (Stević and Brković 2020). In this method, few comparisons are made, and constraints are defined while determining the optimal values of the criteria; thus, the method minimizes the possibility of error in comparisons. In particular, methods such as BWM and AHP determine criterion weights with high pairwise comparisons, increasing the possibility of error (Pamučar et al. 2018).

The following steps are applied to determine the criterion weights according to the FUCOM method (Pamučar et al. 2018; Stević and Brković 2020):

Step 1: The experts rank the criteria/sub-criteria—the importance level of the criteria considered in the ranking.

$$C_{j(1)} > C_{j(1)} > \cdots > C_{j(k)} \tag{1}$$

where k is the rank of the criteria. The equality sign is used for criteria of equal importance.

Step 2: The ranked criteria are compared, and their comparative priority is determined.

$$\Phi = (\varphi_{1/2}, \varphi_{2/3}, \ldots, \varphi_{k/(k+1)}) \tag{2}$$

where $\varphi_{k/k+1}$ represents the importance (priority) of $C_{j(k)}$ over $C_{j(k+1)}$.

Step 3: The final values of the weight coefficients of the criteria are determined, considering two conditions:

Condition 1: The ratio of the weighting coefficients of the criteria should be equal to the comparative significance between the criteria.

$$\frac{w_k}{w_{k+1}} = \varphi_{k/(k+1)} \tag{3}$$

Condition 2: The values of the weight coefficients have a mathematical transitivity condition.

$$\frac{w_k}{w_{k+2}} = \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} \tag{4}$$

Step 4: The model is defined to calculate the final values of the weighting coefficients of the criteria.

$$\begin{aligned} &\min \ x \\ &\text{s.t.} \\ &\left| \frac{w_{j(k)}}{w_{j(k+1)}} - \varphi_{k/(k+1)} \right| \le x, \ \forall j \\ &\left| \frac{w_{j(k)}}{w_{j(k+2)}} - \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} \right| \le x, \ \forall j \\ &\sum_{j=1}^{n} w_j = 1 \\ &w_j \ge 0, \ \forall j \end{aligned} \tag{5}$$

Step 5: The final values of the evaluation criteria/sub-criteria $(w_1, w_2, \ldots, w_n)^T$ are calculated.

Combined compromise solution (CoCoSo)

Three collection strategies, SAW, weighted aggregated sum product assessment (WASPAS), and exponentially weighted product (EWP), are integrated to obtain reliable and stable results in the CoCoSo method. This integration distinguishes CoCoSo from other MCDM methods (Ecer 2021). This method ranks alternatives according to their collective performance score and envisages the integration of the weighted-sum model and weighed-product model methods to determine the sum and power of the weighted comparability sequence (Kumar et al. 2022). The essence of this method is the combination of compromise perspectives, which distinguishes it from other MCDM techniques; it also includes the estimation of the final solution consensus, albeit with conflicting criteria (Ulutaş et al. 2021). As Ecer (2021) indicated, the λ parameter in the method is fixed at 0.5. Furthermore, in this study, the λ parameter is fixed at 0.5 in all calculations.

Grey relational analysis (GRA)

GRA is an integral part of the body of knowledge of the grey system theory proposed in 1982 by Deng Julong, followed by the development of its first GRA model in 1984. Deng's GRA is a technique for absolute measurement (or normative evaluation). It estimates a degree called grey relational grade, which is ideally a weighted average of grey relational coefficients and is essentially a positive correlation metric (Javed et al. 2022). One of the main advantages of the gray systems theory is that it provides satisfactory results from small quantities of data and many factors of variables (Malek et al. 2017).

Multi-attributive border approximation area comparison (MABAC)

The MABAC technique was developed by Pamučar and Ćirović (2015). The technique developers applied a sensitivity analysis consisting of three stages and reported that MABAC showed stability (consistency) of its solution in all cases. The basis of the MABAC method is seen in the definition of the distance of the criterion function of each alternative from the border approximation area (Pamučar and Ćirović 2015), comprising regions, upper, lower, and border approximation areas. The upper (lower) approximation area contains the ideal (anti-ideal) alternative. The MABAC approach needs simple mathematical operations, integrates the gains and losses easily, allows combining with other methodologies, and creates functional outcomes (Pamučar and Ćirović 2015; Sun et al. 2018; Aydin et al. 2022).

Multi-attribute ideal real comparative analysis (MAIRCA)

The most important advantage of the MAIRCA method is the different linear normalization approach, which contributes to obtaining more effective results (Ecer 2021). Like TOPSIS, this method focuses on the positive and negative ideal solutions (Gul and Ak 2020). Furthermore, the method considers the gap between the ideal and empirical ratings; each criterion sums this gap, and as a result, the total gap for each alternative is formed. Finally, an alternative with the lowest gap value was selected (Gul and Ak 2020).

Multi-objective optimization based on simple ratio analysis (MOOSRA)

The MOOSRA technique was developed by Das et al. (2012). This technique calculates the simple ratio of the beneficial and cost criteria. Negative values do not appear during the calculation process, and results are less sensitive to variation in the rational values of the criteria (Narayanamoorthy et al. 2020). This method also requires less computational time, is more simplistic and more stable, and requires minimal mathematical calculations (Sarkar et al. 2015).

Operational competitiveness ratings (OCRA)

The OCRA technique was developed by Parkan in 1994 (Parkan 1994). It aims to evaluate the operational competitiveness of the production units. The OCRA method adopts an intuitive approach for capturing the experts' inputs and can also consider the dependence of the criteria weights on the alternatives. The OCRA methodology has been used as a robust MCDM tool for sequencing problems (Thakur 2022).

Technique for order of preference by similarity to ideal solution (TOPSIS)

In the TOPSIS method, the deviation of the best alternative from the perfect positive solution should be minimum, and the geometric separation from the ideal-negative solution should be maximum. Therefore, this method includes determining each criterion 's weights, normalization, geometric distance, and ideal solutions (Chodha et al. 2022). In this method, the most suitable alternative is the one closest to the positive ideal solution and the farthest from the negative ideal solution (Khan and Maity 2017). TOPSIS can be considered one of the most well-known MCDM techniques.

The Portuguese acronym for interactive and multi-criteria decision-making (TODIM)

TODIM was developed by Gomes and Lima (1992). TODIM has some advantages, such as simple and easy application, readily comprehensible for practitioners. TODIM relies on prospect theory, which explains how individuals make decisions when facing risk. In this theory, individuals respond asymmetrically to gains and losses; that is, losses with the same level of gains have a higher absolute value. This response-level difference can be quantitatively embedded in TODIM with an attenuation factor (Alali and Tolga 2019). This study's attenuation factor is fixed at 0.5.

Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR)

The VIKOR method was developed for the multi-criteria optimization of complex systems in 1998 by Opricovic (Opricovic 1998). It determines the compromise-ranking list, the compromise solution, and the weight stability intervals for the preference stability of the compromise solution obtained with the initial (given) weights. This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. It introduces the multi-criteria ranking index based on the particular measure of "closeness" to the "ideal" solution (Opricovic and Tzeng 2004).

Copeland

Copeland considers the number of wins and losses for each determining criterion and ranks the options. The winner is the one who compares with all alternatives and provides an advantage (Naderi et al. 2013). Copeland ranked options favorably on all MCDM assessments (Ecer 2021). Different MCDM methods can give different results. For example, while the best alternative for the X method is A, the most suitable alternative for the Y method might be B. In such cases, it is unclear which method's results are reliable or which alternative to choose. The Copeland method is used to solve this critical problem and obtain a generally accepted ranking, considering the different results (Beheshtinia and Omidi 2017).

Analysis results

Data set

This study uses MCDM methods to evaluate the financial performances of 22 companies (banks excluded) in the sustainable index every year between 2019 and 2021. The sustainability index in Turkey was first published in November 2014. Nine different performance indicators were used as decision criteria. The financial performances of the companies were calculated separately for each year. These data were for 2019 2020, and 2021. The financial statement data were retrieved from finnet.com, and stock market data were retrieved from finance.yahoo.com; for each firm in the dataset, the yearly return was calculated with the equation presented in the last row of Table 4. Moreover, Table 4 shows the initial decision matrix with non-normalized data for 2021.

Table 4 Decision matrix (2021)

Firms	Code	C1 Max	C2 Max	C3 Min	C4 Max	C5 Max	C6 Max	C7 Max	C8 Max	C9 Max
EREGL	A1	1.0058	0.6336	53.7467	0.4621	6.6566	16.407	6.0242	12.6490	1.1607
AEFES	A2	1.1367	0.9492	48.7436	0.6725	61.6255	17.8115	13.2139	19.0129	0.2685
AKSEN	A3	1.4714	0.9734	75.2520	0.8014	4.0517	10.0510	4.7680	16.7721	1.5298
ARCELİK	A4	1.3836	0.7772	44.3366	0.4339	2.6363	27.3210	35.3908	27.8810	0.6651
ASELS	A5	1.1565	0.8653	77.5584	0.6448	5.9837	22.3596	15.1422	43.5052	0.2602
BRISA	A6	1.4318	0.8066	54.3411	0.6689	8.7691	20.9432	11.0392	18.5431	0.1232
CCOLA	A7	1.2942	0.8986	55.2654	2.4918	12.3414	9.7831	9.6109	53.6972	0.5994
DOAS	A8	2.7982	1.4761	33.1334	0.5396	2.3559	38.7935	23.5661	19.5382	0.5808
FROTO	A9	1.5789	1.2309	76.2845	1.6615	13.4935	13.3104	12.3781	86.7219	0.8081
KCHOL	A10	0.8539	0.2077	88.1334	0.2681	5.9157	19.0712	9.5686	41.1444	0.6595
MGROS	A11	0.6640	0.2938	97.0384	2.0040	7.7582	7.9790	0.9894	66.9474	−0.0752
OTKAR	A12	1.3885	0.8440	75.0141	0.7528	3.1610	20.2411	23.0994	69.5957	0.0157
PETKIM	A13	2.5633	1.1494	58.1998	0.9437	8.1121	21.2072	19.2111	43.3616	0.7240
SAHOL	A14	0.7675	0.1277	87.3617	0.0373	4.0647	77.0341	67.2912	40.0086	0.4990
TAVHL	A15	0.9177	0.4547	70.6607	0.1050	17.4489	28.5902	9.5692	3.4777	0.7063
TOASO	A16	1.7267	1.3628	68.0795	0.4939	133.9806	43.674	14.4135	22.2998	1.4147
TUPRS	A17	0.7275	0.6481	74.3715	0.2753	27.9741	28.6738	8.4352	9.0622	0.7223
THYAO	A18	1.1753	0.8256	75.5323	1.2646	12.4772	19.5192	11.054	57.1320	1.3716
TTKOM	A19	1.1546	0.7997	75.5734	0.5875	77.9049	44.8877	16.8105	40.4315	0.3102
TCELL	A20	1.0223	0.5303	82.6132	1.4724	6.3551	8.6084	2.2760	19.5713	0.2654
ULKER	A21	0.6821	0.3340	76.0710	0.7543	3.4114	16.8707	6.6264	22.8128	−0.2425
VESTL	A22	3.0591	1.3542	83.5621	0.4777	3.8956	18.5718	−1.2955	−5.4380	0.1720

Weight determination with the FUCOM method

The authors prepared a survey and invited four experts to fill out the forms: expert 1 was an academic working in finance; expert 2 was an academic and was competent in accounting finance; expert 3 was an academic working in finance and insurance; and expert 4 was an academic working in management and finance. All experts were familiar with the working principles of the FUCOM method and were competent in their fields. Furthermore, experts were confirmed to know all performance indicators and their opinions were taken. The first step of the FUCOM technique was to rank the criteria according to their significance, presented in Table 5.

Next, the listed criteria were compared, and the comparative importance of the evaluation criteria was determined. The comparative importance of the evaluation criteria was obtained with the help of experts' opinions, as presented in Table 6.

In the next step, the final values of the weighting coefficients of the evaluation criteria were performed using the model (5). Applying Eqs. (3) and (4) and the data in Table 3 allowed us to create a unique model for determining the weighting coefficients of the criteria for each expert.

Table 5 Expert evaluation permutations

Expert	Rank
E1	$C6 \succ C8 \succ C1 \succ C3 \succ C7 \succ C4 \succ C9 \succ C2 \succ C5$
E2	$C7 \succ C8 \succ C9 \succ C6 \succ C1 \succ C2 \succ C3 \succ C4 \succ C5$
E3	$C9 \succ C7 \succ C1 \succ C6 \succ C8 \succ C3 \succ C4 \succ C2 \succ C5$
E4	$C1 \succ C3 \succ C2 \succ C4 \succ C5 \succ C6 \succ C7 \succ C8 \succ C9$

Table 6 Comparative significance of criteria

Expert	Comparative significance ($\varphi_{k/(k+1)}$)								
E1	C6	C8	C1	C3	C7	C4	C9	C2	C5
	1.00	1.00	2.00	1.50	1.00	1.33	1.00	1.00	1.25
E2	C7	C8	C9	C6	C1	C2	C3	C4	C5
	1.00	2.00	1.00	1.00	1.50	1.00	1.33	1.00	1.25
E3	C9	C7	C1	C6	C8	C3	C4	C2	C5
	1.00	2.00	1.00	1.50	1.00	1.00	1.33	1.25	1.20
E4	C1	C3	C2	C4	C5	C6	C7	C8	C9
	1.00	2.00	1.50	1.33	1.00	1.25	1.00	1.20	1.67

For expert 1, the mathematical model can be expressed as follows:

$$\min \chi$$
$$\text{subject to} \begin{cases} \left|\frac{w_6}{w_8} - 1\right| = \chi, \left|\frac{w_8}{w_1} - 2\right| = \chi, \left|\frac{w_1}{w_3} - 1.5\right| = \chi \\ \left|\frac{w_3}{w_7} - 1\right| = \chi, \left|\frac{w_7}{w_4} - 1.33\right| = \chi, \left|\frac{w_4}{w_9} - 1\right| = \chi \\ \left|\frac{w_9}{w_2} - 1\right|, \left|\frac{w_2}{w_5} - 1.25\right| = \chi \\ \left|\frac{w_6}{w_1} - 2\right| = \chi, \left|\frac{w_8}{w_3} - 3\right| = \chi, \left|\frac{w1}{w_7} - 1.5\right| = \chi \\ \left|\frac{w_3}{w_4} - 1.33\right| = \chi, \left|\frac{w_7}{w_9} - 1.33\right| = \chi, \left|\frac{w_4}{w_2} - 1\right| = \chi \\ \left|\frac{w_9}{w_5} - 1.25\right| = \chi \\ \sum_{i=1}^{9} w_i = 1, w_i \geq 0, \forall_i \end{cases} \tag{6}$$

Similar models were created for each expert evaluation. The model mentioned above was solved with MATLAB, and each expert's results (weights of the criteria) are presented in Table 7.

Table 7 indicates that FUCOM provides entirely consistent values of weighting coefficients, as DFC = 0 for each of the four expert assessments. The final weight coefficient values were reached by taking the arithmetic average of the four expert evaluation weights. As a result of the consensus obtained with the arithmetic mean, the

Table 7 Weight of criteria

Expert	$w1$	$w2$	$w3$	$w4$	$w5$	$w6$	$w7$	$w8$	$w9$	DFC (χ)
E1	0.1382	0.0691	0.0922	0.0691	0.0553	0.2765	0.0922	0.1382	0.0691	0
E2	0.0862	0.0862	0.0647	0.0647	0.0517	0.1293	0.2586	0.1293	0.1293	0
E3	0.1382	0.0553	0.0922	0.0691	0.0461	0.0922	0.1382	0.0922	0.2765	0
E4	0.3286	0.1095	0.1643	0.0822	0.0822	0.0657	0.0657	0.0548	0.0469	0
Average	0.1728	0.0800	0.1033	0.0713	0.0588	0.1409	0.1387	0.1036	0.1305	–

criteria weights can be summarized as follows. The highest weight (0.1728) belongs to the first criterion. The following criteria are the sixth (0.1409) and seventh (0.1387), and the weights of these two criteria are very close. The three lowest weights belong to the second (0.08), fourth (0.0713), and fifth (0.0588) criteria.

Nine different MCDMs were applied to the decision matrix; Table 8 presents the results, indicating that the prioritization of the alternatives based on different methods varies. For example, alternative 16 is the best alternative according to CoCoSo and VIKOR. It is the second-best alternative per GRA, MABAC, OCRA, and TOPSIS. It is the third best alternative according to the MOOSRA technique. Finally, it is ranked 21st in MAIRCA and VIKOR techniques. Managing these different rankings was a difficult task. The Copeland technique achieved a consensus between the different rankings. Based on the Copeland rankings, the rankings of the alternative are as follows $A16 \succ A8 \succ A13 \succ A7 \succ A9 \succ A4 \succ A14 \succ A18 \succ A2 \succ A19 \succ A3 \succ A12 \succ A1 \succ A5 \succ A6 \succ A22 \succ A17 \succ A15 \succ A10 \succ A11 \succ A20 \succ A21$. The best alternative is the 16th, and the worst is the 21st.

Weight simulation

Changing the weights used as input in the MCDM analysis can change the ordering, which is the output of the analysis. For this reason, it is necessary to determine the effect different weight sets have on the research results. This study created different weight sets consisting of random values, and the robustness of the results obtained by expert evaluations was verified.

The expert in the FUCOM analysis performed two types of evaluation. First, the criteria weights were ranked from most to least important. Our study had nine criteria, so $9! = 362,880$ different possible rankings. Second, importance degrees were assigned to the criteria (number of criteria = k), which were ordered from the most important to the least important. Generally, integers between 1 and 9 were used in these assignments (n), which were made with the help of pairwise comparisons. It was assumed that the experts made comparisons with integers; if decimal numbers could be used, there would be many more possibilities. In such a case, the total number of evaluations was calculated as $\binom{n+k-1}{n} = \binom{9+9-1}{9} = 24,310$; however, since the first criterion always had 1 degree of importance ($\varphi_1 = 1$) and a total number of evaluations $\binom{9+8-1}{8} = 12{,}870$, different evaluations are possible.

In the case of trying each possibility one by one, there were 362,880 × 12,870 = 4,67 0,265,600 different weight sets; however, it is impossible to evaluate such a high computation volume with today's computing technology in a reasonable time. Considering

Table 8 Overall scores and ranking results of alternatives

		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22
CoCoSo	Score	20.85	22	22.1	24.53	20.77	20.99	23.93	28.01	25.61	17.75	12.95	22.08	27.23	21.56	18.84	28.66	19.05	24.21	23.54	17.11	13.95	19.54
	Rank	14	11	9	5	15	13	7	2	4	19	22	10	3	12	18	1	17	6	8	20	21	16
Gray Relational	Score	0.442	0.439	0.483	0.475	0.417	0.423	0.49	0.605	0.522	0.394	0.406	0.445	0.519	0.559	0.402	0.571	0.404	0.488	0.446	0.388	0.369	0.512
	Rank	13	14	9	10	16	15	7	1	4	20	17	12	5	3	19	2	18	8	11	21	22	6
MABAC	Score	−0.018	0.008	0.0262	0.0929	−0.028	−0.021	0.0763	0.2414	0.1243	−0.108	−0.145	0.0169	0.1715	0.0968	−0.079	0.2143	−0.073	0.0786	0.0516	−0.122	−0.178	0.0207
	Rank	14	13	10	6	16	15	8	1	4	19	21	12	3	5	18	2	17	7	9	20	22	11
MAIRCA	Score	0.032	0.031	0.03	0.027	0.033	0.032	0.028	0.02	0.026	0.036	0.038	0.031	0.024	0.027	0.035	0.022	0.035	0.028	0.029	0.037	0.039	0.03
	Rank	9	10	13	17	7	8	15	22	19	4	2	11	20	18	5	21	6	16	14	3	1	12
MOOSRA	Score	73.962	90.264	65.671	129.35	56.828	69.511	97.944	208.89	85.84	41.291	32.871	67.591	113.14	90.135	50.988	120.86	51.646	80.465	79.13	36.338	28.295	50.631
	Rank	11	6	14	2	15	12	5	1	8	19	21	13	4	7	17	3	16	9	10	20	22	18
OCRA	Score	70.139	86.497	76.095	41.026	64.818	76.683	102.9	68.117	79.733	56.053	95.714	54.179	70.082	0	66.681	101.16	73.242	73.447	83.835	93.999	76.547	95.664
	Rank	14	6	11	21	18	9	1	16	8	19	3	20	15	22	17	2	13	12	7	5	10	4
TOPSIS	Score	0.296	0.263	0.349	0.407	0.271	0.23	0.333	0.447	0.391	0.254	0.242	0.333	0.41	0.569	0.254	0.486	0.259	0.387	0.366	0.187	0.14	0.309
	Rank	13	15	9	5	14	20	10	3	6	18	19	11	4	1	17	2	16	7	8	21	22	12
TODIM	Score	0.385	0.664	0.562	0.671	0.594	0.529	0.83	0.858	0.958	0.166	0.078	0.622	0.976	0.2	0.211	10	0.326	0.864	0.743	0.2	0	0.223
	Rank	14	9	12	8	11	13	6	5	3	20	21	10	2	18	17	1	15	4	7	19	22	16
VIKOR	Score	0.663	0.576	0.543	0.37	0.611	0.485	0.486	0	0.386	0.836	0.961	0.458	0.235	0.628	0.774	0.142,	0.848	0.476	0.517	0.78	0.992	0.561
	Rank	7	10	12	19	9	15	14	22	18	4	2	17	20	8	6	21	3	16	13	5	1	11
COPELAND	Score	−3	5	1	9	−7	−7	13	19	13	−15	−17	−1	17	9	−13	21	−11	9	5	−19	−21	−7
	Rank	13	9	11	6	14	15	4	2	5	19	20	12	3	7	18	1	17	8	10	21	22	16

Table 9 Descriptive statistics of the weights

		*w*1	*w*2	*w*3	*w*4	*w*5	*w*6	*w*7	*w*8	*w*9
Average of Expert										
Weight Simulation	Evaluations	0.1728	0.08	0.1033	0.0713	0.0588	0.1409	0.1387	0.1036	0.1305
	Mean	0.1065	0.1077	0.1066	0.1186	0.1152	0.1052	0.1057	0.1201	0.1144
	Minimum	0.0146	0.0137	0.0137	0.0137	0.0137	0.0137	0.0149	0.0137	0.0146
	Maximum	0.5255	0.5294	0.5255	0.5217	0.5294	0.5294	0.5294	0.518	0.5294
	Median	0.0682	0.0682	0.0702	0.0765	0.0664	0.0644	0.0701	0.0804	0.0806
	Std. Dev	0.091	0.0931	0.0877	0.0974	0.1039	0.0919	0.088	0.0951	0.0904
	Skewness	1.6558	1.7269	1.6508	1.442	1.5215	1.7107	1.7178	1.362	1.5438
	Kurtosis	5.192	5.3609	5.2572	4.3153	4.3168	5.3207	5.5154	4.1447	4.9272

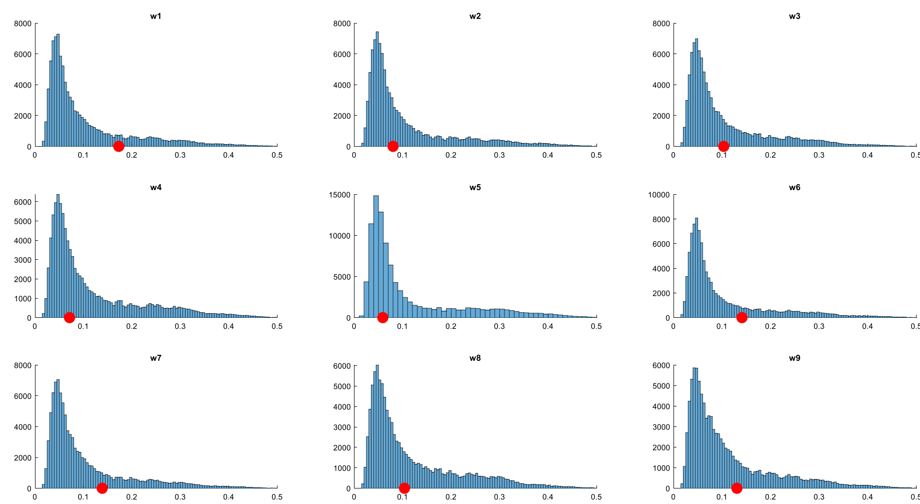

Fig. 2 Weight distributions of the criteria

the computational capacity of the hardware used in the analysis, 100 randomly selected weight permutations and 1,000 randomly selected importance levels for each weight ranking were tried, resulting in a total of 100,000 different weight sets.

Table 9 presents descriptive statistics of the weights; the first row includes the average of the expert evaluations. The minimum weight of a single criterion was around 0.01, and the maximum was around 0.5. The mean was around 0.1, and the median was about 0.06. Skewness and kurtosis values indicate a non-normal distribution shape.

Figure 2 presents the histogram distribution of the weights across the criteria, with the average of the expert evaluations indicated by a red mark. Considering the distributions in the figure, the evaluations made by the experts cannot be considered as an extreme value with a very low probability of occurrence. The distributions have a right-skewed form, indicating that the criteria cannot have high weights. This result may potentially occur because the study was conducted with nine criteria.

The analysis was re-run for each weight set in the simulation data (100,000 weight sets). Nine MCDM technique evaluations were performed for each weight set, and a single ranking was obtained with the Copeland technique. Figure 3 presents the Copeland ranking histograms for each alternative. The figures also include the expert evaluation rankings with a red mark.

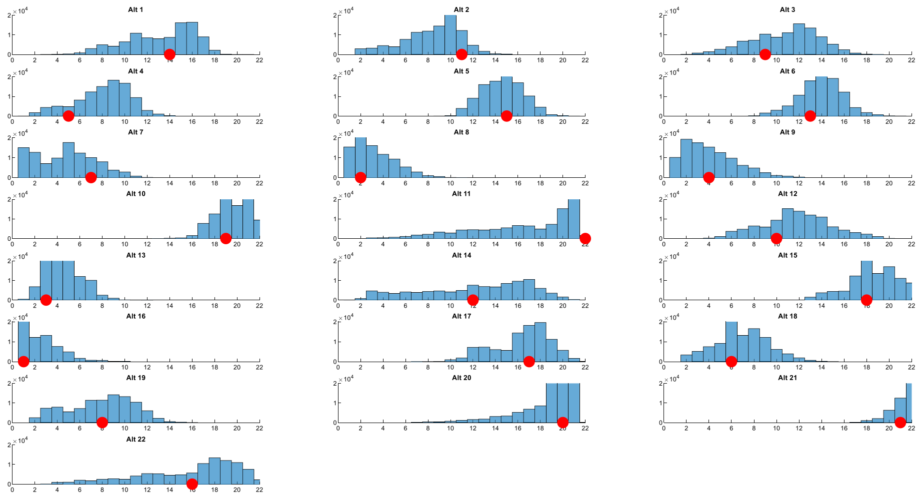

Fig. 3 Weight simulation results

Table 10 Descriptive statistics of Copeland rankings in weight simulation

Alternatives	Expert Ranks	Weight simulation descriptive statistics						
		Mean	Min	Max	Median	St. Dev	Skewness	Kurtosis
A1	13	13.1989	3	21	14	3.0031	− 0.5141	2.3531
A2	9	8.3358	2	15	9	2.5965	− 0.574	2.8505
A3	11	10.782	2	19	11	2.9509	− 0.3458	2.593
A4	6	8.0252	1	14	8	2.4312	− 0.5111	2.7584
A5	14	14.6107	9	21	15	1.816	0.0222	2.467
A6	15	13.9239	8	21	14	1.881	− 0.1819	3.2407
A7	4	4.6802	1	12	5	2.583	0.2081	2.1873
A8	2	2.9787	1	11	2	1.7009	1.0858	3.7498
A9	5	4.0924	1	13	4	2.2828	0.7547	3.1099
A10	19	19.5869	13	22	20	1.5237	− 0.3601	2.7243
A11	20	16.5212	3	22	18	4.4872	− 0.8195	2.6763
A12	12	11.7392	3	21	12	3.0177	0.0021	2.7479
A13	3	4.5833	1	12	4	1.5782	0.4097	2.8058
A14	7	12.1886	1	21	13	4.7844	− 0.4366	2.0962
A15	18	18.5811	12	22	19	2.1348	− 0.4342	2.8266
A16	1	1.9978	1	10	1	1.5063	1.7036	5.964
A17	17	16.3876	7	22	17	2.4736	− 0.5452	2.5748
A18	8	6.9177	2	15	7	2.3545	0.0581	2.7473
A19	10	7.861	2	16	8	2.8782	− 0.2456	2.212
A20	21	18.5334	7	22	19	2.5968	− 1.5987	5.5298
A21	22	21.6407	17	22	22	0.7897	− 2.5449	9.7174
A22	16	15.8338	3	22	17	4.3311	− 0.8297	2.8308

Table 10 presents the descriptive statistics of the weight simulation. The first column indicates the alternatives, the second column includes the ranking result of expert evaluation, and the remaining columns indicate the descriptive statistics of the weight simulation process.

The number of observations in the interquartile was used to measure the performance. If the interval weight was more significant than 25% and less than 75% in the weight simulation, that observation was called an observation in the interquartile. Accordingly, 19 of 22 alternatives were in the interquartile; 86.36% (=19/22) of expert evaluations and weight simulation results were compatible.

Table 11 presents the values of how many times each alternative was ranked in each position. Rows indicate the alternatives, and columns indicate the ranks (positions). For example, alternative 1 is never ranked in the first or second rank during the simulation and is ranked third in only 13 simulations (0.00013 = 13/100,000). Similarly, alternative 16 is ranked first in 58,967 simulations (0.58967 = 58,967/100,000). Different alternatives can take the first place in different weight sets; however, the 16th alternative was chosen as the best alternative in the largest number of weight sets during the weight simulation process. This finding indicates the superiority of the 16th alternative over the other alternatives. Similarly, the 21st alternative ranked in the last position in most weight sets (0.77987 = 77,987/100,000), indicating the alternative's inferiority.

The simulation numbers show that each alternative is in a higher position than the alternatives presented in Table 12. The values in the table are in the form of pairwise comparisons. For example, alternative 1 took a higher position than alternative 2 in 13,742 weight sets. However, in 86,258 (=100,000–13,742) weight sets, the A2 alternative was in a better position than the A1 alternative. The high values in row A16 are another indicator of the superiority of this alternative over other alternatives; similarly, the low values in row A21 indicate this alternative's inferiority.

A one-way variance analysis was performed to analyze the results statistically. The dataset utilized in ANOVA analysis is a 100,000 × 22 matrix where each row indicates the rank of the alternative for each simulated weight set, and each column indicates the alternatives. Figure 4 presents the box plot of the dataset.

The figure shows that the rank value of the 16th alternative is always in the upper ranks (ranking 1), and the 21st alternative is also in the lower ranks (ranking 22); Table 13 presents the ANOVA test results.

A low p-value in the table indicates that the null hypothesis, which states no difference among group means, is rejected. In other words, the differences among the alternatives' ranks differ statistically, and there are $231 = \binom{22}{2}$ multiple comparisons. Instead of listing all the results, Fig. 5 only indicates the mean of the ranks to save space. Multiple compared tests were performed, and all comparisons were significant at the 1% level. This difference is also significant if one alternative is ranked higher than the others.

Repeating analysis with different periods

The analysis was repeated separately for the data set in 2020 and 2019. Table 14 presents the decision matrix for 2020, MCDM scores and rankings are presented in Table 15, and Fig. 6 presents rankings for weight simulation. Descriptive statistics of Copeland rankings are presented in Table 16 in detail, and Table 17 presents the number of times each alternative is ranked in each position. Table 18 indicates the number of times each alternative is ranked higher than another alternative for 2020. Box plots of the Copeland rankings are presented in Fig. 7, ANOVA results are presented in Table 19, and finally, post hoc results are presented in Fig. 8. The ranking result for the year 2020 with the weights determined by the experts is

Table 11 Number of times each alternative is ranked in each position

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22
R1	0	0	0	2	0	0	15,019	15,388	10,135	0	0	0	462	27	0	58,967	0	0	0	0	0	0
R2	0	2919	56	1761	0	0	12,684	37,738	19,254	0	0	0	6820	769	0	12,155	0	3350	2494	0	0	0
R3	13	3254	745	4385	0	0	7129	16,089	17,477	0	367	45	20,099	4696	0	13,166	0	5135	7344	0	0	56
R4	86	4536	1455	5063	0	0	9838	11,680	15,352	0	429	205	23,411	3987	0	7595	0	7504	7902	0	0	957
R5	300	3851	2652	4687	0	0	17,631	9321	12,568	0	670	1000	23,503	3292	0	4865	0	9164	5476	0	0	1020
R6	829	7706	3924	8167	0	0	12,346	5357	9733	0	1080	3682	12,015	4154	0	1694	0	20,117	7162	0	0	2034
R7	3025	11,299	6809	12,322	0	0	10,061	2838	6146	0	1720	4745	10,090	3779	0	713	2	13,120	11,401	164	0	1766
R8	4946	11,938	7264	15,061	0	132	7943	970	4835	0	2175	6433	2503	4363	0	595	7	16,571	11,433	370	0	2461
R9	4249	14,538	10,396	18,280	5	1563	3707	550	2439	0	3244	5774	965	4653	0	116	55	12,186	14,196	322	0	2762
R10	6454	20,759	8773	16,712	195	2960	2835	67	1090	0	2753	9345	114	4184	0	134	964	6179	13,247	725	0	2510
R11	10,886	12,228	11,057	9428	3884	5194	709	2	688	0	4334	15,220	17	4897	0	0	1822	3921	10,400	1145	0	4168
R12	8503	4699	15,677	2872	9063	10,654	98	0	281	0	4493	13,931	1	7601	79	0	7195	1875	6041	1559	0	5378
R13	7971	1618	13,535	1042	16,048	17,939	0	0	2	33	4265	11,955	0	6892	1495	0	7296	683	2173	1795	0	5258
R14	8719	439	9019	218	17,815	23,270	0	0	0	161	4701	10,989	0	6709	3727	0	6032	185	501	3111	0	4404
R15	16,218	216	5246	0	20,364	19,189	0	0	0	344	5482	5989	0	8478	4393	0	5765	10	223	3362	0	4721
R16	16,424	0	2424	0	16,978	12,236	0	0	0	1511	6661	4287	0	9626	4541	0	14,371	0	7	5235	0	5699
R17	8995	0	736	0	10,243	4331	0	0	0	7725	6443	3010	0	10,520	12,310	0	18,217	0	0	6856	107	10,507
R18	2192	0	205	0	4549	1783	0	0	0	12,567	4846	2237	0	6012	23,014	0	19,628	0	0	8498	1020	13,449
R19	185	0	27	0	683	637	0	0	0	27,168	7266	1034	0	3528	13,687	0	11,223	0	0	20,445	2056	12,061
R20	3	0	0	0	172	89	0	0	0	16,831	15,220	86	0	1563	17,031	0	5704	0	0	25,977	6316	11,008
R21	2	0	0	0	1	23	0	0	0	24,189	22,279	33	0	270	11,104	0	1659	0	0	20,399	12,514	7527
R22	0	0	0	0	0	0	0	0	0	9471	1572	0	0	0	8619	0	60	0	0	37	77,987	2254

Table 12 Number of times each alternative is ranked higher than others

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22
A1	0	86,258	85,242	88,408	42,258	53,934	94,708	99,888	97,333	531	27,784	62,110	99,240	48,295	891	100,000	7461	98,595	84,907	12,234	0	29,817
A2	13,742	0	21,578	58,104	438	2	81,226	93,719	83,098	0	8788	20,437	86,079	26,699	21	99,911	209	68,045	61,038	1423	0	9023
A3	14,758	78,422	0	67,042	16,581	15,946	90,505	97,062	94,205	66	17,402	47,612	96,038	39,909	818	100,000	5198	97,058	77,335	3949	0	18,295
A4	11,592	41,896	32,958	0	647	0	79,609	98,182	82,838	0	7984	16,293	88,374	15,531	0	97,134	86	66,782	51,411	2076	0	9127
A5	57,742	99,562	83,419	99,353	0	50,461	100,000	100,000	100,000	319	29,203	91,584	100,000	61,828	12,785	100,000	27,979	99,995	99,960	12,970	0	33,908
A6	46,066	99,998	84,054	100,000	49,539	0	100,000	100,000	99,631	1570	27,108	70,823	100,000	53,544	7088	100,000	19,426	95,868	96,956	10,087	0	30,632
A7	5292	18,774	9495	20,391	0	0	0	67,322	59,677	0	0	281	51,333	14,023	0	75,061	9	18,559	23,947	0	0	3852
A8	112	6281	2938	1818	0	0	32,678	0	34,846	0	1347	974	17,626	2603	0	76,503	0	13,457	6683	0	0	0
A9	2667	16,902	5795	17,162	0	369	40,323	65,154	0	0	0	2	36,614	11,810	0	75,283	7	12,984	21,426	0	0	2741
A10	99,469	100,000	99,934	100,000	99,681	98,430	100,000	100,000	100,000	0	62,614	97,120	100,000	98,209	74,059	100,000	87,671	100,000	100,000	52,057	11,726	77,723
A11	72,216	91,212	82,598	92,016	70,797	72,892	100,000	98,653	100,000	37,386	0	82,542	98,756	74,420	44,657	98,668	55,351	97,098	89,702	33,265	1807	58,088
A12	37,890	79,563	52,388	83,707	8416	29,177	99,719	99,026	99,998	2880	17,458	0	99,379	44,331	9022	98,367	18,137	87,748	80,060	4706	0	21,945
A13	760	13,921	3962	11,626	0	0	48,667	82,374	63,386	0	1244	621	0	9693	0	85,009	0	17,858	19,149	0	0	56
A14	51,705	73,301	60,091	84,469	38,172	46,456	85,977	97,397	88,190	1791	25,580	55,669	90,307	0	7823	97,183	23,001	75,416	75,123	13,411	777	27,025
A15	99,109	99,979	99,182	100,000	87,215	92,912	100,000	100,000	100,000	25,941	55,343	90,978	100,000	92,177	0	100,000	93,397	100,000	99,951	41,220	11,632	69,073
A16	0	89	0	2866	0	0	24,939	23,497	24,717	0	1332	1633	14,991	2817	0	0	0	2886	0	0	0	12
A17	92,539	99,791	94,802	99,914	72,021	80,574	99,991	100,000	99,993	12,329	44,649	81,863	100,000	76,999	6603	100,000	0	99,966	99,676	27,269	3548	46,236
A18	1405	31,955	2942	33,218	5	4132	81,441	86,543	87,016	0	2902	12,252	82,142	24,584	0	97,114	34	0	36,090	0	0	7990
A19	15,093	38,962	22,665	48,589	40	3044	76,053	93,317	78,574	0	10,298	19,940	80,851	24,877	49	100,000	324	63,910	0	1235	0	8276
A20	87,766	98,577	96,051	97,924	87,030	89,913	100,000	100,000	100,000	47,943	66,735	95,294	100,000	86,589	58,780	100,000	72,731	100,000	98,765	0	203	69,041
A21	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	88,274	98,193	100,000	100,000	99,223	88,368	100,000	96,452	100,000	100,000	99,797	0	93,764
A22	70,183	90,977	81,705	90,873	66,092	69,368	96,148	100,000	97,259	22,277	41,912	78,055	99,944	72,975	30,927	99,988	53,764	92,010	91,724	30,959	6236	0

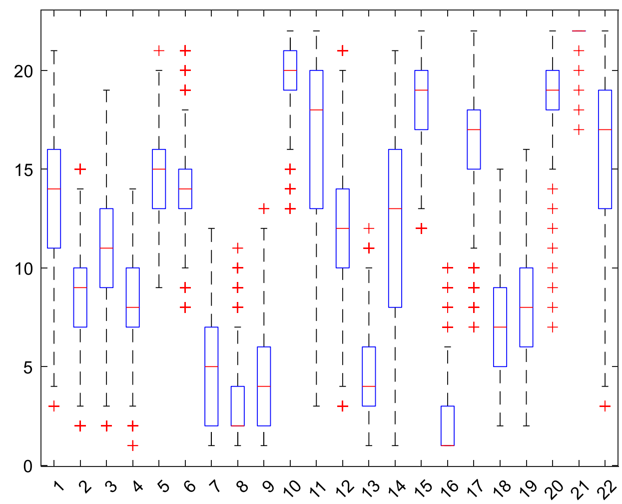

Fig. 4 Box plot of the rank dataset

Table 13 ANOVA results

Source	SS	df	MS	F	Prob
Columns	7.23e7	21	3,446,037.01	468,460.8	0
Error	1.62e7	219,978	7.36		
Total	8.86e7	219,999			

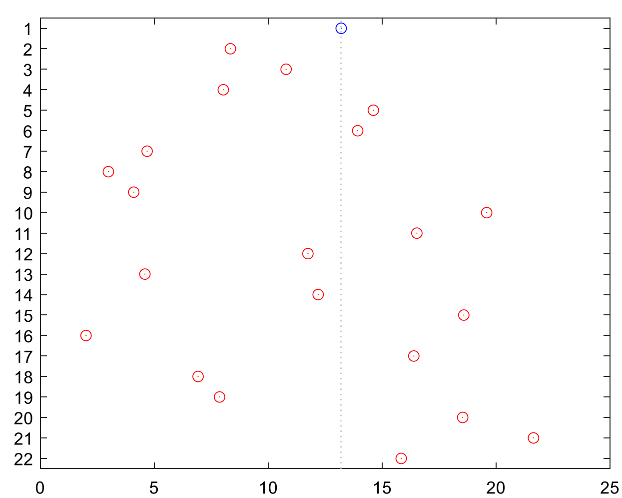

Fig. 5 Multiple comparison summaries

$$A22 \succ A8 \succ A16 \succ A6 \succ A4 \succ A12 \succ A9 \succ A14 \succ A19 \succ A3 \succ A2 \succ A13 \succ .$$
$$A7 \succ A5 \succ A1 \succ A18 \succ A21 \succ A10 \succ A20 \succ A17 \succ A11 \succ A15$$

As a result of the weight simulation, the values of 19 of the 22 companies are in the interquartile range (0.86 = 19/22).

Table 20 presents the decision matrix for 2019, while the MCDM scores and rankings are presented in Table 21. Rankings for weight simulation are presented in Fig. 9, and Table 22 shows the descriptive statistics of Copeland rankings. Table 23 presents how often each alternative is ranked in each position, while Table 24 indicates how often each alternative is ranked higher than another alternative for 2020. Box plots of the Copeland rankings are presented in Fig. 10, ANOVA results in Table 25, and post hoc results in Fig. 11. The ranking result for 2019 with the weights determined by the experts is $A8 \succ A15 \succ A16 \succ A19 \succ A12 \succ A22 \succ A4 \succ A9 \succ A6 \succ A18 \succ A2 \succ A13 \succ A14 \succ A1 \succ A3 \succ A10 \succ A7 \succ A17 \succ A5 \succ A21 \succ A20 \succ A11$. As a result of the weight simulation, the values of 20 of the 22 companies are in the interquartile range (0.91 = 20/22).

It is understood that the rankings for 2021, 2020, and 2019 differ. A company's financial statements and stock market performances do not remain the same every year, and this difference causes the rankings to change.

Discussion

This research determined the long-term performance of 22 companies included in the sustainability index in Turkey using MCDM methods. One of the critical research results is related to the weights of financial performance indicators. This study determined criterion weights using the FUCOM method, revealing that the current ratio was the criterion that affected financial performance the most. This finding differs from the findings of similar studies in the literature. For example, Abdel-Basset et al. (2020) found that the financial ratios that impact manufacturing firms' financial performance were the quick and debt-to-equity ratios, respectively. Furthermore, among 20 performance indicators, asset turnover ranked 13th and debt ratio third regarding criterion weights. In their research on SMEs, Roy and Shaw (2021) calculated the criteria weights for each firm separately. They determined that the return on total capital-employed ratio was the criterion with the highest weight for five of the six firms. Shen et al. (2017) found that the criterion with the highest weight was the research and development expense ratio while examining the effect of research and development on financial performance. Visalakshmi et al. (2015) examined the financial performance of GREENEX companies. They determined that the criterion with the highest effect on performance was the current ratio and quick ratio, and the criterion with the most negligible effect was ROA. Ghadikolaei et al. (2014) found that the criterion with the highest weight was cash value, and the criterion with the lowest weight was ROE. Their study also determined the financial performance of companies operating in Iran. Similarly, Erdoğan et al. (2016) found that the ratio with the highest impact on the financial performance of the food companies in BIST was the leverage ratio. The different results from these studies reveal that the most important criteria affecting financial performance and those with the most negligible impact differ regarding the period, sector, company, and financial ratios examined together.

This study's second most important finding is that the companies with the highest financial performance differ by MCDM methods. That is, the companies with the highest performance for all four methods regarding the examined periods are not the same in any period. One of the most important reasons for this situation is that each method's methodological flow and calculation methods in ranking the companies differ; therefore, it would be incorrect to make inferences about which of the four methods should be used to make a more accurate performance ranking based on the results of the current study. In this context, the study results are similar to those of the extant literature. For example, Ecer (2021) determined that the best alternative is the same for all methods (SECA, ARAS, COPRAS, MAIRCA, and MARCOS) except for the CoCoSo method; however, these results differ from the findings of similar studies in the literature. For example, Baležentis et al. (2012) found that the best alternative selected by fuzzy VIKOR, Fuzzy TOPSIS, and Fuzzy ARAS methods are the same. Similarly, Ghadikolaei et al. (2014) found that the two best alternatives in performance ranking were the same for all three methods (fuzzy VIKOR, ARAS-F, and fuzzy COPRAS).

Another result of the current research is the integration of the rankings suggested by the MCDM methods with the Copeland method. In addition, a weight simulation was performed, where expert evaluations were simulated with random evaluations. The results indicated that the Copeland method ensured a consensus among different methods. This result complied with the results of similar studies in the literature. For example, Ecer (2021) consolidated the results of the six MCDM methods (SECA, MARCOS, MAIRCA, COCOSO, ARAS, and COPRAS) with Copeland and Borda methods and tested the robustness of the ranking results by performing sensitivity analysis. In conclusion, it was revealed that the best alternative of the six MCDM methods and the alternatives of Copeland and Borda methods were the same, confirmed by sensitivity analysis. Beheshtinia and Omidi (2017) integrated the different sequencing results obtained by the four MCDM methods (MDL-FVIKOR, MDL-FTOPSIS, AHP-FVIKOR, and AHP-FTOPSIS) with the Copeland method and created a final ranking. Furthermore, they found that the best alternative was the same in all methods, including the Copeland method; only the other alternatives differed. Kiani et al. (2022) ranked the alternatives using three MCDM methods (fuzzy SAW, fuzzy TOPSIS, and fuzzy VIKOR) and used the Borda and Copeland methods to obtain final results since each method produced different ranking results. As a result, the Borda and Copeland methods gave the same results for all alternatives.

Managerial implications

The most crucial managerial result of this research concerns the findings related to the determinants of financial performance and the weights of these determinants. In the research, 22 companies were ranked by their financial performance regarding the 9 performance indicators; the criteria were weighted FUCOM methods. Furthermore, validation of the results was performed with a weight simulation; therefore, the results were sufficiently robust and reliable that managerial inferences could be made. The current ratio has been the most critical determinant of performance in the current research. The subsequent vital ratios were EBITDA and net profit margin (NPM); as the NPM increases, the efficiency of the business also increases. A constantly rising NPM indicates that a company can generate more profit with less equity over time; therefore, managers must develop strategies to increase net income. Covering expenses and making a net profit starts with the correct pricing. To improve profitability, managers must define a target gross profit margin to cover operating expenses, make competitive pricing, and monitor the gross profit margin monthly. With a solid profit analysis (financial modeling), it is possible to determine when the prices will increase, thus increasing the gross profit margin and making a profit. Break-even analysis is vital for pricing and profitability; managers must comprehensively evaluate what needs to change for strategic goals and pricing to be more accurate, looking at the break-even point. First, it is crucial to determine the fixed and variable costs correctly. In addition, one of the first things to be done to increase business profitability is to reduce fixed expenses. The business should try to convert many of its expenses into variable expenses. Costs can be reduced by performing a break-even analysis. For example, it may be beneficial to reduce financing costs or to reduce costs and offer the same quality at a more affordable price. Conversely, the hours of working machines can be reduced by decreasing the labor hours.

Conclusions

Measuring financial performance is one of the oldest known methods of comparing companies competing in the same industry. This research ranked companies included in the sustainability index in Turkey in 2019, 2020, and 2021 according to their financial performance. Twenty-two firms were ranked according to nine criteria, including eight financial ratios and one stock market indicator. The model proposed in the research included determining the criteria weights with FUCOM and performance ranking with CoCoSo, GRA, MABAC, MAIRCA, MOOSRA, OCRA, TOPSIS, TODIM, and VIKOR. According to the FUCOM method results, the current ratio is the criterion with the highest weight; in other words, it was the most influential on the financial performance ranking. Each MCDM method gave a different ranking, so these results were consolidated using the Copeland method and Borda rule. According to the results, the A16 (TOASO) alternative is the best. Afterward, a weight simulation was performed to test the robustness of Copeland's results. Expert evaluations were simulated with random evaluations, and 100,000 weight sets were created; the analysis was re-run for each weight set. The results indicate that the ranks of the expert evaluations and the mean of the weight evaluations are similar, indicating the robustness of the results.

Limitations of the research

The research examined companies (excluding banks) traded in the BIST sustainability index included in the sustainability index in 2019, 2020, and 2021; data were limited to these years. The decision matrix includes eight financial ratios and one stock market indicator. FUCOM determined criterion weights, and nine MCDM methods were used for performance ranking. Another limitation of this study was using a subjective weight determination technique. Objective weight determination techniques, such as MAIRCA, SECA, and SAW, can be used in other studies. In this study, parameters of the MCDM techniques (such as attenuation factor in TODIM or β coefficient in CoCoSo) were fixed as the default values proposed by the developers of the techniques. Optimizing these parameters is a valuable future research direction.

In the weight simulation process, random assessments were used. Random evaluations allow for a more objective evaluation of the results; however, it leads to results spread over an extensive range.

Future work directions

Future studies can include banks in the alternatives, and indexes containing only banks can also be used. Researchers can also analyze the performance of firms over even longer terms (like the last ten years or the last 20 years) and implement more financial ratios (especially cost-oriented) and stock market indicators (such as the risk of stock return). Future studies can also determine the criterion weights with a different method (entropy, equal weighting, and BWM) and use different MCDM methods (such as VIKOR, SAW, DEMATEL, and fuzzy AHP).

Expert opinions can guide weight simulations, and random numbers can be generated based on expert evaluations; in this case, a narrower distribution of the results can be achieved.

The order of alternatives also changed in different periods. Future studies can create a new decision matrix by averaging the decision matrices of different periods; the ranking can then be made over the decision matrix containing these average values.

Appendix A: Results for the year 2020

See Tables 14, 15, 16, 17, 18, 19 and Figs. 6, 7, 8.

Table 14 Decision matrix (2020)

Firms	Code	C1 Max	C2 Max	C3 Min	C4 Max	C5 Max	C6 Max	C7 Max	C8 Max	C9 Max
EREGL	A1	1.2493	0.9069	50.526	0.5289	9.8727	17.7585	5.4329	11.3458	0.5784
AEFES	A2	1.0504	0.9389	51.326	0.7609	52.273	21.2453	7.7173	13.2254	0.0876
AKSEN	A3	1.3875	1.0136	69.873	0.8781	5.7602	12.3921	7.0438	20.832	1.424
ARCELİK	A4	1.5905	0.966	46.9174	0.4724	2.9108	24.3875	27.7021	24.9487	0.5795
ASELS	A5	1.2788	0.9009	76.2662	0.6991	6.8597	22.2976	12.7441	37.5386	0.484
BRISA	A6	1.773	1.3254	54.3715	0.7516	13.8239	21.6391	9.1321	17.1513	1.5803
CCOLA	A7	1.0302	0.4044	67.7436	2.6556	6.8682	8.6125	5.5125	45.5572	0.6303
DOAS	A8	3.0217	1.8461	29.0933	0.5526	3.171	20.7977	10.9517	8.8165	1.7788
FROTO	A9	1.4105	1.1121	71.0713	2.0309	20.1921	10.684	8.4829	59.5538	1.0563
KCHOL	A10	0.8241	0.2003	86.0227	0.2262	7.6419	17.8152	8.8632	27.2609	0.0499
MGROS	A11	0.7047	0.33	99.7824	1.8722	8.6209	7.7254	− 1.3996	− 1297.28	0.7516
OTKAR	A12	1.4946	0.8025	76.7581	0.6711	2.1779	23.0924	21.2557	61.3761	1.6117
PETKIM	A13	1.9985	1.2172	62.1756	0.6072	12.6601	14.9189	8.828	14.1084	0.489
SAHOL	A14	0.7671	0.0745	84.682	0.043	5.7238	55.3507	41.3357	23.4212	0.1305
TAVHL	A15	0.846	0.7102	73.7083	0.0754	37.627	4.2744	− 94.5289	− 27.4687	− 0.1514
TOASO	A16	1.7798	1.3486	59.6396	0.549	138.7858	44.5561	14.9954	20.3977	0.5804
TUPRS	A17	0.6471	0.5498	78.9164	0.2479	20.7728	17.7855	− 12.0307	− 14.1461	− 0.1172
THYAO	A18	1.1802	0.8954	77.0554	1.2096	15.4575	12.8435	7.5739	39.9267	− 0.1148
TTKOM	A19	0.934	0.7927	73.0843	0.6325	113.6255	45.5844	11.2336	26.4	0.0418
TCELL	A20	1.082	0.7614	80.9174	1.0339	8.2128	0.7815	− 3.8311	− 21.1676	0.1575
ULKER	A21	0.8046	0.5403	72.5777	0.7957	5.305	16.717	8.8519	26.9698	− 0.0283
VESTL	A22	5.4049	3.4476	63.8197	0.5254	10.7872	17.2447	12.8029	21.1391	0.8835

Table 15 Overall scores and ranking results of alternatives

	CoCoSo		Gray Relational		MABAC		MAIRCA		MOOSRA		OCRA		TOPSIS		TODIM		VIKOR		COPELAND	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
A1	2.1196	11	0.5113	12	0.0207	12	0.0261	11	6.2644	10	2.1987	15	0.5558	13	0.8396	15	0.6067	13	−7	15
A2	2.1069	12	0.5113	13	0.016	13	0.0263	10	6.3608	9	4.7553	5	0.5535	14	0.879	12	0.655	10	1	11
A3	2.196	8	0.5353	10	0.0534	9	0.0246	14	6.0343	12	1.0502	20	0.5803	11	0.8895	10	0.5413	14	3	10
A4	2.2432	5	0.5519	8	0.0762	6	0.0236	17	9.537	5	3.2449	8	0.6139	6	0.9201	7	0.4726	17	11	5
A5	2.0723	14	0.5051	15	0.0022	15	0.027	8	4.7972	15	3.1968	9	0.5741	12	0.9068	8	0.6203	12	−5	14
A6	2.4072	4	0.5765	5	0.1338	4	0.021	19	9.6443	4	3.0814	11	0.6165	5	0.9752	3	0.3707	19	15	4
A7	2.0851	13	0.5337	11	0.015	14	0.0264	9	5.2301	14	3.2896	7	0.5509	15	0.8535	13	0.6605	9	−3	13
A8	2.6239	2	0.6624	2	0.2309	2	0.0166	21	21.798	1	3.1215	10	0.6661	2	0.9369	6	0.0103	22	19	2
A9	2.242	6	0.5399	9	0.0676	7	0.024	16	6.5383	7	3.4642	6	0.5873	8	0.9786	2	0.5209	15	9	7
A10	1.7605	18	0.4696	18	−0.1035	18	0.0318	5	2.3174	18	1.0965	19	0.5273	18	0.7065	18	0.8333	4	−13	18
A11	1.3629	21	0.4196	21	−0.1696	21	0.0348	2	−0.6244	21	1.6093	18	0.3968	21	0	22	0.9308	2	−19	21
A12	2.1704	9	0.5749	6	0.093	5	0.0228	18	6.9491	6	2.1312	16	0.6231	4	0.9505	5	0.4753	16	11	6
A13	2.1581	10	0.5106	14	0.0319	10	0.0256	13	6.0989	11	2.4557	13	0.5819	10	0.8806	11	0.4318	18	−1	12
A14	1.8221	17	0.5951	4	0.0229	11	0.026	12	5.4517	13	7.2472	3	0.6039	7	0.733	17	0.7091	7	7	8
A15	1.2453	22	0.4135	22	−0.2221	22	0.0372	1	−3.2275	22	0.1412	21	0.3183	22	0.3928	21	0.9568	1	−21	22
A16	2.5072	3	0.6025	3	0.173	3	0.0192	20	10.7794	3	11.1135	1	0.6448	3	1	1	0.3268	20	17	3
A17	1.6389	20	0.4508	20	−0.1208	20	0.0326	3	1.384	20	2.0131	17	0.4776	20	0.5715	20	0.8905	3	−17	20
A18	1.9056	15	0.485	16	−0.0551	16	0.0296	7	3.4984	16	3.0592	12	0.5393	16	0.8482	14	0.7036	8	−9	16
A19	2.2124	7	0.5531	7	0.0637	8	0.0242	15	6.4893	8	10.3562	2	0.5835	9	0.9043	9	0.6287	11	7	9
A20	1.6869	19	0.4575	19	−0.1044	19	0.0318	4	2.0231	19	0	22	0.4995	19	0.6284	19	0.7783	6	−15	19
A21	1.855	16	0.4801	17	−0.0701	17	0.0303	6	3.1079	17	2.2555	14	0.5309	17	0.7875	16	0.8015	5	−11	17
A22	2.6588	1	0.6745	1	0.2404	1	0.0161	22	12.0745	2	5.643	4	0.7084	1	0.9589	4	0.0549	21	21	1

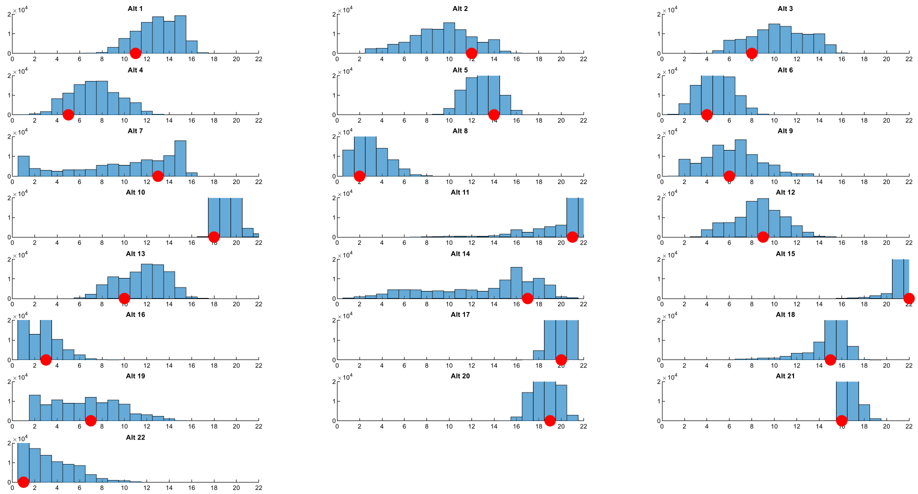

Fig. 6 Weight simulation results

Table 16 Descriptive statistics of Copeland Rankings in Weight Simulation

Alternatives	Expert ranks	Weight simulation descriptive statistics						
		Mean	Min	Max	Median	St. Dev	Skewness	Kurtosis
A1	15	12.973	6	18	13	1.9042	− 0.3714	2.5638
A2	11	9.3736	3	16	10	2.7894	− 0.1651	2.5351
A3	10	10.4221	3	16	10	2.5827	− 0.0876	2.1858
A4	5	7.294	1	14	7	2.1622	0.0931	2.5019
A5	14	12.9732	8	17	13	1.3867	− 0.1807	2.5946
A6	4	4.7772	1	11	5	1.5355	0.1707	2.5285
A7	13	9.7378	1	17	11	4.7828	− 0.5818	2.0227
A8	2	2.8348	1	10	2	1.382	0.8966	3.5493
A9	7	6.2117	1	14	6	2.4965	0.2601	2.7581
A10	18	18.8486	17	22	19	1.0109	0.9267	3.0883
A11	21	20.5337	7	22	21	2.365	− 2.3146	8.9743
A12	6	8.5472	3	15	9	2.2103	− 0.1076	2.6017
A13	12	11.5672	6	17	12	2.1417	− 0.2554	2.2908
A14	8	13.0831	1	21	15	4.7476	− 0.6229	2.2041
A15	22	21.3901	16	22	21	0.7524	− 2.2596	12.7215
A16	3	2.337	1	9	2	1.4473	0.9229	3.3471
A17	20	19.9103	16	22	20	0.7987	− 0.4398	2.9848
A18	16	15.0497	7	19	15	1.6372	− 2.0969	8.4962
A19	9	6.5071	2	16	7	3.1271	0.2572	2.2118
A20	19	18.6741	15	22	19	1.0806	− 0.2462	2.66
A21	17	16.8626	15	21	17	0.5977	0.3927	4.4216
A22	1	3.0924	1	11	2	2.1646	0.9569	3.2564

Table 17 How many times each alternative is ranked in each position

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22
A1	0	0	0	0	0	123	163	528	3108	7645	11,389	15,848	18,732	16,361	19,307	6408	369	19	0	0	0	0
A2	0	0	2440	2653	4687	5755	9231	12,480	12,236	15,704	12,169	8504	5654	7078	1208	201	0	0	0	0	0	0
A3	0	0	2	127	1435	6764	7173	8618	12,063	15,043	13,823	10,329	9907	9998	4468	250	0	0	0	0	0	0
A4	126	530	1661	8272	11,114	15,491	17,118	17,242	11,433	8617	6236	1900	242	18	0	0	0	0	0	0	0	0
A5	0	0	0	0	0	0	0	20	345	3277	12,660	19,033	26,423	25,857	10,038	2342	5	0	0	0	0	0
A6	348	5738	15,066	25,051	20,589	19,386	9866	3500	396	58	2	0	0	0	0	0	0	0	0	0	0	0
A7	10,170	3915	2990	2576	3193	3224	3408	5506	6134	5623	6951	8269	7912	10,438	17,897	1773	21	0	0	0	0	0
A8	13,202	37,144	22,369	14,082	8287	3704	830	354	24	4	0	0	0	0	0	0	0	0	0	0	0	0
A9	105	8609	6440	9607	15,700	13,155	18,347	10,953	6740	5663	2127	1303	1220	31	0	0	0	0	0	0	0	0
A10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	290	49,596	22,806	21,207	4476	1625
A11	0	0	0	0	0	0	27	161	283	407	494	466	420	760	1544	3794	2544	4311	5365	6149	23,528	49,747
A12	0	0	205	3810	7280	7436	10,200	18,311	19,704	13,701	10,407	5842	2528	471	105	0	0	0	0	0	0	0
A13	0	0	0	0	0	388	2211	7051	11,084	10,389	13,564	17,611	17,301	13,752	5654	845	150	0	0	0	0	0
A14	282	896	1455	2306	4450	4539	4432	3592	3929	3557	4638	4381	3762	5223	9487	15,997	8550	10,338	6923	900	363	0
A15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	164	333	608	1471	2561	46,379	48,484
A16	42,743	12,812	25,517	10,335	5176	2564	671	159	23	0	0	0	0	0	0	0	0	0	0	0	0	0
A17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	105	4715	21,787	50,901	22,360	122
A18	0	0	0	0	0	0	451	511	966	986	1829	3382	3595	9027	30,067	42,074	6861	242	9	0	0	0
A19	0	13,138	8087	10,657	8917	8951	11,954	9091	10,596	8522	3518	3132	2304	986	126	21	0	0	0	0	0	0
A20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1967	14,447	21,895	40,517	18,268	2883	22
A21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	24,154	66,325	8276	1122	14	11	0
A22	33,024	17,218	13,768	10,524	9172	8520	3918	1923	936	804	193	0	0	0	0	0	0	0	0	0	0	0

Table 18 How many times each alternative is ranked higher than other alternative

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22
A1	0	16,668	21,719	13	46,368	0	36,695	0	4093	100,000	96,877	7430	26,894	58,221	100,000	0	100,000	80,563	7345	99,999	99,817	0
A2	83,332	0	59,602	27,207	86,702	11,999	59,820	3735	25,946	100,000	98,415	45,101	74,958	74,752	100,000	0	100,000	96,410	8379	100,000	100,000	6287
A3	78,281	40,398	0	27,084	79,662	0	53,216	0	10,251	100,000	99,922	21,521	59,815	67,046	100,000	1254	100,000	97,401	21,345	100,000	100,000	595
A4	99,987	72,793	72,916	0	99,998	18,825	66,359	2558	37,186	100,000	99,236	67,571	98,146	86,057	100,000	1805	100,000	97,056	44,308	100,000	100,000	5803
A5	53,632	13,298	20,338	2	0	0	34,149	0	2865	100,000	97,560	2229	33,669	58,490	100,000	0	100,000	84,047	2409	99,999	99,998	0
A6	100,000	88,001	100,000	81,175	100,000	0	78,543	8836	72,705	100,000	100,000	99,704	100,000	89,363	100,000	15,176	100,000	100,000	64,499	100,000	100,000	24,283
A7	63,305	40,180	46,784	33,641	65,851	21,457	0	16,459	18,251	100,000	100,000	38,927	52,584	66,879	100,000	14,936	100,000	96,588	32,980	100,000	99,918	17,480
A8	100,000	96,265	100,000	97,442	100,000	91,164	83,541	0	86,186	100,000	100,000	99,991	100,000	97,222	100,000	41,186	100,000	100,000	82,486	100,000	100,000	41,035
A9	95,907	74,054	89,749	62,814	97,135	27,295	81,749	13,814	0	100,000	100,000	72,168	96,213	81,605	100,000	15,461	100,000	100,000	53,760	100,000	100,000	17,105
A10	0	0	0	0	0	0	0	0	0	0	80,067	0	0	324	95,169	0	85,693	197	0	53,664	28	0
A11	3123	1585	78	764	2440	0	0	0	0	19,933	0	461	2497	9292	49,962	0	26,075	4417	714	15,235	10,057	0
A12	92,570	54,899	78,479	32,429	97,771	296	61,073	9	27,832	100,000	99,539	0	82,488	79,489	100,000	2866	100,000	96,870	33,345	100,000	100,000	5326
A13	73,106	25,042	40,185	1854	66,331	0	47,416	0	3787	100,000	97,503	17,512	0	66,307	100,000	0	100,000	90,753	13,488	100,000	100,000	0
A14	41,779	25,248	32,954	13,943	41,510	10,637	33,121	2778	18,395	99,676	90,708	20,511	33,693	0	98,927	350	98,120	56,279	9345	82,192	74,389	7138
A15	0	0	0	0	0	0	0	0	0	4831	50,038	0	0	1073	0	0	1872	1	0	2772	408	0
A16	100,000	100,000	98,746	98,195	100,000	84,824	85,064	58,814	84,539	100,000	100,000	97,134	100,000	99,650	100,000	0	100,000	100,000	100,000	100,000	100,000	59,336
A17	0	0	0	0	0	0	0	0	0	14,307	73,925	0	0	1880	98,128	0	0	0	0	20,539	189	0
A18	19,437	3590	2599	2944	15,953	0	3412	0	0	99,803	95,583	3130	9247	43,721	99,999	0	100,000	0	1156	99,995	94,463	0
A19	92,655	91,621	78,655	55,692	97,591	35,501	67,020	17,514	46,240	100,000	99,286	66,655	86,512	90,655	100,000	0	100,000	98,844	0	100,000	100,000	24,849
A20	1	0	0	0	1	0	0	0	0	46,336	84,765	0	0	17,808	97,228	0	79,461	5	0	0	6989	0
A21	183	0	0	0	2	0	82	0	0	99,972	89,943	0	0	25,611	99,592	0	99,811	5537	0	93,011	0	0
A22	100,000	93,713	99,405	94,197	100,000	75,717	82,520	58,965	82,895	100,000	100,000	94,674	100,000	92,862	100,000	40,664	100,000	100,000	75,151	100,000	100,000	0

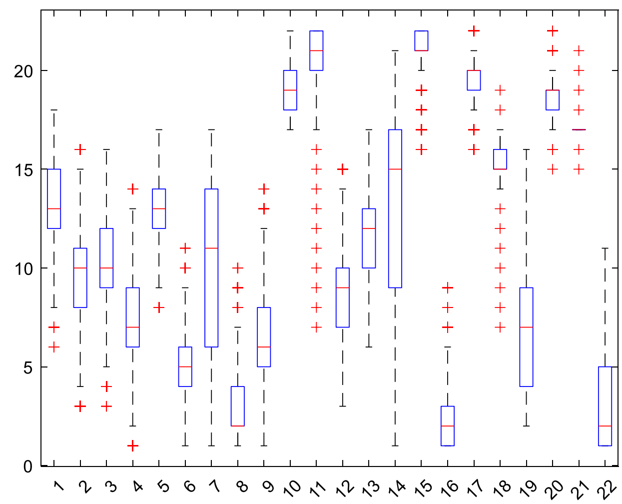

Fig. 7 Box plot of the rank dataset

Table 19 ANOVA results

Source	SS	df	MS	F	Prob
Columns	7.67e7	21	3,651,692.64	677,118.65	0
Error	1.19e7	219,978	5.39		
Total	8.86e7	219,999			

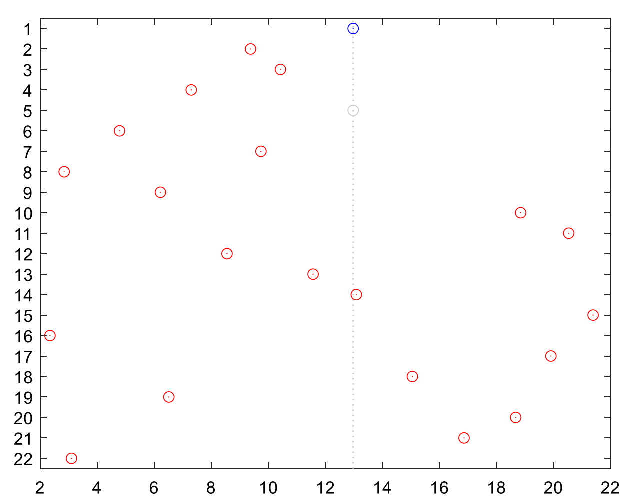

Fig. 8 Multiple comparison summary

Appendix B: Results for the year 2019

See Tables 20, 21, 22, 23, 25 and Figs. 9, 10, 11.

Table 20 Decision matrix (2019)

Firms	Code	C1 Max	C2 Max	C3 Min	C4 Max	C5 Max	C6 Max	C7 Max	C8 Max	C9 Max
EREGL	A1	1.3254	0.9099	47.3993	0.5073	10.3273	16.4025	5.5587	9.9915	0.3004
AEFES	A2	0.9115	0.7465	55.077	0.6562	19.6377	25.164	8.1623	13.0454	0.1535
AKSEN	A3	1.5755	1.1181	71.7359	0.9197	5.6732	10.4514	2.9836	9.8674	0.3555
ARCELİK	A4	1.8048	1.0046	47.0648	0.5076	2.9085	21.9312	25.7649	24.8376	0.1284
ASELS	A5	0.9467	0.6053	83.0096	0.674	5.6065	17.1634	3.2041	12.7099	− 0.0804
BRISA	A6	1.5455	1.0632	53.8254	0.7672	14.0495	18.7787	7.6949	14.4626	0.4563
CCOLA	A7	0.813	0.4944	73.1499	2.1102	10.5183	6.0475	0.7797	6.1641	0.4657
DOAS	A8	2.554	1.4751	33.0497	0.5885	2.944	19.8742	12.7223	11.5323	1.6463
FROTO	A9	1.1748	0.8455	71.5664	2.3899	21.4562	8.543	4.9975	42.0047	0.3406
KCHOL	A10	1.3931	1.0206	67.1925	1.0103	8.7722	6.9953	3.8725	16.3201	0.1579
MGROS	A11	0.6995	0.3301	97.7673	1.6037	8.6975	9.1719	− 2.1213	− 153.165	0.4824
OTKAR	A12	1.872	1.0791	76.187	0.9077	3.1641	17.7631	14.465	55.1391	0.5355
PETKIM	A13	1.8615	1.0923	67.2402	0.7886	12.5622	13.1141	6.5475	15.7256	− 0.1062
SAHOL	A14	0.7423	0.0939	83.6403	0.0462	6.0112	49.8502	37.0813	20.942	0.082
TAVHL	A15	1.1961	1.0325	65.9216	0.1861	80.0519	43.9194	50.7845	27.5294	0.0629
TOASO	A16	1.5276	1.1212	60.4442	0.5249	134.5089	44.7767	13.655	18.1569	0.3653
TUPRS	A17	0.8002	0.62	72.2239	0.5115	43.5972	15.9655	6.0385	11.1198	− 0.0939
THYAO	A18	1.1376	0.8112	66.2026	1.4753	25.2251	13.1226	7.8406	34.2242	− 0.1128
TTKOM	A19	0.882	0.788	76.3392	0.5928	93.8618	46.8771	10.1736	25.4879	0.5358
TCELL	A20	0.9928	0.5507	76.3355	1.6141	9.463	4.2489	0.6533	4.5154	0.0079
ULKER	A21	0.6558	0.4482	80.5684	0.8829	6.0619	13.601	2.0487	9.5335	0.2685
VESTL	A22	1.2824	1.1176	61.4265	0.61	13.1654	16.7052	12.9592	22.9233	1.0486

Table 21 Overall scores and ranking results of alternatives

	CoCoSo		Gray Relational		MABAC		MAIRCA		MOOSRA		OCRA		TOPSIS		TODIM		VIKOR		COPELAND	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
A1	2.4448	9	0.4708	12	0.0171	11	0.0284	12	7.7137	9	2.4674	15	0.4289	13	0.7082	15	0.4127	15	−3	14
A2	2.3568	13	0.4568	15	−0.0091	14	0.0296	9	6.6257	10	2.9009	12	0.4296	12	0.7204	12	0.6419	8	−1	11
A3	2.382	12	0.4626	13	0.0024	13	0.0291	10	5.3646	15	3.0838	11	0.428	14	0.7203	13	0.4708	14	−7	15
A4	2.6802	7	0.526	6	0.1281	4	0.0233	19	11.4492	4	1.5771	19	0.5129	8	0.8304	9	0.2713	19	9	7
A5	1.9344	19	0.4141	20	−0.1196	19	0.0346	4	2.9729	21	2.7756	14	0.3864	20	0.466	18	0.722	5	−15	19
A6	2.6409	8	0.4899	10	0.0721	8	0.0259	15	8.6362	6	2.8677	13	0.4673	10	0.8922	5	0.3252	17	5	9
A7	2.0713	17	0.4405	17	−0.0801	17	0.0328	6	4.4023	17	4.1531	5	0.4114	17	0.5213	17	0.7665	4	−11	17
A8	3.3866	1	0.7252	1	0.3139	1	0.0149	22	23.8905	1	1.3832	21	0.6135	1	0.9185	3	0.0162	22	21	1
A9	2.4357	10	0.4978	9	0.0164	12	0.0284	11	6.5969	11	5.1325	2	0.4739	9	0.8404	8	0.4735	13	7	8
A10	2.2715	14	0.4521	16	−0.0282	16	0.0304	7	5.0492	16	3.2205	9	0.4165	16	0.7153	14	0.5462	10	−9	16
A11	1.1724	22	0.3735	22	−0.2314	22	0.0397	1	−0.0235	22	3.4702	8	0.1777	22	0	22	0.9736	1	−21	22
A12	2.7321	4	0.5251	7	0.1071	5	0.0243	18	7.9968	8	2.2986	17	0.5454	3	0.9274	2	0.2017	20	13	5
A13	2.4084	11	0.477	11	0.0195	9	0.0283	14	5.5094	14	3.4735	7	0.4213	15	0.7547	11	0.4861	12	−1	12
A14	2.1224	16	0.5273	5	0.0182	10	0.0283	13	6.3858	12	0	22	0.5277	6	0.4225	21	0.719	6	−1	13
A15	3.0435	3	0.6071	2	0.199	3	0.0201	20	11.6654	2	1.6132	18	0.5965	2	0.8664	6	0.2796	18	19	2
A16	3.073	2	0.5808	3	0.2007	2	0.02	21	11.5242	3	5.5295	1	0.5402	5	1	1	0.1037	21	17	3
A17	2.0051	18	0.4201	18	−0.1009	18	0.0338	5	3.7413	18	3.0925	10	0.3917	19	0.5248	16	0.7933	3	−13	18
A18	2.194	15	0.46	14	−0.0224	15	0.0302	8	5.6271	13	4.2719	4	0.436	11	0.7751	10	0.5278	11	1	10
A19	2.7103	5	0.5291	4	0.0948	6	0.0249	17	8.0688	7	4.4034	3	0.5258	7	0.8625	7	0.5645	9	15	4
A20	1.8226	20	0.4171	19	−0.1218	20	0.0347	3	2.9963	20	3.9313	6	0.3723	21	0.4247	20	0.6962	7	−19	21
A21	1.7991	21	0.4089	21	−0.1345	21	0.0353	2	3.1748	19	2.46	16	0.3941	18	0.4337	19	0.9111	2	−17	20
A22	2.6992	6	0.502	8	0.0895	7	0.0251	16	9.3752	5	1.4573	20	0.5417	4	0.9151	4	0.3279	16	11	6

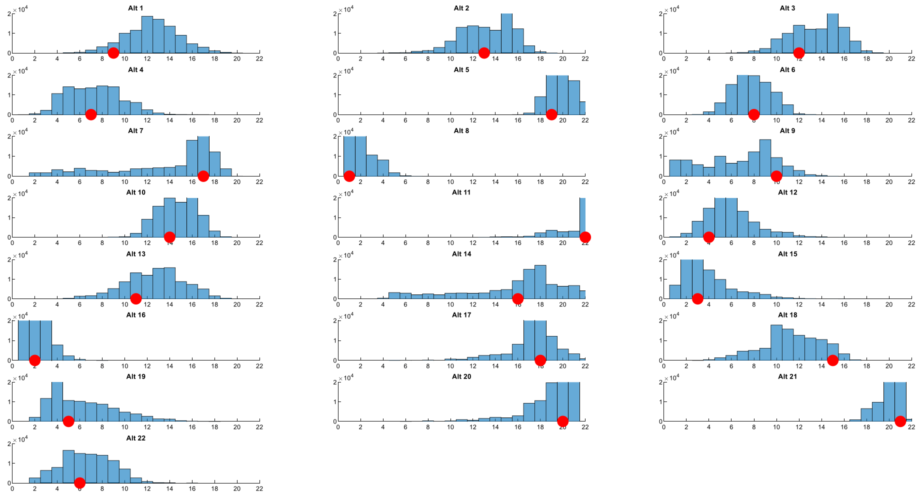

Fig. 9 Weight simulation results

Table 22 Descriptive statistics of Copeland Rankings in Weight Simulation

Alternatives	Expert ranks	Weight simulation descriptive statistics						
		Mean	Min	Max	Median	St. Dev	Skewness	Kurtosis
A1	14	12.4454	5	20	12	2.3432	−0.0426	2.9453
A2	11	13.2319	4	19	13	2.2903	−0.4184	2.7513
A3	15	13.5037	6	19	14	2.2557	−0.3012	2.3578
A4	7	7.2313	1	17	7	2.3426	0.2484	2.4672
A5	19	19.6687	16	22	19	1.0945	0.4084	2.6008
A6	9	7.7833	3	13	8	1.6627	0.1156	2.493
A7	17	13.6423	2	20	16	4.6595	−1.0131	2.7693
A8	1	1.8071	1	8	1	1.0676	1.332	4.2077
A9	8	6.6669	1	15	7	3.2274	−0.265	2.037
A10	16	14.6427	9	20	15	1.7116	−0.0891	2.4046
A11	22	21.6537	13	22	22	1.0452	−3.508	16.6084
A12	5	5.8904	1	16	6	2.0869	0.7693	3.8323
A13	12	12.6331	4	20	13	2.6104	−0.2253	2.822
A14	13	15.6505	4	22	17	4.4763	−0.9111	2.9777
A15	2	3.7398	1	16	3	2.1015	1.4435	5.4583
A16	3	2.1531	1	8	2	1.068	0.8817	3.6702
A17	18	17.3885	5	22	18	2.0525	−1.2991	6.5046
A18	10	11.3093	3	17	11	2.5775	−0.2768	2.6974
A19	4	6.2064	2	18	5	2.8622	0.8732	3.1273
A20	21	18.8462	6	22	19	2.2207	−1.8286	7.1484
A21	20	20.2631	17	22	21	0.9535	−1.156	3.8707
A22	6	6.6428	2	16	7	2.2562	0.0934	2.5143

Table 23 How many times each alternative is ranked in each position

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22
A1	0	0	0	0	53	415	1521	3158	5271	10,071	11,572	18,715	17,228	13,710	9025	4732	2997	1197	331	4	0	0
A2	0	0	0	5	162	210	863	1262	2832	6097	13,094	13,845	13,169	11,647	20,050	12,370	3708	669	17	0	0	0
A3	0	0	0	0	0	24	267	1103	2298	7198	10,035	14,144	12,001	12,290	20,137	13,172	6114	1183	34	0	0	0
A4	2	502	2158	10,724	14,201	13,241	13,612	14,632	14,165	6995	6193	2462	850	172	61	21	9	0	0	0	0	0
A5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	837	9152	42,783	23,309	17,315	6594
A6	0	0	65	1462	6001	15,364	23,632	19,875	16,532	11,471	5056	491	51	0	0	0	0	0	0	0	0	0
A7	0	1725	1775	3299	2331	3985	2933	2796	2083	2569	3771	3919	4237	4443	5241	18,049	20,860	12,191	3749	44	0	0
A8	52,869	26,247	10,654	8152	1753	282	25	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A9	8161	8137	5815	4540	10,066	6574	7484	12,215	18,376	9368	5143	2891	817	380	33	0	0	0	0	0	0	0
A10	0	0	0	0	0	0	0	0	97	299	1940	9166	15,827	19,969	17,808	20,299	11,133	3189	267	6	0	0
A11	0	0	0	0	0	0	0	0	0	0	0	0	20	160	135	197	554	2237	3504	2844	3125	87,224
A12	187	2043	8119	14,825	21,077	22,114	13,222	7772	4062	2723	2497	821	336	197	4	1	0	0	0	0	0	0
A13	0	0	0	25	253	1389	1616	2985	5228	8673	13,244	12,118	15,524	15,888	8795	7348	5041	1512	336	25	0	0
A14	0	0	0	385	3198	2923	2207	2509	2076	2892	2964	2950	2993	4265	4727	9275	15,045	17,102	7338	6323	6771	4057
A15	7007	21,173	31,190	14,716	9874	5029	3615	3164	2248	930	593	222	108	62	66	3	0	0	0	0	0	0
A16	31,774	35,468	22,072	7762	2306	525	90	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A17	0	0	0	0	20	61	35	195	140	722	703	1585	2516	2916	3240	8158	23,214	34,394	12,158	5728	3337	878
A18	0	0	2	411	1380	2501	4661	5022	6144	17,778	15,768	12,605	11,269	10,500	8351	3307	301	0	0	0	0	0
A19	0	2096	11,718	25,742	10,678	10,280	9487	8819	6796	4772	3843	2612	1314	1209	408	179	46	1	0	0	0	0
A20	0	0	0	0	0	18	4	309	179	277	943	653	1535	2081	1918	2870	9276	10,631	19,709	29,481	20,046	70
A21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	865	6542	9774	32,236	49,406	1177
A22	0	2609	6432	7952	16,647	15,065	14,726	14,163	11,473	7165	2641	801	205	111	1	9	0	0	0	0	0	0

Table 24 How many times each alternative is ranked higher than other alternative

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22
A1	0	67,095	62,160	1910	100,000	50	70,738	0	9610	75,383	99,296	6648	48,314	77,842	708	0	96,209	40,200	4189	93,150	100,000	1956
A2	32,905	0	53,059	2344	100,000	2620	66,291	5	7715	60,641	99,391	5068	44,027	78,539	15	0	98,425	28,900	475	93,386	100,000	3009
A3	37,840	46,941	0	3918	99,995	45	63,740	0	3916	72,821	99,826	1	31,733	70,295	677	0	89,174	28,504	5918	93,538	100,000	748
A4	98,090	97,656	96,082	0	100,000	59,498	81,635	488	50,902	99,282	99,984	28,410	99,260	95,719	6557	2023	99,518	85,609	34,326	98,309	100,000	43,521
A5	0	0	5	0	0	0	4133	0	0	420	88,960	0	11	16,690	0	0	6168	0	0	47,691	69,057	0
A6	99,950	97,380	99,955	40,502	100,000	0	81,532	0	47,141	99,998	100,000	21,712	97,297	89,559	11,066	4	99,873	82,929	28,747	99,702	100,000	24,328
A7	29,262	33,709	36,260	18,365	95,867	18,468	0	2446	81	45,541	100,000	12,829	36,345	61,698	8732	4191	74,361	30,254	12,766	100,000	99,956	14,637
A8	100,000	99,995	100,000	99,512	100,000	100,000	97,554	0	88,871	100,000	100,000	98,366	100,000	99,635	84,564	58,530	100,000	99,800	92,464	100,000	100,000	100,000
A9	90,390	92,285	96,084	49,098	100,000	52,859	99,919	11,129	0	99,731	100,000	41,461	91,417	86,834	22,443	17,774	99,926	99,956	40,150	100,000	100,000	41,857
A10	24,617	39,359	27,179	718	99,580	2	54,459	0	269	0	99,724	11	24,980	66,777	417	0	84,708	15,043	3429	94,231	100,000	225
A11	704	609	174	16	11,040	0	0	0	0	276	0	0	801	6173	0	0	6861	0	3	227	7745	1
A12	93,352	94,932	99,999	71,590	100,000	78,288	87,171	1634	58,539	99,989	100,000	0	99,697	93,581	24,345	4133	99,117	95,718	47,592	99,917	100,000	61,368
A13	51,686	55,973	68,267	740	99,989	2703	63,655	0	8583	75,020	99,199	303	0	76,239	2016	0	91,458	32,594	9212	92,483	99,994	6579
A14	22,158	21,461	29,705	4281	83,310	10,441	38,302	365	13,166	33,223	93,827	6419	23,761	0	0	3	60,955	22,311	3238	75,731	83,015	9279
A15	99,292	99,985	99,323	93,443	100,000	88,934	91,268	15,436	77,557	99,583	100,000	75,655	97,984	100,000	0	24,792	100,000	96,027	83,313	99,579	100,000	83,852
A16	100,000	100,000	100,000	97,977	100,000	99,996	95,809	41,470	82,226	100,000	100,000	95,867	100,000	99,997	75,208	0	100,000	99,519	100,000	100,000	100,000	96,623
A17	3791	1575	10,826	482	93,832	127	25,639	0	74	15,292	93,139	883	8542	39,045	0	0	0	2954	0	74,659	90,135	156
A18	59,800	71,100	71,496	14,391	100,000	17,071	69,746	200	44	84,957	100,000	4282	67,406	77,689	3973	481	97,046	0	13,734	100,000	100,000	15,650
A19	95,811	99,525	94,082	65,674	100,000	71,253	87,234	7536	59,850	96,571	99,997	52,408	90,788	96,762	16,687	0	100,000	86,266	0	99,213	100,000	59,705
A20	6850	6614	6462	1691	52,309	298	0	0	0	5769	99,773	83	7517	24,269	421	0	25,341	0	787	0	76,405	787
A21	0	0	0	0	30,943	0	44	0	0	0	92,255	0	6	16,985	0	0	9865	0	0	23,595	0	0
A22	98,044	96,991	99,252	56,479	100,000	75,672	85,363	0	58,143	99,775	99,999	38,632	93,421	90,721	16,148	3377	99,844	84,350	40,295	99,213	100,000	0

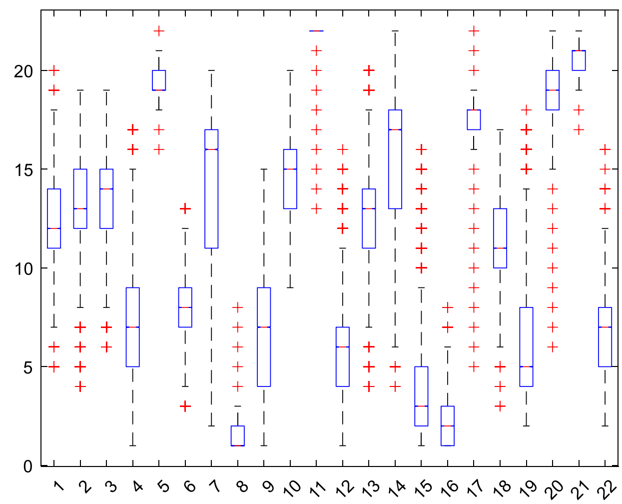

Fig. 10 Box plot of the rank dataset

Table 25 ANOVA results

Source	SS	df	MS	F	Prob
Columns	7.56e7	21	3,600,926.51	612,654.78	0
Error	1.29e7	219,978	5.88		
Total	8.86e7	219,999			

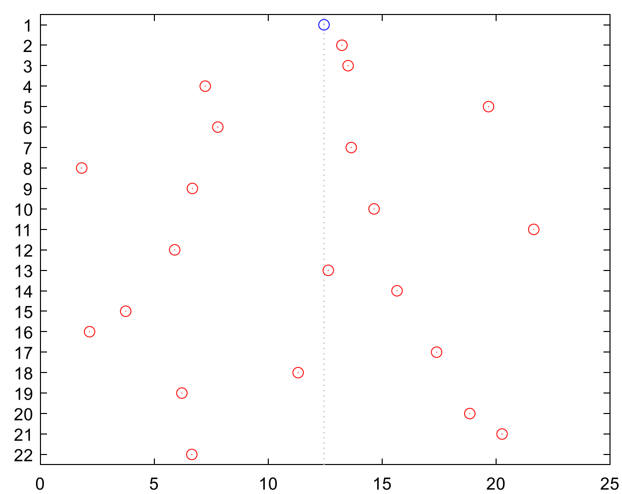

Fig. 11 Multiple comparison summary

Abbreviations

AHP	Analytical hierarchy process
ANOVA	Analysis of variance
ANP	Analytical network process
ARAS	Additive ratio assessment
BIST	Borsa Istanbul
BWM	Best–Worst Method
CoCoSo	Combined compromise solution
CODAS	Combinative distance-based assessment
COPRAS	Complex proportional assessment

DEMATEL	Decision Making Trial and Evaluation Laboratory
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
EDAS	Evaluation Based on distance from average solution
EWP	Exponentially weighted product
GRA	Grey relational analysis
FUCA	Faire un choix Adequat
FUCOM	Fully consistency method
MABAC	Multi-attributive border approximation area comparison
MAIRCA	Multi-attribute ideal real comparative analysis
MCDM	Multi-criteria decision making
MOOSRA	Multi-objective optimization on the basis of simple ratio analysis
OCRA	Operational competitivenes ratings
PROMETHEE	Preference Ranking Organization Method for Enrichment of Evaluations
ROE	Return on equity
SAW	Simple additive weighting
SECA	Simultaneous evaluation of criteria and alternatives
St. Dev.	Standard deviation
TODIM	The Portuguese acronym for interactive multi-criteria decision making
VIKOR	Vise Kriterijumska Optimizacija I Kompromisno Resenje
WASPAS	Weighted aggregated sum product assessment

Acknowledgements
Not applicable.

Author contributions
AK: Investigation; Data curation; Methodology; Writing—original draft; Writing—review &editing. DP: Conceptualization; Data curation; Formal analysis; Methodology; Supervision. HEG: Investigation; Methodology; Data curation; Writing—original draft; Writing—review &editing. MO: Writing—original draft; Methodology; Validation; Visualization; Resources; Software. All authors read and approved the final manuscript.

Funding
The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Availability of data and materials
The datasets generated and/or analyzed in this study are available in the World Bank database, https://www.enterprisesurveys.org/en/data. However, the reader may contact the corresponding author for more details on the data.

Declarations

Competing interests
The authors have no relevant financial or non-financial interests to disclose.

Received: 3 July 2022 Accepted: 6 May 2023
Published online: 15 January 2024

References

Abdel-Basset M, Ding W, Mohamed R, Metawa N (2020) An integrated plithogenic MCDM approach for financial performance evaluation of manufacturing industries. Risk Manag 22:192–218. https://doi.org/10.1057/s41283-020-00061-4

Abdelli A, Mokdad L, Hammal Y (2020) Dealing with value constraints in decision making using MCDM methods. J Comput Sci 44:101154. https://doi.org/10.1016/j.jocs.2020.101154

Acar M, Temiz H (2018) Sürdürülebilirlik endeksinde işlem gören firmaların finansal performansı: Olay çalışması örneği. Hitit Üniversitesi Sosyal Bilimler Enstitüsü Dergisi 11:1971–1987. https://doi.org/10.17218/HITITSOSBIL.441200

Açıkgöz G (2020) Investigation of the effect of the assessment of the company on the financial tables and the sampling of FAVÖK (EBITDA) method on a ring open company. J Ind Policy Technol 2:61–76

Akben-Selcuk E (2019) Corporate social responsibility and financial performance: the moderating role of ownership concentration in Turkey. Sustainability 2019(11):3643. https://doi.org/10.3390/SU11133643

Akbulut OY, Hepşen A (2021) Finansal performans ve pay senedi getirileri arasındaki ilişkinin Entropy ve CoCoSo ÇKKV teknikleri ile analiz edilmesi. Ekonomi Politika Finans Araştırmaları Dergisi 6:681–709. https://doi.org/10.30784/epfad.945770

Akyüz F, Bilgiç S (2016) Borsa İstanbul (BİST)'da İşlem Gören Bilişim Firmalarının Aktif Karlılıları ile Kaldıraç Oranı, Cari Oran, Nakit Oranı ve Asit Test Oranının İstatistiksel Analiz Yöntemiyle Karşılaştırılması. Uşak Üniversitesi Sosyal Bilimler Dergisi 9:88–102

Alali F, Tolga AC (2019) Portfolio allocation with the TODIM method. Expert Syst Appl 124:341–348. https://doi.org/10.1016/j.eswa.2019.01.054

Aldalou E, Perçin S (2020) Gıda ve İçecek İndeksinin Finansal Performans Değerlendirmesinde. Uluslararası Ekonomi Ve Yenilik Dergisi 6:1–19

Alimohammadlou M, Bonyani A (2017) A novel hybrid MCDM model for financial performance evaluation in Iran's food industry. Account Financ Control 1:38–45. https://doi.org/10.21511/afc.01(2).2017.05

Alossta A, Elmansouri O, Badi I (2021) Resolving a location selection problem by means of an integrated AHP-RAFSI approach. Rep Mech Eng 2:135–142. https://doi.org/10.31181/RME200102135A

Armağan İÜ, Özdağoğlu A, Keleş MK (2021) COVID-19 Salgınının Banka PErformanslarına Etkisinin SECA Yöntemiyle Değerlendirilmesi. Oğuzhan Sosyal Bilimler Dergisi 3:114–124

Ates S (2020) Membership of sustainability index in an emerging market: Implications for sustainability. J Clean Prod 250:119465. https://doi.org/10.1016/J.JCLEPRO.2019.119465

Ayçin E, Güçlü P (2020) BIST Ticaret Endeksinde Yer Alan İşletmelerin Finansal Performanslarının Entropi ve MAIRCA Yöntemleri ile Değerlendirilmesi. Muhasebe Ve Finansman Dergisi 673739:287–312. https://doi.org/10.25095/mufad.673739

Aydin N, Seker S, Şen C (2022) A new risk assessment framework for safety in oil and gas industry: application of FMEA and BWM based picture fuzzy MABAC. J Pet Sci Eng 219:111059. https://doi.org/10.1016/J.PETROL.2022.111059

Aytekin A (2019) Evaluation of the financial performance of tourism companies traded in BIST via a hybrid MCDM model. Int J Appl Res Manag Econ 2:20–32. https://doi.org/10.33422/IJARME.V2I4.274

Badi I, Abdulshahed A (2021) Sustainability performance measurement for Libyan Iron and Steel Company using Rough AHP. J Decis Anal Intell Comput 1(1):22–34. https://doi.org/10.31181/jdaic1001202222b

Badi I, Bouraima MB, Jibril ML (2022) Risk assessment in construction projects using the grey theory. J Eng Manag Syst Eng 1(2):58–66

Bağcı H, Yerdelen Kaygın C (2020) BİST Holding ve Yatırım Endeksinde Yer Alan Şirketlerin Finansal Performanslarının MCDM Yöntemleri İle Ölçümü. Muhasebe Ve Finansman Dergisi 756394:295–318. https://doi.org/10.25095/mufad.756394

Bahrami S, Rastegar M (2022) Security-based critical power distribution feeder identification: application of fuzzy BWM-VIKOR and SECA. Int J Electr Power Energy Syst 134:107395. https://doi.org/10.1016/j.ijepes.2021.107395

Bakır M, Akan Ş, Özdemir E (2021) Regional aircraft selection with fuzzy piprecia and fuzzy marcos: a case study of the Turkish airline industry. Facta Univ Ser Mech Eng 19:423–445. https://doi.org/10.22190/FUME210505053B

Baležentis A, Baležentis T, Misiunas A (2012) An integrated assessment of Lithuanian economic sectors based on financial ratios and fuzzy MCDM methods. Technol Econ Dev Econ 18:34–53. https://doi.org/10.3846/20294913.2012.656151

Baydaş M, Elma OE (2021) An objective criteria proposal for the comparison of MCDM and weighting methods in financial performance measurement: an application in Borsa Istanbul. Decis Mak Appl Manag Eng 4:257–279. https://doi.org/10.31181/DMAME210402257B

Baydas M, Pamučar D (2022) Determining objective characteristics of MCDM methods under uncertainty : an exploration study with financial data. Mathematics 10:2–25

Beheshtinia MA, Omidi S (2017) A hybrid MCDM approach for performance evaluation in the banking industry. Kybernetes 46:1386–1407. https://doi.org/10.1108/K-03-2017-0105/FULL/PDF

Bektaş S (2021) ENTROPİ ve MaİrcaYöntemİyle Türk Katilim Bankalarinin Fİnansal Performans Siralamasi. Int J Soc Inq 14:113–144. https://doi.org/10.37093/ijsi.950553

Bhadu J, Kumar P, Bhamu J, Singh D (2021) Lean production performance indicators for medium and small manufacturing enterprises: modelling through analytical hierarchy process. Int J Syst Assur Eng Manag 13:978–997. https://doi.org/10.1007/s13198-021-01375-6

Biswas T, Chatterjee P, Choudhuri B (2020) Selection of commercially available alternative passenger vehicle in automotive environment. Oper Res Eng Sci Theory Appl 3:16–27. https://doi.org/10.31181/ORESTA200113B

Buračas A, Rutkauskas V, Joshi L (2015) Metaeconomics : stochastics & nanotech : new approaches to contemporary reality. LAP Lambert Academic Publishing, Saarbrücken

Chang SC, Tsai PH (2016) A hybrid financial performance evaluation model for wealth management banks following the global financial crisis. Technol Econ Dev Econ 22:21–46. https://doi.org/10.3846/20294913.2014.986771

Chen FH, Hsu TS, Tzeng GH (2011) A balanced scorecard approach to establish a performance evaluation and relationship model for hot spring hotels based on a hybrid MCDM model combining DEMATEL and ANP. Int J Hosp Manag 30:908–932. https://doi.org/10.1016/j.ijhm.2011.02.001

Cheng C-H, Chen C-T, Huang S-F (2012) Combining fuzzy integral with order weight average (OWA) method for evaluating financial performance in the semiconductor industry. Afr J Bus Manage 6:6358–6368. https://doi.org/10.5897/ajbm11.534

Chodha V, Dubey R, Kumar R et al (2022) Selection of industrial arc welding robot with TOPSIS and Entropy MCDM techniques. Mater Today Proc 50:709–715. https://doi.org/10.1016/j.matpr.2021.04.487

Chowdhury P, Paul SK (2020) Applications of MCDM methods in research on corporate sustainability: a systematic literature review. Manag Environ Qual Int J 31:385–405. https://doi.org/10.1108/MEQ-12-2019-0284

Çimen A (2019) The impact of sustainability index on firm performance: an event study. Int J Contemp Econ Adm Sci 9:170–183. https://doi.org/10.5281/zenodo.3262277

Cohen S, Thiraios D, Kandilorou M (2008) Performance parameters interrelations from a balanced scorecard perspective: an analysis of Greek companies. Manag Audit J 23:485–503. https://doi.org/10.1108/02686900810875307

Das MC, Sarkar B, Ray S (2012) Decision making under conflicting environment: a new MCDM method. Int J Appl Decis Sci 5:142–162. https://doi.org/10.1504/IJADS.2012.046505

Davis S, Albright T (2004) An investigation of the effect of Balanced Scorecard implementation of financial performance. Manag Acc Res 15:135–153. https://doi.org/10.1016/j.mar.2003.11.001

Dekker D, Post T (2001) A quasi-concave DEA model with an application for bank branch performance evaluation. Eur J Oper Res 132:296–311. https://doi.org/10.1016/S0377-2217(00)00153-3

Deng Y, Chan FTS, Wu Y, Wang D (2011) A new linguistic MCDM method based on multiple-criterion data fusion. Expert Syst Appl 38:6985–6993. https://doi.org/10.1016/j.eswa.2010.12.016

Dinçer Ö, Altınay A (2020) The effect of declarations of sustainability reports on financial performances of banks in Turkey. https://doi.org/10.20944/PREPRINTS202001.0145.V1

Dong JY, Chen Y, Wan SP (2018) A cosine similarity based QUALIFLEX approach with hesitant fuzzy linguistic term sets for financial performance evaluation. Appl Soft Comput J 69:316–329. https://doi.org/10.1016/j.asoc.2018.04.053
Dukić D, Božanić D, Božani B et al (2022) Selection of unployed aircraft for training of small-range aircraft defense system AHP—TOPSIS optimization methods. Yugoslav J Oper Res 32:389–406. https://doi.org/10.2298/YJOR211125007D
Ecer F (2021) A consolidated MCDM framework for performance assessment of battery electric vehicles based on ranking strategies. Renew Sustain Energy Rev 143:110916. https://doi.org/10.1016/j.rser.2021.110916
Erdoğan NK, Altınırmak S, Karamaşa Ç (2016) Comparison of multi criteria decision making (MCDM) methods with respect to performance of food firms listed in BIST. Copernic J Finance Account 5:67. https://doi.org/10.12775/cjfa.2016.004
Ersoy N (2021) An integrated MCDM approach to evaluate public transportation. In: Administrative economic science and research, theory. pp 157–182
Ertuğrul I, Karakaşoğlu N (2009) Performance evaluation of Turkish cement firms with fuzzy analytic hierarchy process and TOPSIS methods. Expert Syst Appl 36:702–715. https://doi.org/10.1016/j.eswa.2007.10.014
Esbouei SK, Ghadikolaei AS, Antucheviciene J (2014) Using FANP and fuzzy VIKOR for ranking manufacturing companies based on their financial performance. Econ Comput Econ Cybern Stud Res 48:141–162
Estiasih SP, Putra AC (2021) Factors affecting financial performance of pharmaceutical companies listed of Indonesia. Cuad Econ 44:106–115. https://doi.org/10.32826/cude.v1i125.1010
Farrokh M, Heydari H, Janani H (2016) Two comparative MCDM approaches for evaluating the financial performance of Iranian basic metals companies. Iran J Manag Stud 9:359–382
Feizi F, Karbalaei-Ramezanali AA, Farhadi S (2021) FUCOM-MOORA and FUCOM-MOOSRA: new MCDM-based knowledge-driven procedures for mineral potential mapping in greenfields. SN Appl Sci 3:1–19. https://doi.org/10.1007/s42452-021-04342-9
Ghadikolaei AS, Esbouei SK, Antuchevičienė J (2014) Applying fuzzy MCDM for financial performance evaluation of Iranian companies. Technol Econ Dev Econ 20:274–291. https://doi.org/10.3846/20294913.2014.913274
Ghosh S, Bhattacharya M (2022) Analyzing the impact of COVID-19 on the financial performance of the hospitality and tourism industries: an ensemble MCDM approach in the Indian context. Int J Contemp Hosp Manag 34:3113–3142. https://doi.org/10.1108/IJCHM-11-2021-1328/FULL/PDF
Gomes LFAM, Lima MMPP (1992) TODIM: Basics and application to multicriteria ranking of projects with environmental impacts. Found Comput Decis Sci 16:113–127
Grida M, Mohamed R, Zaid AH et al (2020) A novel plithogenic MCDM framework for evaluating the a novel plithogenic MCDM framework for evaluating the performance of IoT based supply chain performance of IoT based supply chain recommended. Neutrosophic Sets Syst 33:2020
Gul M, Ak MF (2020) Assessment of occupational risks from human health and environmental perspectives: a new integrated approach and its application using fuzzy BWM and fuzzy MAIRCA. Springer, Berlin Heidelberg
Ic YT, Celik B, Kavak S, Baki B (2020) Development of a multi-criteria decision-making model for comparing the performance of Turkish commercial banks. J Adv Manag Res 18:250–272. https://doi.org/10.1108/JAMR-05-2020-0083
Iç YT, Yurdakul M, Pehlivan E (2022) Development of a hybrid financial performance measurement model using AHP and DOE methods for Turkish commercial banks. Soft Comput 26:2959–2979. https://doi.org/10.1007/s00500-021-06589-1
Ignatius J, Behzadian M, Malekan HS, Lalitha D (2012) Financial performance of Iran's Automotive sector based on PROMETHEE II. In: 2012 IEEE 6th ınternational conference on management of ınnovation and technology, ICMIT 2012, pp 35–38. https://doi.org/10.1109/ICMIT.2012.6225775
Inani SK, Gupta R (2017) Evaluating financial performance of Indian IT firms: an application of a multi-criteria decision-making technique. Int J Behav Account Finance 6:126. https://doi.org/10.1504/ijbaf.2017.10007498
Islamoglu M, Apan M, Oztel A (2015) An evaluation of the financial performance of REITs in Borsa Istanbul: a case study using the entropy-based TOPSIS method. Int J Financ Res. https://doi.org/10.5430/ijfr.v6n2p124
Javed SA, Gunasekaran A, Mahmoudi A (2022) DGRA: Multi-sourcing and supplier classification through Dynamic Grey Relational Analysis method. Comput Ind Eng 173:108674. https://doi.org/10.1016/J.CIE.2022.108674
Jokić Ž, Božanić D, Pamučar D (2021) Selection of fire position of mortar units using LBWA and Fuzzy MABAC model. Oper Res Eng Sci Theory Appl 4:115–135. https://doi.org/10.31181/ORESTA20401156J
Karaömer Y, Oypan O (2020) Measurement and evaluation of brand value of banks in BIST sustainability ındex: a financial apporach. Bolu Abant İzzet Baysal Univ J Grad School Soc Sci 20:189–202. https://doi.org/10.11616/BASBED.V20I53206.618102
Keskin AI, Dincer B, Dincer C (2020a) Exploring the impact of sustainability on corporate financial performance using discriminant analysis. Sustainability (switzerland). https://doi.org/10.3390/su12062346
Keskin AI, Dincer B, Dincer C (2020b) Exploring the impact of sustainability on corporate financial performance using discriminant analysis. Sustainability 12:2346. https://doi.org/10.3390/SU12062346
Khan A, Maity K (2017) Application of MCDM-based TOPSIS method for the selection of optimal process parameter in turning of pure titanium. Benchmarking 24:2009–2021. https://doi.org/10.1108/BIJ-01-2016-0004
Kiani M, Bagheri M, Ebrahimi A, Alimohammadlou M (2022) A model for prioritizing outsourceable activities in universities through an integrated fuzzy-MCDM method. Int J Constr Manag 22(5):784–800. https://doi.org/10.1080/15623599.2019.1645264
Kılıç M, Gurler HE, Kaya A, Lee CW (2022) the impact of sustainability performance on financial performance: does firm size matter? evidence from Turkey and South Korea. Sustainability 14:16695. https://doi.org/10.3390/su142416695
Kiptum CK, Bouraima MB, Stević Ž, Okemwa S, Birech S, Qiu YJ (2022) Sustainable strategies for the successful operation of the bike-sharing system using an ordinal priority approach. J Eng Manag Syst Eng 1(2):43–50
Knápková A, Homolka L, Pavelková D (2014) Využití balanced scorecard a vliv jeho využívání na finanční výkonnost podniků v ČR. E a M: Ekonomie Manag 17:146–160. https://doi.org/10.15240/tul/001/2014-2-011
Kou G, Peng Y, Wang G (2014) Evaluation of clustering algorithms for financial risk analysis using MCDM methods. Inf Sci 275:1–12. https://doi.org/10.1016/j.ins.2014.02.137

Kou G, Olgu Akdeniz Ö, Dinçer H et al (2021a) Fintech investments in European banks: a hybrid IT2 fuzzy multidimensional decision-making approach. Financ Innov 7:39. https://doi.org/10.1186/s40854-021-00256-y

Kou G, Xu Y, Peng Y, Shen F, Chen Y, Chang K, Kou S (2021b) Bankruptcy prediction for SMEs using transactional data and two-stage multiobjective feature selection. Decis Support Syst 140:113429. https://doi.org/10.1016/j.dss.2020.113429

Kumar V, Kalita K, Chatterjee P et al (2022) A SWARA-CoCoSo-based approach for spray painting robot selection. Informatica (netherlands) 33:35–54. https://doi.org/10.15388/21-INFOR466

Kumaran S (2021) Financial performance index of IPO firms using VIKOR-CRITIC techniques. Financ Res Lett. https://doi.org/10.1016/j.frl.2021.102542

Kung JY, Chuang TN, Ky CM (2011) A fuzzy MCDM method to select the best company based on financial report analysis. In: IEEE ınternational conference on fuzzy systems, vol. 7. pp. 2013–2017. https://doi.org/10.1109/FUZZY.2011.6007679

Lam WS, Lam WH, Jaaman SH, Liew KF (2021) Performance evaluation of construction companies using integrated entropy–fuzzy vikor model. Entropy 23:1–16. https://doi.org/10.3390/e23030320

Lee HC, Chang C (2018) Comparative analysis of MCDM methods for ranking renewable energy sources in Taiwan. Renew Sustain Energy Rev 92:883–896. https://doi.org/10.1016/j.rser.2018.05.007

Lee PTW, Lin CW, Shin SH (2012) A comparative study on financial positions of shipping companies in Taiwan and Korea using entropy and grey relation analysis. Expert Syst Appl 39:5649–5657. https://doi.org/10.1016/j.eswa.2011.11.052

Malek A, Ebrahimnejad S, Tavakkoli-Moghaddam R (2017) An improved hybrid grey relational analysis approach for green resilient supply chain network assessment. Sustainability 9:1433. https://doi.org/10.3390/SU9081433

Mihalovic M (2015) The assessment of corporate financial performance via discriminant analysis. Acta Oeconomica Cassaviensia 8:57–69

Moghimi R, Anvari A (2014) An integrated fuzzy MCDM approach and analysis to evaluate the financial performance of Iranian cement companies. Int J Adv Manuf Technol 71:685–698. https://doi.org/10.1007/s00170-013-5370-6

Muhammad LJ, Badi I, Haruna AA, Mohammed IA (2021) Selecting the best municipal solid waste management techniques in Nigeria using multi criteria decision making techniques. Rep Mech Eng 2:180–189. https://doi.org/10.31181/RME2001021801B

Naderi H, Shahosseini H, Jafari A (2013) Evaluation MCDM multi-disjoint paths selection algorithms using fuzzy-copeland ranking method. Int J Commun Netw Inf Secur (IJCNIS). https://doi.org/10.17762/IJCNIS.V5I1.288

Narang M, Joshi MC, Bisht K, Pal A (2022) Stock portfolio selection using a new decision-making approach based on the integration of fuzzy CoCoSo with Heronian mean operator. Decis Mak Appl Manag Eng 5:90–112. https://doi.org/10.31181/DMAME0310022022N

Narayanamoorthy S, Annapoorani V, Kang D et al (2020) A novel assessment of bio-medical waste disposal methods using integrating weighting approach and hesitant fuzzy MOOSRA. J Clean Prod 275:122587. https://doi.org/10.1016/J.JCLEPRO.2020.122587

Opricovic S (1998) Multicriteria optimization of civil engineering systems. Faculty of Civil Engineering, Belgrade

Opricovic S, Tzeng GH (2004) Compromise solution by MCDM methods: a comparative analysis of VIKOR and TOPSIS. Eur J Oper Res 156:445–455. https://doi.org/10.1016/S0377-2217(03)00020-1

Osintsev N, Rakhmangulov A, Baginova V (2021) Evaluation of logistics flows in green supply chains based on the combined DEMATEL-ANP Method. Facta Univ Ser Mech Eng 19:473–498. https://doi.org/10.22190/FUME210505061O

Öztürk H (2017) Borsa İstanbul'da ŞD/FAVÖK (Şirket Değeri/Faiz, Amortisman ve Vergi Öncesi Kar) ve F/K (Fiyat/ Kazanç) Çarpanları Üzerine Bir Analiz. Maliye Finans Yazıları 87–104

Pala O (2021) BIST İnşaat Endeksinde Bütünleşik CCSD-COCOSO Tabanlı Finansal Performans Analizi. Afyon Kocatepe Üniversitesi Sosyal Bilimler Dergisi 23:1500–1513

Pamučar D, Ćirović G (2015) The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC). Expert Syst Appl 42:3016–3028. https://doi.org/10.1016/J.ESWA.2014.11.057

Pamučar D, Stević Ž, Sremac S (2018) A new model for determiningweight coefficients of criteria in MCDM models: full Consistency Method (FUCOM). Symmetry (basel) 10:1–22. https://doi.org/10.3390/sym10090393

Parkan C (1994) Operational competitiveness ratings of production units. Manag Decis Econ 15:201–221. https://doi.org/10.1002/MDE.4090150303

Peng Y, Kou G, Wang G, Shi Y (2011) FAMCDM: A fusion approach of MCDM methods to rank multiclass classification algorithms. Omega (westport) 39:677–689. https://doi.org/10.1016/j.omega.2011.01.009

Puška A, Štilić A, Stojanović I (2023) Approach for multi-criteria ranking of Balkan countries based on the index of economic freedom. J Decis Anal Intell Comput 3(1):1–14. https://doi.org/10.31181/jdaic10017022023p

Rosenbloom ES (1997) A probabilistic interpretation of the final rankings in AHP. Eur J Oper Res 96:371–378. https://doi.org/10.1016/S0377-2217(96)00049-5

Roy PK, Shaw K (2021) A credit scoring model for SMEs using AHP and TOPSIS. Int J Finance Econ. https://doi.org/10.1002/ijfe.2425

Saaty TL, Ergu D (2016) When is a decision-making method trustworthy? Criteria Eval Multi-Criteria Decis Mak Methods 14:1171–1187. https://doi.org/10.1142/S021962201550025X

Şahin Z, Yılmaz Z, Çankaya F (2017) Sustainability reporting and performances of the companies in the istanbul stock exchange sustainability index. Int J Soc Behav Educ Bus Ind Eng 11:343–354

Sarkar A, Panja SC, Das D, Sarkar B (2015) Developing an efficient decision support system for non-traditional machine selection: an application of MOORA and MOOSRA. Prod Manuf Res 3:324–342. https://doi.org/10.1080/21693277.2014.895688

Shaverdi M, Ramezani I, Tahmasebi R, Rostamy AAA (2016) Combining fuzzy AHP and fuzzy TOPSIS with financial ratios to design a novel performance evaluation model. Int J Fuzzy Syst 18:248–262. https://doi.org/10.1007/s40815-016-0142-8

Shen KY, Tzeng GH (2015) A decision rule-based soft computing model for supporting financial performance improvement of the banking industry. Soft Comput 19:859–874. https://doi.org/10.1007/s00500-014-1413-7
Shen KY, Yan MR, Tzeng GH (2017) Exploring R and D influences on financial performance for business sustainability considering dual profitability objectives. Sustainability (switzerland). https://doi.org/10.3390/su9111964
Stević Ž, Brković N (2020) A novel integrated FUCOM-MARCOS model for evaluation of human resources in a transport company. Logistics 4:4. https://doi.org/10.3390/logistics4010004
Sun R, Hu J, Zhou J, Chen X (2018) A hesitant fuzzy linguistic projection-based MABAC method for patients' prioritization. Int J Fuzzy Syst 20:2144–2160. https://doi.org/10.1007/S40815-017-0345-7/TABLES/7
Tavana M, Khalili-Damghani K, Rahmatian R (2015) A hybrid fuzzy MCDM method for measuring the performance of publicly held pharmaceutical companies. Ann Oper Res 226:589–621. https://doi.org/10.1007/s10479-014-1738-8
Thakur DV (2022) Locating temporary waste treatment facilities in the cities to handle the explosive growth of HCWs during pandemics: a novel Grey-AHP-OCRA hybrid approach. Sustain Cities Soc 82:103907. https://doi.org/10.1016/J.SCS.2022.103907
Topal A (2021) Çok kriterli karar verme analizi ile elektrik üretim şirketlerinin finansal performans analizi: Entropi tabanlı Cocoso yöntemi. Bus Manag Stud Int J 9:532–546. https://doi.org/10.15295/bmij.v9i2.1794
Tsolas IE (2020) Financial performance assessment of construction firms by means of RAM-Based composite indicators. Mathematics. https://doi.org/10.3390/MATH8081347
Ulutaş A, Popovic G, Radanov P et al (2021) A new hybrid fuzzy psi-piprecia-cocoso mcdm based approach to solving the transportation company selection problem. Technol Econ Dev Econ 27:1227–1249. https://doi.org/10.3846/tede.2021.15058
Varmazyar M, Dehghanbaghi M, Afkhami M (2016) A novel hybrid MCDM model for performance evaluation of research and technology organizations based on BSC approach. Eval Program Plann 58:125–140. https://doi.org/10.1016/J.EVALPROGPLAN.2016.06.005
Visalakshmi S, Lakshmi P, Shama MS, Vijayakumar K (2015) An integrated fuzzy DEMATEL-TOPSIS approach for financial performance evaluation of GREENEX industries. Int J Oper Res 23:340–362. https://doi.org/10.1504/IJOR.2015.069626
Wang YJ (2008) Applying FMCDM to evaluate financial performance of domestic airlines in Taiwan. Expert Syst Appl 34:1837–1845. https://doi.org/10.1016/j.eswa.2007.02.029
Wanke P, Kalam Azad MA, Barros CP, Hadi-Vencheh A (2016) Predicting performance in ASEAN banks: an integrated fuzzy MCDM–neural network approach. Expert Syst 33:213–229. https://doi.org/10.1111/exsy.12144
Wu HY, Tzeng GH, Chen YH (2009) A fuzzy MCDM approach for evaluating banking performance based on Balanced Scorecard. Expert Syst Appl 36:10135–10147. https://doi.org/10.1016/j.eswa.2009.01.005
Wu Q, Liu X, Qin J et al (2022) Knowledge-Based Systems An integrated generalized TODIM model for portfolio selection based on financial performance of firms. Knowl Based Syst 249:1–18. https://doi.org/10.1016/j.knosys.2022.108794
Xiao H, Zhang Y, Kou G, Zhang S, Branke J (2023) Ranking and selection for pairwise comparison. Nav Res Logist. https://doi.org/10.1002/nav.22093
Yalcin N, Bayrakdaroglu A, Kahraman C (2012) Application of fuzzy multi-criteria decision making methods for financial performance evaluation of Turkish manufacturing industries. Expert Syst Appl 39:350–364. https://doi.org/10.1016/j.eswa.2011.07.024
Yalçın N, Bayrakdaroğlu A (2012) Strategic financial performance evaluation of the Turkish companies traded on ISE. Ege Akademik Bakis (ege Academic Review) 12:529. https://doi.org/10.21121/eab.2012419514
Yalçın N, Ünlü U (2018) A multi-criteria performance analysis of initial public offering (IPO) firms using critic and vikor methods. Technol Econ Dev Econ 24:534–560. https://doi.org/10.3846/20294913.2016.1213201

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.