Knowledge and Decision Systems with Applications

www.kadsa.org
eISSN: 3079-6318

Evaluating Financial Performance with SPC-LOPCOW-MARCOS Hybrid Methodology: A Case Study for Firms Listed in BIST Sustainability Index

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ARTICLE INFO

Article history:
Received 24 February 2025
Received in revised form 26 March 2025
Accepted 29 March 2025
Available online 30 March 2025

Keywords:
Financial Performance; Real Sector Firms; SPC; LOPCOW;MARCOS

ABSTRACT

Periodic analysis of financial performance is instrumental in enabling manufacturing firms to enhance their operational efficiency, manage risks effectively, make strategic decisions, maintain a competitive advantage, ensure sustainability, and promote good corporate governance. This research introduces an innovative decision-making methodology for evaluating and ranking the financial performance of firms by utilizing financial ratio metrics. To this end, the present study puts forward a novel decision-making methodology for evaluating the performance of a corporation, integrating the Symmetry Point Criterion (SPC), the Logarithmic Percentage Change Based Objective Weighting (LOPCOW), and the Measurement of Alternatives and Ranking by Consensus Solution (MARCOS). The feasibility of the proposed decision approach in the existing work is evaluated through a real-time case study. The case analysis concentrates on the financial performance assessment of 16 real sector firms whose shares are traded in the Borsa Istanbul (BIST) Sustainability 25 Index (XSD25). In order to examine the financial performance of firms in the real sector, ten financial performance indicators are selected based on earlier literature. The SPC and LOPCOW procedures were applied to ascertain the weight values of the assessment indicators, and the MARCOS procedure was employed to rank the firms' financial performance. The findings of the weighting process indicate that the three most influential criteria are the ratio of total debt to total equity, the return on equity, and the average price-earnings ratio. According to the MARCOS ranking procedure, ENKAI was the company with the highest financial performance compared to its peers during the analysis period.

1. Introduction

Evaluating the performance of firms is crucial for sustaining their activities, gaining a competitive advantage in the sector, fostering growth, and successfully completing operations. In today's globalized and highly competitive business environment, assessing firm performance is vital not only for managers, credit institutions, financial analysts, and current or potential investors but also for the development of national economies and ensuring sustainable growth [1].

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http://www.doi.org/10.59543/kadsa.v1i.13879

Analyzing firm performance is a comprehensive process that involves considering various performance measures, including economic, financial, and managerial aspects. This analysis provides valuable insights to both internal and external stakeholders on operational efficiency, profitability, leverage, and market performance [2]. From an economic perspective, firms can promote sustainable economic growth by making investment decisions that boost economic activity and create jobs. Strong financial performance can further contribute to national economic development by attracting more investment, enhancing the quality of economic activities, and supporting job creation [3].

For a firm, analyzing financial performance is also crucial in implementing and guiding corporate governance policies [4]. An effective corporate governance mechanism helps minimize agency problems and maximize the value for the firm's stakeholders. This, in turn, enhances overall firm performance by ensuring that the firm's operations are efficient, transparent, and aligned with the interests of all stakeholders [5]. On the other hand, Financial performance measurements across various sectors provide decision-making mechanisms with valuable data for effectively managing market risks [6]. Objective data obtained from financial analysis plays a critical role in predicting potential losses and vulnerabilities, identifying operational inefficiencies, and taking corrective actions for failed financial management processes. This proactive approach to risk management not only protects the firm's assets and resources but also enhances its resilience in the face of economic uncertainty [7]. Consequently, financial performance measurement serves as a fundamental tool for determining operational efficiency, improving strategic decision-making processes, and promoting corporate governance policies [8].

In today's rapidly globalizing world, the continuous development of technology, economic uncertainty, and various market dynamics have made financial performance measurement a critical requirement for firms across all sectors. Assessing financial performance and evaluating the objective results of these assessments are essential for firms to gain a competitive advantage in financial markets and their respective industries, as well as to maintain stable operations. Therefore, this study aims to present a new integrated decision methodology to address the challenge of evaluating financial performance in firms. The developed methodology integrates the SPC, LOPCOW, and MARCOS procedures. The SPC and LOPCOW models are employed to objectively weight the financial assessment metrics, while MARCOS is utilized to rank the alternative firms. To test the introduced MCDM framework and demonstrate its applicability, a real-time case study was conducted. This case analysis focused on the financial performance of 16 real sector firms whose stocks are listed in the BIST-XSD25 index.

The presented methodology aims at integrating the SPC-LOPCOW and MARCOS procedures. Of these, SPC and LOPCOW are utilized to objectively weight the financial assessment criteria, while MARCOS is utilized to rank the chosen decision alternatives. In order to test the proposed conceptual framework and demonstrate its applicability, a real-time case study was conducted in the study. In this case analysis, the financial performance of 16 real sector firms whose stocks are listed in the BIST - XSD25 index for the year 2023 has been preferred as the sample in the current study. All in all, the current work makes significant contributions to the existing body of literature. Firstly, it utilizes the BIST - XSD25 index as a sample for the first time, providing novel insights into this specific market segment. Secondly, the study employs the MARCOS methodology, integrated with the SPC and LOPCOW methods, to evaluate the sample, marking a pioneering application of these combined techniques. Lastly, the study introduces an alternative set of evaluation criteria for assessing corporate financial performance, offering a new framework for researchers and decision-makers to enhance the robustness and comprehensiveness of financial performance analysis.

The remainder of this study is structured as follows: The second section provides a comprehensive literature review. The third section elaborates on the methodology underpinning the conceptual framework presented in the study. The fourth section presents the results derived from the application of the proposed decision framework. The fifth section covers sensitivity analysis. The sixth section discusses policy recommendations, while the final section discusses the findings and offers recommendations for future research and practice.

1.1 Literature Review

There are many empirical studies in the literature that focus on gauging and assessing firm performance employing MCDM approaches. Some of them are examined in Table 1. Based on a detailed review of the studies in the literature, 3 critical research gaps were identified. As can be seen from Table 1, there is no research in the literature conducted for manufacturing companies included in the BIST Sustainability Index. In addition, the pervious works in the literature have conducted financial performance analyses with diverse criteria sets. Finally, the SPC-LOPCOW-MARCOS hybrid model was not employed in these studies. The aim of this research is to fill the three research gaps mentioned thanks to the sample taken and the introduced hybrid methodology.

Table 1 Literature Review

Study	Weighting Procedure	Ranking Procedure	Period	Sample Used
Lee *et al.*, [9]	Entropy	GIA	1999-2009	The performance of 4 firms in the manufacturing sector operating in Taiwan and Korea is examined.
Yalcin *et al.*, [10]	AHP-F	TOPSIS and VIKOR	2007	The financial performance of manufacturing firms whose stocks are listed in BIST is examined.
Esbouei ve Ghadikolaei [11]	AHP-F	COPRAS	2002-2011	The study analyses the financial performance of 10 manufacturing firms operating in Iran.
Esbouei *et al.*, [12]	ANP-F	VIKOR-F	2011	The analyses compared the financial performance of 143 manufacturing firms listed on the Tehran Stock Exchange.
Safaei Ghadikolaei *et al.*, [13]	AHP-F	VIKOR-F, ARAS-F and COPRAS-F	2002-2011	The real sector firms listed on the Tehran Stock Exchange and manufacturing automotive parts are evaluated and ranked in terms of their performance.
Shaverdi *et al.*, [14]	AHP-F	TOPSIS-F	2003-2013	The performance of 7 manufacturing firms operating in the petrochemical sector in Iran was analyzed.
Anthony *et al.*, [15]	Entropy	TOPSIS, COPRAS and DEA	2010-2018	It examines the performance of 7 manufacturing firms in the Indian chemical industry.
Akbulut [16]	CRITIC	MABAC	2014-2018	The relationship between financial performance and stock returns of 18 firms in the BIST cement sector is empirically examined.

Weerathunga *et al.,* [17]	Entropy	TOPSIS	2017-2018	The sustainability performance of 25 hotel companies listed on the Colombian Stock Exchange was compared.
Akbulut and Hepşen [1]	Entropy	CoCoSo	2015-2019	This study focuses on the relationship between financial performance and stock returns of 27 real sector firms operating in the BIST chemicals, petroleum, rubber and plastic products sector.
Ersoy [18]	LOPCOW	RSMVC	2017-2021	This study examines the financial performance of 11 firms whose shares are listed in the BIST retail sector.
Yavuz and Sönmez [19]	CRITIC and Entropy	MABAC	2019-2021	The financial performance of the firms traded in the BIST Corporate Governance Index has been researched.
Bozdoğan *et al.,* [20]	CRITIC	TOPSIS and ELECTRE	2013-2022	The financial performance of 15 cement firms operating in the BIST was evaluated.
Çokmutlu and Abdullayev [21]	CRITIC	CoCoSo and COPRAS	2018-2022	The financial performance of 17 firms traded in the BIST technology index is considered within the scope of the analyses.
Avcı and Ergen [22]	MEREC	MAIRCA	2023	A comparison was made of the performance of 24 firms from the energy sector on the Fortune 500 list.
Akpınar and Karyağdı [23]	CRITIC	TOPSIS	2021-2023	It examines the financial performance of 13 companies with shares listed in the BIST construction and cement industry.

A detailed examination of the previous studies in Table 1 reveals two critical research gaps. The first research gap is related to the lack of a generally accepted or applied set of criteria for financial performance measurement in the previous literature. To fill this gap, the present study proposes an alternative set of criteria for financial performance evaluation, consisting of both accounting-based and market-based financial measures. The second important gap is related to the applied methodology. Previous studies have mostly applied AHP, CRITIC, TOPSIS, MAIRCA, CoCoSo and COPRAS algorithms, whose limitations or structural problems are frequently discussed in the literature. In order to fill this gap, the present study proposes an integrated decision methodology consisting of SPC, LOPCOW and MARCOS procedures. Furthermore, the suggested decision-making approach will be applied to a case study focusing on financial performance analysis for the first time in the literature.

2. Methodological Framework

This section details the proposed decision framework, namely the SPC-LOPCOW-MARCOS hybrid technique, to solve the financial performance evaluation problem for manufacturing firms operating in the BIST sustainability industry. The significance levels of financial assessment metrics are weighted based on two diverse objective weighting methodologies (i.e., SPC and LOPCOW). Next, the findings from the two criteria weighting approaches are integrated to compute the final importance weights of the financial ratio metrics. Following the calculation of the final weight values, the

MARCOS approach is presented for ranking firms according to their financial performance. The framework of the model proposed in this study is shown in Figure 1.

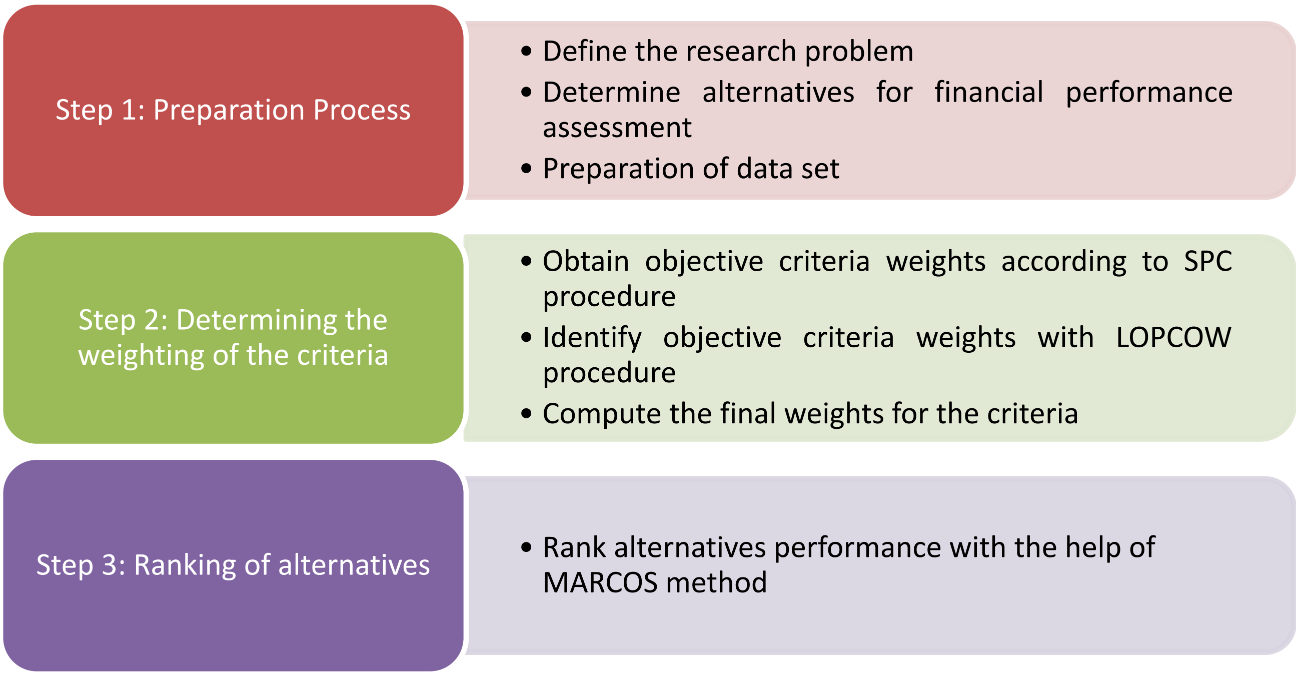

Figure 1 Proposed Decision-Making Methodology

2.1 SPC Objective Weighting Procedure

SPC procedure was introduced to the literature by Gligorić *et al.,* [24], and is utilized in the process of objectively determining the weighting coefficients of the assessment criteria. This procedure differs from other weighting approaches in that it allows calculations to be made taking into account the points of symmetry of the assessment criteria. The SPC weighting has several advantages that make it a valuable method in MCDM, particularly in financial performance evaluation. These advantages can be listed as follows: (i) SPC considers the distribution of criteria values and assigns weights based on their statistical properties, ensuring a fair and balanced weighting scheme, (ii) Unlike subjective weighting methods (e.g., AHP, expert-based weighting), SPC relies entirely on data-driven calculations, eliminating biases in the weighting process, (iii) The method ensures that criteria with similar statistical significance receive proportionate weights, preventing overemphasis on outliers or extreme values, (iv) Particularly useful in financial performance evaluation, SPC helps determine the importance of various financial indicators (e.g., liquidity, profitability, leverage) in a structured and unbiased manner, (v) SPC can be effectively integrated with ranking methods like MARCOS, TOPSIS, or VIKOR, enhancing the robustness of decision-making frameworks, and (vi) The mathematical foundation of SPC makes the weighting process clear and easily interpretable, improving the transparency and credibility of financial performance assessments.

This method and its extensions have been successfully integrated into the solution process of problems such as assessment of Biofuel industry sustainability factors [25], woodworking machinery selection [26], performance measurement of social movements [27], and sustainable benchmarking of e-scooter micromobility systems [28]. The application process of the SPC methodology consists of the following 6 steps;

Step 1. To solve the decision problem according to the SPC procedure, initial decision matrix is obtained according to Eq. (1).

$$DM = \left|x_{ij}\right|_{m\times n} = \begin{vmatrix} A/C & C_1 & C_2 & \cdots & C_n \\ A_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{vmatrix} \tag{1}$$

Step 2. The symmetry points for the criteria are determined from Eq. (2).

$$SPC_j = \frac{min\{x_{ij}\}+max\{x_{ij}\}}{2} \tag{2}$$

Step 3. The absolute distance matrix is derived from Eq. (3).

$$D = \left|\left|d_{ij}\right|\right|_{m\times n} = \begin{vmatrix} |x_{11}-SPC_1| & |x_{12}-SPC_2| & \cdots & |x_{1n}-SPC_n| \\ |x_{21}-SPC_1| & |x_{22}-SPC_2| & \cdots & |x_{2n}-SPC_n| \\ \vdots & \vdots & \ddots & \vdots \\ |x_{m1}-SPC_1| & |x_{m2}-SPC_2| & \cdots & |x_{mn}-SPC_n| \end{vmatrix} \tag{3}$$

Step 4. The symmetric module matrix is obtain by Eq. (4).

$$R = \left|\left|r_{ij}\right|\right|_{m\times n} = \begin{vmatrix} \left|\frac{\frac{\sum_{i=1}^{m} d_{i1}}{m}}{x_{11}}\right| & \left|\frac{\frac{\sum_{i=1}^{m} d_{i2}}{m}}{x_{12}}\right| & \cdots & \left|\frac{\frac{\sum_{i=1}^{m} d_{in}}{m}}{x_{1n}}\right| \\ \left|\frac{\frac{\sum_{i=1}^{m} d_{i1}}{m}}{x_{21}}\right| & \left|\frac{\frac{\sum_{i=1}^{m} d_{i2}}{m}}{x_{22}}\right| & \cdots & \left|\frac{\frac{\sum_{i=1}^{m} d_{in}}{m}}{x_{2n}}\right| \\ \vdots & \vdots & & \vdots \\ \left|\frac{\frac{\sum_{i=1}^{m} d_{i1}}{m}}{x_{m1}}\right| & \left|\frac{\frac{\sum_{i=1}^{m} d_{i2}}{m}}{x_{m2}}\right| & \ddots \cdots & \left|\frac{\frac{\sum_{i=1}^{m} d_{in}}{m}}{x_{mn}}\right| \end{vmatrix} \tag{4}$$

Step 5. At this step, a vector matrix is created by means of the symmetric module matrix in Eq. (5).

$$Q_j = \left|\frac{\sum_{i=1}^{m} r_{ij}}{m}\right| \tag{5}$$

Step 6. The objective weighting coefficients of the criteria are calculated in the final stage of the SPC procedure by means of Eq. (6).

$$w_j = \frac{Q_j}{\sum_{j=1}^{n} Q_j};\ \sum_{j=1}^{n} w_j = 1 \tag{6}$$

2.2 LOPCOW Objective Weighting Procedure

LOPCOW introduced by Ecer and Pamucar [29] is another objective weight determination technique. The advantages of the LOPCOW procedure are as follows: (i) It measures logarithmic percentage changes in criteria values, ensuring that criteria with greater relative variability receive higher weights. This makes it highly effective in capturing the significance of financial ratios, (ii) Unlike subjective weighting methods (e.g., AHP, BWM), it determines weights purely from data, eliminating biases and expert judgment inconsistencies, (iii) Logarithmic transformation reduces the dominance of criteria with large numerical ranges, ensuring that all financial indicators contribute meaningfully to the decision-making process, (iv) Since LOPCOW considers relative percentage changes rather than raw data values, it mitigates the influence of extreme outliers, making the weighting process more stable, and (v) The mathematical formulation of LOPCOW is clear and reproducible, making it easier for decision-makers and analysts to validate and interpret results.

LOPCOW and its extensions have been successfully implemented in various areas such as evaluating the influence of Covid-19 on performance of firms [30], analyzing the relationship between premium production and financial performance in insurance industry [31], identifying the most efficient natural fibre [32], assessing urban competitiveness [33], and warehouse site selection [34]. The application of the LOPCOW procedure includes 4 steps.

Step 1. Initial matrix is prepared as indicated in Eq. (1).
Step 2. Normalization process is carried out by consideration of the attributes of the performance indicators. In this, Eq. (7) is employed for beneficial criteria and Eq. (8) for non-beneficial criteria.

$$r_{ij} = \frac{x_{ij-min_{ij}}}{mak_{ij}-min_{ij}} \tag{7}$$

$$r_{ij} = \frac{mak_{ij}-x_{ij}}{mak_{ij}-min_{ij}} \tag{8}$$

Step 3. The percentage values for the criterion are calculated by means of Eq. (9).

$$PV_{ij} = \left| ln \left[\frac{\sqrt{\frac{\sum_{i=1}^{n} r_{ij}^2}{n}}}{\sigma} \right] \right| \times 100 \tag{9}$$

Step 4. In the final step of the procedure, objective criterion weights are obtained by applying Eq. (10).

$$w_j = \frac{PV_{ij}}{\sum_{j=1}^{m} PV_{ij}};\ \sum_{j=1}^{n} w_j = 1 \tag{10}$$

2.3 Final Weighting Procedure

The criteria weights obtained from SPC and LOPCOW procedures were combined with Eq. (11) to estimate the final weight values for the criteria [35], [36].

$$w_j^{FINAL} = \frac{w_j^{SPC} \times w_j^{LOPCOW}}{\sum_{j=1}^{n} w_j^{SPC} \times w_j^{LOPCOW}} \tag{11}$$

2.4 MARCOS Ranking Procedure

MARCOS procedure was introduced to literature by Stevic *et al.,* [37]. According to this methodology, the best decision alternative is the one that is closest to the ideal and the one that is distant from the anti-ideal. The MARCOS algorithm offers several advantages in MCDM, making it particularly effective for financial performance assessment. These advantages are as follows: (i) It evaluates alternatives based on their relative closeness to both the ideal (best) and anti-ideal (worst) solutions, ensuring a more comprehensive ranking process, (ii) By incorporating direct, normalized, and utility-based approaches, it generates rankings that are more stable and reliable compared to traditional MCDM methods like TOPSIS or VIKOR, (iii) It ranks alternatives using relative utility functions, which provide better differentiation between close-performing alternatives, (iv) Unlike traditional distance-based MCDM models, it takes into account the entire decision matrix, leading to more holistic and informed decision-making, (v) Since it considers both positive and negative ideal solutions, the method is less sensitive to minor fluctuations in input data compared to other MCDM techniques, (vi) It ensures that the final rankings reflect a broad consensus among multiple criteria, leading to more balanced and justifiable decision outcomes. In the literature, MARCOS methodology and its extensions have been successfully applied to solve various decision making problems such as selection of project management software in human resources [38], analysis of renewable energy sources [39], comparison of passenger transport systems [40], bank performance assessment [35], and assessing insurers' performance [41], selection of a dump truck [42], and road traffic risk analysis [43]. The implementation of the MARCOS procedure consists of 7 steps.

Step 1. The initial matrix introduced in Eq. (1) is prepared.

Step 2. Ideal (AI) and anti-ideal (AAI) solution points of decision alternatives are calculated according to criteria attributes with the help of Eqs. (12-13).

$$AI = \max_i x_{ij} \ \ if\ j \in beneficial\ criteria\ and\ \min_i x_{ij} \ \ if\ j \in non-beneficial\ criteria \tag{12}$$

$$AAI = \min_i x_{ij} \ \ if\ j \in beneficial\ criteria\ \ and\ \max_i x_{ij} \ \ if\ j \in non-beneficial\ criteria \tag{13}$$

Step 3. The criteria are normalized by applying Eq. (14) for the beneficial criteria and Eq. (15) for the non-beneficial criteria.

$$n_{ij} = \frac{x_{ij}}{x_{AI}} \tag{14}$$

$$n_{ij} = \frac{x_{AII}}{x_{ij}} \tag{15}$$

Step 4. Weighted normalized matrix is created through Eq. (16).

$$v_{ij} = n_{ij} \times w_j \tag{16}$$

Step 5. The degree of utility for each alternative is calculated from Eq. (17) and Eq. (18).

$$K_i^- = \frac{S_i}{S_{AII}} \tag{17}$$

$$K_i^+ = \frac{S_i}{S_{AI}} \tag{18}$$

Where, S_i (1, 2, ...m) refers to the weighted matrix sums for the alternatives as shown in Eq. (19).

$$S_i = \sum_{i=1}^{n} v_{ij} \tag{19}$$

Step 6. At this step, the utility functions of the alternatives are calculated according to Eq. (20).

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}} \tag{20}$$

The values of $f(K_i^+)$ and $f(K_i^-)$ indicate the utility functions with respect to the anti-ideal and ideal solution points. These functions are obtained by Eqs. (21-22).

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \tag{21}$$

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \tag{22}$$

Step 7. In the last stage, the alternatives are ranked by considering the final values of the utility function. The alternative with the highest utility function is considered the most successful.

3. Sample, Data, and Findings

The aim of this research is to present a new integrated MCDM framework for financial performance analysis in firms. In order to implement and test the presented financial performance assessment methodology, a case study has been executed within the framework of the research. This case analysis is based on 16 firms (R1-AEFES, R2-ARCLK, R3-BIMAS, R4-CIMSA, R5-DOAS, R6-ENJSA, R7-ENKAI, R8-EREGL, R9-FROTO, R10-MAVI, R11-MGROS, R12- PETKM, R13-SISE, R14-TOASO, R15-TUPRS, R16-ULKER) focused on the comparative assessment of the performance of real sector firms. The BIST-XSD25 index, which will be published from 21 November 2022, is an index composed of the firms with the best sustainability performance and the most liquid firms. The main reason for limiting the study to 2023 is therefore the introduction of the index in 2022. As 9 of the firms in the index are not manufacturing firms (3 airlines, 3 banks, 2 holding firms and 1 IT company), they are not included in the analyses. In order to analyses the performance of the real sector firms covered by the analyses, 10 assessment criteria were chosen on the basis of previous literature. The data for the assessment criteria were obtained from Bloomberg Data Terminal. Table 2 provides information on the chosen performance criteria.

Table 2 Chosen Performance Criteria

Criteria	Code	Qualification
Current Ratio	I1	Max
Cash Ratio	I2	Max
Total Debt / Total Assets	I3	Min
Total Debt / Total Equity	I4	Min
Return on Equity	I5	Max
Return on Assets	I6	Max
Average Price Earnings Ratio	I7	Max
Market Value / Book Value	I8	Max
Tobin's Q Ratio	I9	Max
Total Asset Turnover Rate	I10	Max

3.1 The Results of SPC Procedure

The analysis process is started with the determination of weighting coefficients based on the SPC methodology. In the first step of the SPC procedure, the decision matrix given in Table 3 is obtained according to Eq. (1).

Table 3 Decision Matrix

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
R1	1.1482	0.5306	0.2268	0.4631	0.3428	0.0830	0.0324	0.1627	1.0636	0.2969
R2	1.2433	0.3541	0.3948	1.7109	0.1447	0.0313	0.1270	0.1772	1.1304	0.6743
R3	1.0071	0.1292	0.1508	0.3203	0.2434	0.1126	0.0759	0.3872	1.7662	1.7641
R4	1.3615	0.7105	0.2253	0.3690	0.2052	0.0997	0.0639	0.1149	1.2391	0.3643
R5	1.8004	0.4825	0.1588	0.2576	0.5406	0.3341	0.0283	0.1434	1.2240	1.4365
R6	0.8476	0.2179	0.2594	0.5930	0.0775	0.0350	0.0232	0.6563	0.9698	1.0492
R7	2.8503	2.1372	0.0130	0.0164	0.1008	0.0776	0.9319	0.0955	0.9579	0.1584
R8	1.5065	0.2891	0.2185	0.3537	0.0267	0.0166	0.0774	0.2115	0.8623	0.4181
R9	1.0939	0.1617	0.3491	1.0376	0.7903	0.2507	0.0907	0.3177	1.8594	1.4175
R10	1.2699	0.6067	0.2371	0.6634	0.6110	0.1979	0.1824	0.2598	1.4225	0.5787
R11	0.8436	0.2855	0.1115	0.2833	0.2782	0.1016	0.0507	0.1418	1.2673	1.5070
R12	0.7601	0.1622	0.3183	0.5934	0.1546	0.0743	0.0625	0.2757	0.9479	0.5781
R13	1.6915	0.6722	0.2928	0.5102	0.1201	0.0590	0.0600	0.1425	0.9931	0.3191
R14	1.7012	0.6989	0.1504	0.3208	0.4809	0.1979	0.1210	0.2943	1.8659	1.1696
R15	1.2955	0.6313	0.0963	0.1741	0.2830	0.1500	0.0334	0.1120	1.2038	1.4265
R16	2.3944	0.7549	0.1588	0.4939	0.2252	0.0529	0.1814	0.2334	1.1990	0.5891

Symmetry points of the criteria were identified by means of Eq. (2). The results of the symmetry points are displayed in Table 4

Table 4 Symmetry Points

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
$\mathbf{SPC_j}$	1.8052	1.1332	0.2039	0.8637	0.4085	0.1754	0.4776	0.3759	1.3641	0.9612

Absolute distance matrix obtained from Eq. (3) is shown in Table 5.

Table 5 Absolute Distance Matrix

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
R1	0.6570	0.6026	0.0229	0.4006	0.0657	0.0924	0.4452	0.2132	0.3005	0.6643
R2	0.5619	0.7791	0.1909	0.8473	0.2638	0.1441	0.3506	0.1987	0.2337	0.2869
R3	0.7981	1.0040	0.0531	0.5434	0.1651	0.0628	0.4017	0.0113	0.4021	0.8029
R4	0.4437	0.4227	0.0214	0.4947	0.2033	0.0757	0.4137	0.2610	0.1250	0.5969
R5	0.0048	0.6507	0.0450	0.6061	0.1321	0.1587	0.4493	0.2325	0.1401	0.4753
R6	0.9576	0.9153	0.0555	0.2707	0.3310	0.1404	0.4543	0.2804	0.3943	0.0880
R7	1.0451	1.0040	0.1909	0.8473	0.3077	0.0978	0.4543	0.2804	0.4062	0.8029
R8	0.2987	0.8441	0.0146	0.5100	0.3818	0.1587	0.4002	0.1644	0.5018	0.5431
R9	0.7113	0.9715	0.1452	0.1740	0.3818	0.0754	0.3869	0.0582	0.4953	0.4562
R10	0.5353	0.5265	0.0332	0.2003	0.2025	0.0225	0.2952	0.1161	0.0584	0.3826
R11	0.9616	0.8477	0.0924	0.5804	0.1302	0.0737	0.4269	0.2341	0.0968	0.5458
R12	1.0451	0.9710	0.1145	0.2703	0.2539	0.1011	0.4151	0.1002	0.4162	0.3831
R13	0.1137	0.4610	0.0890	0.3534	0.2884	0.1164	0.4176	0.2334	0.3710	0.6421
R14	0.1040	0.4343	0.0535	0.5429	0.0724	0.0225	0.3565	0.0816	0.5018	0.2084
R15	0.5097	0.5019	0.1076	0.6896	0.1255	0.0254	0.4442	0.2639	0.1603	0.4652
R16	0.5892	0.3783	0.0451	0.3697	0.1833	0.1225	0.2962	0.1425	0.1651	0.3722

At this stage, the symmetric module matrix is obtained by use of Eq. (4). The findings obtained as a result of the calculations carried out for the relevant matrix are reported in Table 6.

Table 6 Symmetric Module Matrix

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
R1	0.5082	1.3328	0.3513	1.0392	0.6359	1.1226	12.3575	1.1029	0.2802	1.6242
R2	0.4694	1.9971	0.2018	0.2813	1.5065	2.9792	3.1535	1.0130	0.2637	0.7152
R3	0.5794	5.4734	0.5283	1.5026	0.8957	0.8270	5.2770	0.4636	0.1687	0.2734
R4	0.4286	0.9953	0.3537	1.3044	1.0626	0.9344	6.2646	1.5615	0.2405	1.3237
R5	0.3241	1.4656	0.5015	1.8682	0.4033	0.2787	14.1428	1.2515	0.2435	0.3357
R6	0.6885	3.2454	0.3072	0.8116	2.8141	2.6618	17.2309	0.2735	0.3073	0.4596
R7	0.2047	0.3309	6.1514	29.3233	2.1628	1.2002	0.4297	1.8790	0.3111	3.0450
R8	0.3874	2.4461	0.3646	1.3608	8.1585	5.5988	5.1731	0.8488	0.3456	1.1534
R9	0.5335	4.3733	0.2282	0.4638	0.2759	0.3714	4.4151	0.5650	0.1603	0.3402
R10	0.4595	1.1656	0.3360	0.7255	0.3568	0.4706	2.1958	0.6908	0.2095	0.8334
R11	0.6917	2.4769	0.7147	1.6990	0.7836	0.9164	7.8965	1.2658	0.2352	0.3200
R12	0.7677	4.3599	0.2503	0.8111	1.4105	1.2541	6.4127	0.6510	0.3144	0.8341
R13	0.3450	1.0520	0.2721	0.9432	1.8156	1.5780	6.6753	1.2599	0.3001	1.5111
R14	0.3430	1.0118	0.5297	1.5003	0.4534	0.4707	3.3086	0.6098	0.1597	0.4123
R15	0.4504	1.1202	0.8272	2.7649	0.7704	0.6210	11.9850	1.6027	0.2476	0.3381
R16	0.2437	0.9368	0.5016	0.9744	0.9681	1.7604	2.2075	0.7690	0.2486	0.8187

In the final step of the SPC procedure, the values for the vectorial matrix (ϱ_j) were first determined using Eq. (5). Following this, the objective weighting coefficients (w_j) for the criteria were determined via Eq. (6). The results of the calculations are presented in Table 7.

Table 7 Results of SPC Procedure

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
Q_j	0.4641	2.1114	0.7762	2.9608	1.5296	1.4403	6.8204	0.9880	0.2523	0.8961
w_j	0.0254	0.1158	0.0426	0.1623	0.0839	0.0790	0.3739	0.0542	0.0138	0.0491
Rank	9	3	8	2	4	5	1	6	10	7

3.2 The Results of LOPCOW Procedure

In the second stage of the assessment process, the objective importance weights of the criteria were arrived at by applying the LOPCOW methodology. In the first step of the LOPCOW procedure, the initial matrix created according to Eq. (1) and shown in Table 3 is generated. The initial matrix prepared according to Eq. (1) is then normalized according to Eqs. (7-8). The findings related to the normalized matrix are shown in Table 8.

Table 8 Normalized Matrix

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
R1	0.1857	0.1999	0.4400	0.7364	0.4140	0.2089	0.0101	0.1199	0.2006	0.0863
R2	0.2312	0.1120	0.0000	0.0000	0.1545	0.0461	0.1142	0.1456	0.2671	0.3213
R3	0.1182	0.0000	0.6390	0.8207	0.2838	0.3023	0.0579	0.5201	0.9007	1.0000
R4	0.2877	0.2895	0.4440	0.7919	0.2337	0.2615	0.0448	0.0346	0.3754	0.1283
R5	0.4977	0.1759	0.6179	0.8577	0.6730	1.0000	0.0056	0.0854	0.3604	0.7960
R6	0.0419	0.0442	0.3547	0.6597	0.0665	0.0578	0.0000	1.0000	0.1071	0.5548
R7	1.0000	1.0000	1.0000	1.0000	0.0970	0.1920	1.0000	0.0000	0.0953	0.0000
R8	0.3571	0.0796	0.4617	0.8010	0.0000	0.0000	0.0596	0.2068	0.0000	0.1618
R9	0.1597	0.0162	0.1197	0.3973	1.0000	0.7373	0.0742	0.3961	0.9935	0.7841
R10	0.2439	0.2378	0.4130	0.6182	0.7652	0.5710	0.1751	0.2930	0.5582	0.2617
R11	0.0399	0.0778	0.7420	0.8425	0.3294	0.2677	0.0302	0.0825	0.4035	0.8399
R12	0.0000	0.0164	0.2002	0.6595	0.1674	0.1815	0.0431	0.3213	0.0853	0.2614
R13	0.4456	0.2704	0.2670	0.7086	0.1223	0.1335	0.0404	0.0837	0.1303	0.1001
R14	0.4502	0.2837	0.6401	0.8204	0.5948	0.5708	0.1076	0.3546	1.0000	0.6298
R15	0.2561	0.2500	0.7817	0.9070	0.3356	0.4200	0.0112	0.0294	0.3403	0.7897
R16	0.7819	0.3116	0.6180	0.7182	0.2599	0.1142	0.1741	0.2459	0.3355	0.2682

The percentage values of the criteria obtained by means of Eq. (9) and the weights of the criteria obtained by means of Eq. (10) are reported in Table 9.

Table 9 Results of LOPCOW Procedure

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
PV_{ij}	42.0279	27.2191	73.5963	115.8733	44.5740	40.4253	8.8612	31.8400	42.8885	49.9700
w_j	0.0881	0.0570	0.1542	0.2428	0.0934	0.0847	0.0186	0.0667	0.0899	0.1047
Rank	6	9	2	1	4	7	10	8	5	3

3.3 Final Weighting Procedure Results

In this section of the current paper, SPC and LOPCOW weights are integrated with Eq. (12) to determine the final weights for the chosen performance indicators. The results of the final weights are presented in Table 10.

Table 10 Results of Final Weighting

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
$\mathbf{w_j^{SPC}}$	0.0254	0.1158	0.0426	0.1623	0.0839	0.0790	0.3739	0.0542	0.0138	0.0491
$\mathbf{w_j^{LOPCOW}}$	0.0881	0.0570	0.1542	0.2428	0.0934	0.0847	0.0186	0.0667	0.0899	0.1047
$\mathbf{w_j^{FINAL}}$	0.0260	0.0765	0.0761	0.4568	0.0908	0.0775	0.0805	0.0419	0.0144	0.0596
Rank	9	5	6	1	2	4	3	8	10	7

The results obtained with the help of the final weighting methodology show that the three most important criteria affecting the performance of real sector firms in the period 2023 are I4 (ratio of total debt to total equity), I5 (return on common equity) and I7 (average price-earnings ratio). On the other hand, I9 (Tobin's Q ratio), I1 (current ratio) and I8 (ratio of market value to book value) are the three criteria that have lower effects on firm performance compared to other criteria.

3.4 The Results of MARCOS Procedure

In line with the purpose of the present case study, this section ranks the performance of alternative real sector firms on the basis of the MARCOS methodology. The MARCOS procedure is started with the preparation of the decision matrix shown in Table 3. Then, ideal and anti-ideal solution points for the alternatives were identified with the help of Eqs. (12-13). In the third phase of the procedure, the initial matrix was normalized considering the obtained solution points. The normalized values obtained by applying Eqs. (14-15) are given in Table 11.

Table 11 Normalized Matrix

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
R1	0.4028	0.2483	0.0571	0.0354	0.4338	0.2483	0.0348	0.2480	0.5700	0.1683
R2	0.4362	0.1657	0.0328	0.0096	0.1831	0.0936	0.1363	0.2700	0.6058	0.3822
R3	0.3533	0.0605	0.0859	0.0512	0.3080	0.3370	0.0814	0.5899	0.9466	1.0000
R4	0.4777	0.3324	0.0575	0.0445	0.2596	0.2983	0.0686	0.1751	0.6641	0.2065
R5	0.6317	0.2258	0.0815	0.0637	0.6841	1.0000	0.0304	0.2185	0.6560	0.8143
R6	0.2974	0.1020	0.0499	0.0277	0.0980	0.1047	0.0249	1.0000	0.5197	0.5947
R7	1.0000	1.0000	1.0000	1.0000	0.1276	0.2322	1.0000	0.1456	0.5134	0.0898
R8	0.5285	0.1353	0.0593	0.0464	0.0338	0.0498	0.0831	0.3222	0.4621	0.2370
R9	0.3838	0.0757	0.0371	0.0158	1.0000	0.7504	0.0973	0.4840	0.9965	0.8035
R10	0.4455	0.2839	0.0546	0.0247	0.7731	0.5923	0.1957	0.3959	0.7624	0.3280
R11	0.2960	0.1336	0.1162	0.0579	0.3521	0.3042	0.0544	0.2161	0.6792	0.8543
R12	0.2667	0.0759	0.0407	0.0277	0.1956	0.2223	0.0670	0.4201	0.5080	0.3277
R13	0.5934	0.3145	0.0442	0.0322	0.1520	0.1766	0.0644	0.2171	0.5322	0.1809
R14	0.5968	0.3270	0.0861	0.0512	0.6085	0.5922	0.1299	0.4485	1.0000	0.6630
R15	0.4545	0.2954	0.1345	0.0943	0.3581	0.4489	0.0359	0.1706	0.6452	0.8086
R16	0.8401	0.3532	0.0815	0.0332	0.2850	0.1583	0.1947	0.3556	0.6426	0.3339
AI	1.0000	1.0000	0.0328	0.0096	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

AII	0.2667	0.0605	1.0000	1.0000	0.0338	0.0498	0.0249	0.1456	0.4621	0.0898

By means of the final weights of the criteria, Eq. (16) was employed to create the weighted normalized matrix presented in Table 12.

Table 12 Weighted Normalized Matrix

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
R1	0.0105	0.0190	0.0043	0.0162	0.0394	0.0192	0.0028	0.0104	0.0082	0.0100
R2	0.0113	0.0127	0.0025	0.0044	0.0166	0.0073	0.0110	0.0113	0.0087	0.0228
R3	0.0092	0.0046	0.0065	0.0234	0.0280	0.0261	0.0066	0.0247	0.0136	0.0596
R4	0.0124	0.0254	0.0044	0.0203	0.0236	0.0231	0.0055	0.0073	0.0096	0.0123
R5	0.0164	0.0173	0.0062	0.0291	0.0621	0.0775	0.0024	0.0092	0.0094	0.0486
R6	0.0077	0.0078	0.0038	0.0126	0.0089	0.0081	0.0020	0.0419	0.0075	0.0355
R7	0.0260	0.0765	0.0761	0.4568	0.0116	0.0180	0.0805	0.0061	0.0074	0.0054
R8	0.0137	0.0104	0.0045	0.0212	0.0031	0.0039	0.0067	0.0135	0.0067	0.0141
R9	0.0100	0.0058	0.0028	0.0072	0.0908	0.0582	0.0078	0.0203	0.0144	0.0479
R10	0.0116	0.0217	0.0042	0.0113	0.0702	0.0459	0.0157	0.0166	0.0110	0.0196
R11	0.0077	0.0102	0.0088	0.0265	0.0320	0.0236	0.0044	0.0090	0.0098	0.0509
R12	0.0069	0.0058	0.0031	0.0126	0.0178	0.0172	0.0054	0.0176	0.0073	0.0195
R13	0.0154	0.0241	0.0034	0.0147	0.0138	0.0137	0.0052	0.0091	0.0077	0.0108
R14	0.0155	0.0250	0.0066	0.0234	0.0552	0.0459	0.0105	0.0188	0.0144	0.0395
R15	0.0118	0.0226	0.0102	0.0431	0.0325	0.0348	0.0029	0.0071	0.0093	0.0482
R16	0.0218	0.0270	0.0062	0.0152	0.0259	0.0123	0.0157	0.0149	0.0093	0.0199
AI	0.0260	0.0765	0.0025	0.0044	0.0908	0.0775	0.0805	0.0419	0.0144	0.0596
AII	0.0069	0.0046	0.0761	0.4568	0.0031	0.0039	0.0020	0.0061	0.0067	0.0054

At the end of the MARCOS methodology, first the utility degrees for the alternatives were calculated based on Eqs. (17-19). Afterwards, the utility functions and success scores of the alternatives were calculated applying Eqs. (20-23). The aggregated results of the calculations are as detailed in Table 13.

Table 13 Results of MARCOS Procedure

	S_i	K_i^-+	K_i^+-	$f(K_i^+)$	$f(K_i^-)$	$f(K_i)$	Rank
R1	0.1401	0.2954	0.2451	0.5466	0.4534	0.1781	11
R2	0.1085	0.2290	0.1900	0.5466	0.4534	0.1380	15
R3	0.2023	0.4269	0.3541	0.5466	0.4534	0.2573	7
R4	0.1440	0.3037	0.2519	0.5466	0.4534	0.1831	10
R5	0.2782	0.5869	0.4868	0.5466	0.4534	0.3538	2
R6	0.1358	0.2865	0.2377	0.5466	0.4534	0.1727	12
R7	0.7642	1.6122	1.3374	0.5466	0.4534	0.9718	1
R8	0.0977	0.2061	0.1709	0.5466	0.4534	0.1242	16
R9	0.2651	0.5593	0.4640	0.5466	0.4534	0.3371	3
R10	0.2277	0.4804	0.3985	0.5466	0.4534	0.2896	5
R11	0.1829	0.3858	0.3201	0.5466	0.4534	0.2326	8
R12	0.1133	0.2390	0.1983	0.5466	0.4534	0.1441	14
R13	0.1177	0.2484	0.2061	0.5466	0.4534	0.1497	13
R14	0.2548	0.5374	0.4458	0.5466	0.4534	0.3240	4
R15	0.2225	0.4695	0.3894	0.5466	0.4534	0.2830	6

R16	0.1681	0.3546	0.2942	0.5466	0.4534	0.2138	9
AI	0.4740						
AII	0.5714						

Considering the ranking scores in Table 13, among the real sector firms whose shares are listed in the BIST - XSD25 index for the period 2023, R7 (ENKAI) has shown a higher financial performance than the other firms assessed within the framework of the analyses. This firm is followed by R5 (DOAS), R9 (FROTO), R14 (TOASO), R10 (MAVI), R15 (TUPRS), R3 (BIMAS), R11 (MGROS), R16 (ULKER), R4 (CIMSA), R1 (AEFES), R6 (ENJSA), R13 (SISE), R12 (PETKM), R2 (ARCLK), and R8 (EREGL).

4. Sensitivity Analysis

In this section, a sensitivity analysis has been carried out so as to indicate the validity and of the empirical findings obtained in the current research. In this regard, the impacts of changing the weight scores based on the SPC and LOPCOW methodologies on the final success ranking are analyzed for 50 different scenarios that we form. For this aim, the procedure proposed by [30] and [44] was employed. According to this procedure based on changing the weights, the most influential performance metric (I4) was decreased by 2% in each scenario. This 2% value was distributed equally among the remaining 9 performance metrics and new weight vectors were obtained. The new weights were integrated into the MARCOS procedure and the changes in the ranking of the alternatives were analyzed. The sensitivity analysis output is pictorially demonstrated in Figure 2. From Figure 2, it is determined that the rankings of the companies occupying the first three and last three ranking positions do not change, however, there are small changes in the ranking positions of the other alternatives. However, these ranking changes are not at a level that will affect the reliability of the initial ranking results obtained from the SPC-LOPCOW-MARCOS hybrid method.

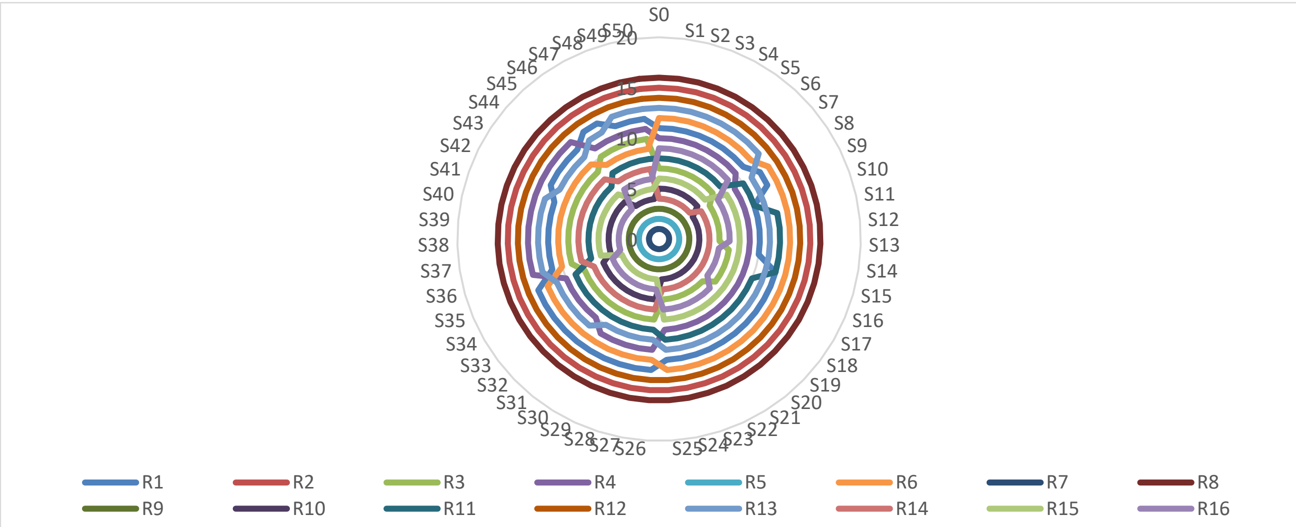

Figure 2 Examining the Influence of Changes in the Criteria Weights on the Rankings of Firms

Finally, the ranking results obtained from the application of the proposed integrated decision-making model were compared with the ranking results obtained from the CRADIS [45], MAIRCA [46] and RAWEC [47] methodologies in the decision-making literature. The findings obtained from these comparisons are shown in Figure 3. Figure 3 shows that the results obtained from the proposed model are highly correlated with the results obtained from other methods. This finding indicates that the proposed decision model produces robust and reliable results.

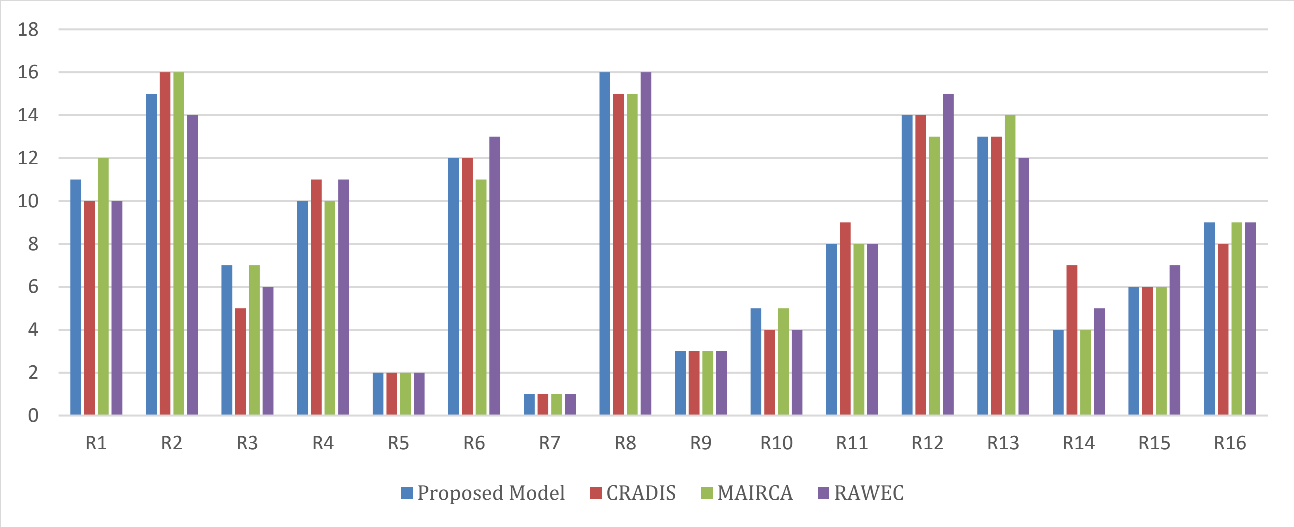

Figure 3 Comparing the proposed model with different decision-making approaches

5. Policy recommendations

Performance analysis, which affects all operational activities of both financial firms (banks, insurers, etc.) and non-financial firms, is a very important tool for achieving sustainable competitive advantage and improving performance in a competitive and dynamic market [48]. The key policy recommendations derived from your study are as follows:

- Firms should improve the disclosure of financial ratios, particularly those related to liquidity, leverage, and profitability, to facilitate better financial performance assessments.
- Manufacturing firms should optimize their debt-to-equity and debt-to-assets ratios to maintain financial stability and enhance investor confidence.
- Given that the sample firms are part of the BIST Sustainability Index, integrating ESG factors with financial performance metrics can help firms attract long-term investors.
- Policymakers and industry regulators may establish standardized financial benchmarks using multi-criteria decision-making (MCDM) methods like MARCOS, SPC, and LOPCOW to assess and compare firm performance.
- Investors can use the study's SPC-LOPCOW-MARCOS framework to make informed investment decisions by considering both liquidity and profitability indicators in firm evaluations.
- Manufacturing firms should tailor their financial strategies based on sectoral performance rankings to enhance competitiveness within the BIST-XSD25 index.
- Government agencies and financial regulators should design incentives (e.g., tax benefits, lower borrowing costs) for firms demonstrating strong financial and sustainability performance.

- Financial institutions and analysts should adopt hybrid weighting models (SPC-LOPCOW) for more accurate and unbiased financial performance assessments.

6. Conclusions

The assessment of financial performance is pivotal for firms to understand the current situation of the business and to ensure sustainable competitive advantage in the long term. Key strategic indicators such as revenue, profitability, leverage, liquidity and market performance are highly effective in identifying the strengths and weaknesses of firms. Objective assessments of financial performance can help to make more effective and efficient use of a firm's resources, minimize systematic and non-systematic risks, and provide a sound basis for growth objectives. In addition, financial performance measures provide both internal and external stakeholders with valuable information to understand a firm's reliability and sustainability. Therefore, the research aims to present a new integrated decision-making methodology for decision-makers in assessing firm performance. The decision framework introduced in this paper consists of the integration of SPC-LOPCOW and MARCOS approaches. While SPC and LOPCOW procedures is applied to identify the final weight scores of the criteria, MARCOS procedure is employed in the process of ranking the alternatives. In order to test the applicability of the introduced decision tool, a case study was carried out in the study. This case analysis focuses on the financial performance of 16 real sector firms whose shares are listed on the BIST - XSD25 index for the year 2023.

The results of the final weighting methodology indicate that the three most impactful criteria on firm performance for the period 2023 are ratio of total debt to total equity, return on common equity and average price-earnings ratio. Besides, the three criteria that have the lowest impacts on the firm's performance for the same period are Tobin's Q ratio, current ratio and ratio of market value to book value.

Based on the findings based on the MARCOS procedure, ENKAI is the most financially successful firm in 2023. The performance rankings of the other firms assessed in the analyses are as follows: DOAS > FROTO > TOASO > MAVI > TUPRS > BIMAS > MGROS > ULKER > CIMSA > AEFES > ENJSA > SISE > PETKM > TUP ARCLK RS > EREGL.

The empirical outcomes of the current research may provide guidance to internal stakeholders, potential investors, and regulators and supervisors in their decision-making processes. The results obtained can facilitate the development of more efficient strategies for future periods by identifying the firm's strengths and weaknesses for internal stakeholders. Similarly, the firm's decision-making mechanisms can develop a more successful strategy for the use of resources by using the research findings. External stakeholders can minimize the risks they may face by assessing the financial soundness of the firms by taking into account the findings of the current studies. On the other hand, investors planning to invest in firms can make their investment decisions taking into account the results of the paper.

Finally, the paper has a number of limitations. The data set, sample and the analysis period utilized in the study can be defined as limitations. In addition, the fact that the study was only carried out within the framework of SPC-LOPCOW and MARCOS procedures can also be considered as a limitation. In subsequent empirical studies, a range of periods and instances can be selected to provide greater depth to the research topic. Furthermore, the employment of non-financial ESG criteria as supplementary evaluation metrics alongside financial criteria is recommended. This approach will facilitate a more comprehensive or multi-dimensional analysis. Furthermore, in subsequent studies, the integration of objective and subjective models in weighting procedures may be proposed. This integration of objective and subjective models will provide decision-makers and practitioners with a range of alternative models to choose from. Finally, the research topic can be expanded by conducting analyses within the scope of fuzzy models or grey set theory within the framework of expert opinions.

Funding
"This research received no external funding".

Data Availability Statement
"The dataset used in the study was derived from the annual reports of the relevant companies".

Acknowledgement
"This research was not funded by any grant".

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