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An Innovative Decision Support Model for the Financial Performance Assessment: A Study of BIST Cement Firms

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ABSTRACT

The regularly assessment of the financial performance of firms in the real sector is highly essential, both in terms of increasing the level of operational efficiency and in terms of effectively managing potential risk factors and obtaining sustainable competitive advantage. This paper introduces a new decision algorithm for the assessment of firm performance. This decision algorithm consists of the integration of Logarithmic Percentage Change-driven Objective Weighting (LOPCOW), Modified Standard Deviation (MSD), Compromise Ranking of Alternatives from Distance to Ideal Solution (CRADIS), Multi-Objective Optimization on the Basis of Simple Ratio Analysis (MOOSRA), Multi Atributive Ideal-Real Comparative Analysis (MAIRCA) and Borda Count methodologies. In order to test the presented decision-making procedure, a real-time case study was applied as part of the study. This case study is focused on analyzing the financial performance of 13 cement industry firms whose shares are listed on the Borsa Istanbul (BIST) for the year 2023. In the process of assessing the performance of these companies, 10 performance indicators were selected with the help of previous literature. LOPCOW and MSD algorithms were applied to determine the final importance weights of these indicators, while CRADIS, MOOSRA, MAIRCA and Borda Count algorithms were employed to rank the firms. The findings of the final weighting algorithm indicate that the three most important performance indicators are total debt to total equity ratio, total debt to total assets ratio and cash ratio. Moreover, according to the final ranking results obtained based on the CRADIS, MOOSRA, MAIRCA and Borda Count algorithms, BUCIM is the most financially successful firm in 2023. Additionally, the findings of the robustness analyses also support the conclusion that the results obtained from the presented model are reliable and applicable.

1. Introduction

The main purpose of economic policy in all developed and developing countries is to ensure a sustainable development environment with balanced growth and capital flows by achieving an optimal balance between the industrial, agricultural and service sectors. For countries, sustainable

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economic growth and development is directly related to the steady increase in production capacity, infrastructure investment and construction activity. In this regard, industrial production and infrastructure investment are considered as the basic elements of economic growth and development [1]. Capital market volatility determines the strength of sectoral interactions by affecting both countries' investment policies and the performance of the real sector. The construction sector, which is one of the most crucial sectors within the real sector, has an extensive ecosystem that feeds many sectors in the real sector in terms of being both an indicator and a carrier of economic growth for national economies [2]. The cement sector is prominent as one of the most critical elements of this ecosystem. In addition to being one of the basic building blocks for the uninterrupted execution of construction activities, the cement sector is a strategic sector that is one of the most sensitive to fluctuations that may occur in the economy. Considered as one of the essential elements of infrastructure systems in the modern sense, the cement sector plays a very key role in the process of providing an environment for economic development and promoting the growth of various sectors [3].

Cement, one of the most widely utilized building materials worldwide, is essential for the construction of roads, bridges, buildings, dams and other structures that are important for urbanization and economic growth [4]. From the financial perspective, the cement sector is a capital-intensive sector that requires significant investments in terms of raw materials, production facilities, logistics and raw materials [5]. The fact that the sector requires high investments, on the one hand, makes it difficult to enter and exit the market and, on the other hand, increases the period of conversion of savings into investments. However, the sector is also critical to national economies in terms of the employment opportunities it provides and its increasing share in exports [6].

The cement sector has been shown to provide significant financial advantages to national economies, but it also leads to many environmental problems and concerns. The process of calcination and burning of fossil fuels in cement production leads to significant greenhouse gas emissions [7]. This impact gives rise to a number of serious environmental concerns, especially with regard to sustainability. However, the disposal of waste arising from cement production and the continuous decrease in raw material resources have also given rise to increased concerns about environmental sustainability. This has obliged producers to develop production processes based on more environmentally sound policies and the use of innovative technologies to decrease the environmental effects of cement [8]. In overcoming these challenges, firms in the cement sector have started to pay more and more attention to alternative raw materials, energy efficient technologies and environmentally sound policies to decrease the carbon footprint [9]. The decisions taken by the country management to regulate and supervise the cement sector is another dimension that significantly affects both the financial and environmental performance of this sector. In this context, various policy actions are being taken in most of the countries to promote sustainability policies and reduce air pollution [10]. The assessment of the financial performance of the cement sector has become a very essential issue in view of this process, which is quite complex for the relevant sector.

The purpose of this study is to suggest a new integrated decision making algorithm for financial performance assessment in the cement industry. The suggested decision algorithm consists of the integration of CRADIS, MOOSRA, MAIRCA and Borda Counting procedures based on LOPCOW and MSD. Among these decision algorithms, LOPCOW and MSD are preferred in the process of determining the objective weight coefficients of the selected performance indicators. In addition, CRADIS, MOOSRA, MAIRCA and Borda Count were applied in the process of comparative ranking of cement firms. The decision algorithm presented in this paper was tested by conducting a real-time case study. The financial data of 13 cement firms, whose shares are listed on the BIST, for the year 2023 were utilized in this case study. The present case study makes several novel contributions to the existing literature: firstly, it combines the LOPCOW and MSD objective weighting algorithms for the cement sector sample; secondly, it applies the CRADIS, MOOSRA, MAIRCA and Borda Count procedures for the first time to the cement sector sample; and thirdly, it proposes the CRADIS, MOOSRA, MAIRCA and Borda Count algorithms based on the LOPCOW and MSD procedures as a new conceptual perspective for decision makers.

The present case study is structured in five sections. In this context, the initial section gives an introduction and review of previous literature, while the second section includes a theoretical description of the suggested decision algorithm. The third section details the empirical findings based on the presented model, and the fourth section reports various sensitivity analyses. The final section of the paper assesses the findings and provides recommendations.

1.1 Literature Review

A review of the existing literature indicates that there are many studies that examine firm performance utilizing decision making methodologies. This section will summarize and give a chronological overview of some of these studies.

Esbouei *et al.,* [11] analyzed the performance of real sector firms listed in Tehran Stock Exchange for the period 2002-2011. The study introduces a conceptual framework integrating the Fuzzy ANP and Fuzzy VIKOR procedures to assess firm performance.

Moghimi and Anvari [12] utilized the Fuzzy AHP and TOPSIS procedures to analyses the financial performance of seven firms in the cement sector, which are traded in Tehran Stock Exchange.

Safaei Ghadikolaei *et al.,* [13] conducted a similar analysis, examining the performance of real sector firms traded in Tehran Stock Exchange that produce automobile parts. In the research conducted for the period 2002-2011, an integrated decision-making model was proposed that included fuzzy AHP, TOPSIS and VIKOR procedures.

Tavana *et al.,* [14] examined the performance of pharmaceutical firms traded on the Swiss Stock Exchange for the year 2014. Utilizing an integrated conceptual framework consisting of Fuzzy AHP, DEMATEL and Fuzzy DEA procedure, the study analyzed the performance of the firms.

Shaverdi *et al.,* [15] assessed the performance of 7 firms operating in the petrochemical industry in Iran for the period 2003-2013 in a study employing Fuzzy AHP and Fuzzy TOPSIS procedures.

Anthony *et al.,* [16] investigated the performance and efficiency of 7 firms in the chemical industry in India for the period 2010-2018 based on Entropy, TOPSIS, COPRAS and DEA methodology.

Işık [17] applied Entropy-based TOPSIS decision procedures to test the relationship between financial performance and stock returns of real sector firms traded in the BIST-30 index for the period 2014-2017.

In the study performed by Aydın [18] Entropy and MAUT algorithms were proposed to evaluate the relationship between financial performance and stock returns of firms whose shares are listed in the BIST chemical, petroleum, rubber and plastic products sector during the period 2015-2018.

Deng *et al.,* [19] investigated the performance of nuclear energy firms in China. Within the scope of the assessment for the period 2007-2016, a decision model including AHP and PROMETHEE II methods was carried out.

Işık and Koşaroğlu [20] utilized the SD and MAUT methodologies to compare the financial performance of oil firms traded on the BIST for the period 2010-2019.

Bozdoğan *et al.,* [21] applied the CRITIC-based TOPSIS and ELECTRE procedures to compare the financial performance of 15 cement firms whose shares are listed on BIST for the period 2013-2022.

Lukić *et al.,* [22] employed AHP and TOPSIS methods to compare the performance of food retail companies in Serbia. In the context of the research, a decision-making tool was applied that included AHP and TOPSIS procedures for 2018.

Akbulut [23] analyzed the relationship between financial performance and stock returns of cement firms whose shares are listed on BIST. The study encompassed the 2014-2018 period and included the CRITIC and MABAC decision procedures.

In a study covering the period 2011-2015, Ban *et al.,* [24] comparatively analyzed the performance of real sector firms whose stocks are listed on the Romanian Stock Exchange by means of Fuzzy AHP and TOPSIS procedures.

Akbulut and Hepşen [25] utilized an integrated decision-making methodology comprising Entropy and CoCoSo algorithms to assess the relationship between financial performance and stock returns of firms whose stocks are listed in the BIST chemical, petroleum, rubber and plastic products sector for the period 2015-2019.

Pala *et al.,* [26] employed the LODECI and CRADIS methods to evaluate the financial performance of 16 firms operating in the BIST cement sector for the period 2020-2022.

2. Methodological Framework

In the present study, CRADIS, MOOSRA, MAIRCA and Borda Count decision-making algorithms based on LOPCOW and MSD procedures were applied to analyze the financial performance of cement firms. These decision algorithms employed LOPCOW and MSD algorithms to identify the objective weights of the assessment criteria. The CRADIS, MOOSRA, MAIRCA and Borda Count algorithms were preferred in the process of ranking the cement firms. The subsequent section is presenting the theoretical framework of these methodologies. The general framework of the decision algorithm proposed in the present paper is shown in Figure 1.

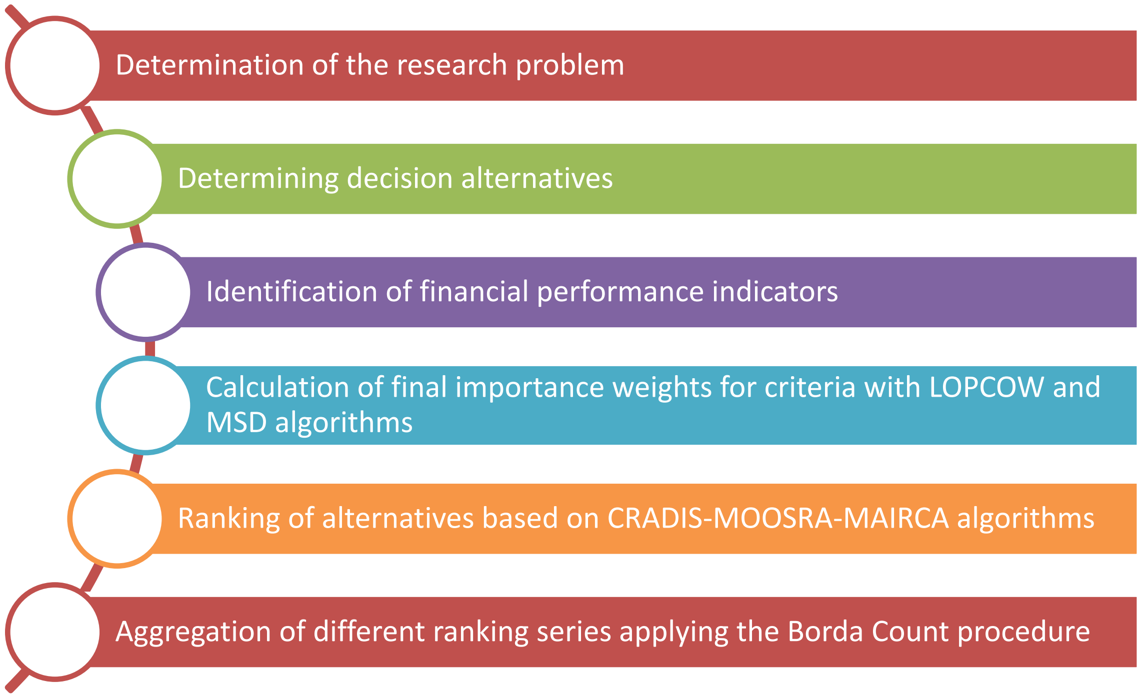

Figure 1 Steps of the proposed decision algorithm

2.1 LOPCOW Algorithm

The LOPCOW algorithm was first introduced in the literature by Ecer and Pamucar [27]. LOPCOW technique, which has low calculation time and strong calculation ability, directly includes indicators with negative values into the analysis without any transformation [28].

The application of the LOPCOW procedure consists of 4 steps.

Step 1. The initial matrix for the solution of the decision problem is prepared in accordance with Eq. (1).

$$X = \left[x_{ij}\right]_{m \times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Step 2. The initial matrix is then normalized on the basis of the attributes of the assessment criteria. In this context, Eq. (2) is applied for beneficial criteria and Eq. (3) is applied for non-beneficial criteria.

$$r_{ij} = \frac{x_{ij - min_{ij}}}{max_{ij} - min_{ij}} \tag{2}$$

$$r_{ij} = \frac{max_{ij} - x_{ij}}{max_{ij} - min_{ij}} \tag{3}$$

Step 3. The percentage values of the performance criteria are determined with the help of Eq. (4). The σ value in Eq. (4) represents the standard errors for the performance criteria and is calculated using Eq. (5).

$$PV_{ij} = \left| ln \left[\frac{\sqrt{\frac{\sum_{i=1}^{n} r_{ij}^2}{n}}}{\sigma} \right] \right| \times 100 \quad (4)$$

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(v_{ij} - \overline{v_j})^2}{m}} \quad (5)$$

Step 4. Objective weights for the performance criteria are calculated with Eq. (6).

$$w_j = \frac{PV_{ij}}{\sum_{j=1}^{m} PV_{ij}}; \ \sum_{j=1}^{n} w_j = 1 \quad (6)$$

2.2 MSD Algorithm

The MSD algorithm was introduced to the decision-making literature by Puška *et al.,* [29] as a modified version of the SD algorithm. The MSD procedure has recently been employed by numerous researchers to calculate objective weight scores for performance indicators. The implementation process of this decision-making algorithm consists of 6 steps [30]- [31].
Step 1. The initial matrix is prepared as given in Eq. (1).
Step 2. The beneficial criteria in the initial matrix are normalized by Eq. (7) and the non-beneficial criteria are normalized by Eq. (8).

$$r_{ij} = \frac{x_{ij}}{max_{ij}} \quad (7)$$

$$r_{ij} = \frac{min_{ij}}{x_{ij}} \quad (8)$$

Step 3. The standard error values for the performance criteria are determined by means of Eq. (5).
Step 4. The column totals ($\sum_{j}^{n} y_{ij}$) are obtained for the performance criteria.
Step 5. The corrected values for the standard error values are obtained by applying Eq. (9).

$$\sigma' = \frac{\sigma}{\sum_{j}^{n} y_{ij}} \quad (9)$$

Step 6. Objective weight scores are determined for the performance indicators with Eq. (10).

$$w_j = \frac{\sigma_j'}{\sum_{j=1}^{n} \sigma_j'} \quad (10)$$

2.3 Final Weighting Algorithm

In this section, the importance weights of the criteria, obtained based on the LOPCOW and MSD algorithms, are integrated with the help of Eq. (11) to obtain the final weight value for each performance indicator [32], [33], [34]. w_j^{LOPCOW} and w_j^{MSD} represent the weight coefficients derived from the LOPCOW and MSD algorithms, respectively.

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

In the assessment of the findings in terms of the final weighting values, the performance indicator with the highest w_j value is regarded as the most important.

2.4 CRADIS Algorithm

The CRADIS algorithm, which was developed in the decision-making literature by Puška *et al.,* [30], is utilized in the process of ranking decision alternatives in terms of ideal and anti-ideal values. This decision-making approach is derived from the integration of ARAS, MARCOS and TOPSIS algorithms [35]. In this context, the CRADIS algorithm offers an innovative and reliable perspective to decision makers and practitioners with its simplicity, flexibility and consistency features [36]. The application process of the CRADIS algorithm consists of the following 8 steps.
Step 1. The initial matrix is constructed by Eq. (1).
Step 2. The values the initial matrix are normalized based on Eq. (7) and Eq. (8).
Step 3. The final importance weights obtained for the performance indicators are integrated into the CRADIS procedure at this stage and the weighted normalized matrix is produced with the help of Eq. (12).

$$y_{ij} = r_{ij} \times w_j \tag{12}$$

Step 4. The determination of ideal and anti-ideal solution points for the performance criteria is obtained by means of Eqs. (13) and (14), respectively.

$$b_i = max y_{ij} \tag{13}$$

$$b_{ai} = min y_{ij} \tag{14}$$

Step 5. Finally, deviation values from the ideal and anti-ideal solution points are calculated by using Eqs. (15-16).

$$d^+ = b_i - y_{ij} \tag{15}$$
$$d^- = y_{ij} - b_{ai} \tag{16}$$

Step 6. The degree of deviation from the ideal and anti-ideal solution points for decision alternatives is calculated based on Eqs. (17-18).

$$s_i^+ = \sum_{j=1}^{n} d^+ \tag{17}$$
$$s_i^- = \sum_{j=1}^{n} d^- \tag{18}$$

Step 7. The utility functions of the decision alternatives are calculated via Eqs. (19) and (20).

$$K_i^+ = \frac{s_0^+}{s_i^+} \tag{19}$$

$$K_i^- = \frac{s_i^-}{s_0^-} \tag{20}$$

In these equations, s_0^+ ve s_0^- values indicate the optimum alternative closest to the ideal solution point and the optimum alternative furthest from the anti-ideal solution point, respectively.
Step 8. In the final step of the CRADIS algorithm, the ranking coefficients for the alternatives are calculated applying Eq. (21).

$$Q_i = \frac{K_i^+ + K_i^-}{2} \tag{21}$$

When assessing the alternatives, the alternative with the highest Q_i value is considered to be the most successful.

2.5 MOOSRA Algorithm

The MOOSRA algorithm is a decision-making procedure that has been developed in the literature by Das *et al.,* [37]. This procedure is utilized in the process of ranking decision alternatives. The application process of this decision-making algorithm is comprised of 4 steps [38].
Step 1. The initial matrix is built as reported in Eq. (1).
Step 2. The initial matrix is normalized according to Eq. (22).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} (x_{ij})^2}} \tag{22}$$

Step 3. Utilizing the importance weights for the performance indicators, a weighted normalized matrix is created in Eq. (12).
Step 4. The performance scores for the decision alternatives are calculated using Eq. (23).

$$S_i = \frac{\sum_{j=1}^{b} w_j \times r_{ij}}{\sum_{j=b+1}^{n} w_j \times r_{ij}} \tag{23}$$

The values b and b+1 in the equation represent the number of beneficial and non-beneficial criteria respectively. The alternative with the highest S_i value as a consequence of the calculations is also considered to be the most successful.

2.6 MAIRCA Algorithm

The MAIRCA algorithm, which was introduced to the decision-making literature by Pamučar *et al.,* [39], is preferred in the process of ranking decision alternatives. The MAIRCA approach differs from other decision-making methodologies in that it allows the identification of the points where the alternatives are closest to the ideal scores [40], [41]. The application process of this approach consists of the following 6 steps.
Step 1. The initial matrix shown in Eq. (1) is prepared.
Step 2. Preference probability values for the alternatives are obtained with the help of Eq. (24).

$$P_{Bi} = \frac{1}{m}; \sum_{i=1}^{m} P_{Bi} = 1 \quad (24)$$

Step 3. Within the scope of Eq. (25), the theoretical assessment matrix is created by integrating criterion importance weights and preference probability values.

$$K_p = \begin{bmatrix} k_{p11} & k_{p12} & \cdots & k_{p1n} \\ k_{p21} & k_{p22} & \cdots & k_{p2n} \\ \vdots & \vdots & \ddots & \vdots \\ k_{pm1} & k_{pm2} & \cdots & k_{pmn} \end{bmatrix} = \begin{bmatrix} P_{B1}w_1 & P_{B1}w_2 & \cdots & P_{B1}w_n \\ P_{B2}w_1 & P_{B2}w_2 & \cdots & P_{B2}w_n \\ \vdots & \vdots & \ddots & \vdots \\ P_{Bm}w_1 & P_{B1}w_2 & \cdots & P_{Bm}w_n \end{bmatrix} \quad (25)$$

Step 4. The actual assessment matrix is constructed by considering the attributes of the performance criteria. Accordingly, Eq. (26) is used for beneficial criteria and Eq. (27) for non-beneficial criteria.

$$k_{rij=}k_{pij} = \frac{d_{ij}-d_i^-}{d_i^+-d_i^-} \quad (26)$$

$$k_{rij=}k_{pij} = \frac{d_{ij}-d_i^+}{d_i^--d_i^+} \quad (27)$$

The following values are indicated: $d_i^+ = mak(d_1, \dots, d_m)$ and $d_i^- = min(d_1, \dots, d_m)$
Step 5. Utilizing the Eqs. (28-29), the values for the total gap matrix are calculated.

$$F = K_p - K_r = \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mn} \end{bmatrix} = \begin{bmatrix} k_{p11}-k_{r11} & k_{p12}-k_{r12} & \cdots & k_{p1n}-k_{r1n} \\ k_{p21}-k_{r21} & k_{p22}-k_{r22} & \cdots & k_{p2n}-k_{r2n} \\ \vdots & \vdots & \ddots & \vdots \\ k_{pm1}-k_{rm1} & k_{pm2}-k_{rm2} & \cdots & k_{pmn}-k_{rmn} \end{bmatrix}$$
(28)

$$f_{ij} = \begin{cases} 0, & if \quad k_{pij} = k_{rij} \\ k_{pij} - k_{rij}, & if \quad k_{pij} > k_{rij} \end{cases} \quad (29)$$

Step 6. Finally, the assessment scores for the decision alternatives are derived with Eq. (30) in the last step of the MAIRCA approach.

$$U_i = \sum_{j=1}^{n} f_{ij} \quad (30)$$

As a consequence, the alternative with the lowest U_i value is regarded as the most successful.

2.7 Borda Count Algorithm

In order to integrate the ranking results based on different decision procedures, the Borda Count methodology, introduced in the literature by Jean-Charles de Borda [42], is employed in the present case study. The Borda Count methodology is a data combining operator that allows the integration of different rank series to obtain a single rank series. According to the Borda Counting procedure, the most unsuccessful alternative in the ranking is assigned a point value of 0, the next alternative is assigned a point value of 1, and the most successful alternative is assigned a point value of (m-1), where m= number of alternatives. The Borda scores of the alternatives are then summed up at the final stages and a total Borda score is obtained for each decision alternative. The alternative with the highest (lowest) Borda score is considered as the most successful (least successful) alternative in the ranking [41].

3. Sample, Data, and Findings

In this paper, an integrated decision algorithm is proposed to assess the financial performance of firms. The suggested decision algorithm is tested in the process of assessing the financial performance of 13 cement firms (AFYON-CF1, AKCNS-CF2, BASCM-CF3, BTCIM-CF4, BSOKE-CF5, BUCIM-CF6, CMENT-CF7, CIMSA-CF8, GOLTS-CF9, KONYA-CF10, NIBAS-CF11, NUHCM-CF12, OYAKC-CF13) whose stocks are listed on BIST for 2023. In order to analyze the financial performance of the cement firms studied in the research, 10 performance indicators were chosen, taking into account the previous literature. The details of the performance indicators obtained from the Refinitiv Eikon database are presented in Table 1.

Table 1 Chosen Performance Criteria

Financial Performance Indicators	Code	Qualification
Current Ratio	P1	Max.
Cash Ratio	P2	Max.
Return on Assets	P3	Max.
Return on Equity	P4	Max.
Total Debt / Total Equity	P5	Min.
Total Debt / Total Assets	P6	Min.
Receivable Turnover Rate	P7	Max.
Inventory Turnover Rate	P8	Max.
Market Value / Book Value	P9	Max.
Price-Earnings Ratio	P10	Max.

3.1 Results of LOPCOW Algorithm

The analysis process of the present case study begins with the weighting of the chosen performance indicators within the framework of the LOPCOW algorithm. In this context, the initial matrix was first created in the LOPCOW algorithm. The initial matrix prepared within the scope of Eq. (1) is reported in Table 2.

Table 2 Initial Matrix

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
CF1	1.9560	0.5270	0.1852	0.2172	0.1728	0.1473	6.7310	9.1846	0.9717	4.4737
CF2	1.4495	0.5444	0.1051	0.1494	0.4214	0.2964	7.4637	11.7344	1.7160	11.4890
CF3	1.6566	0.2727	0.1670	0.2229	0.3346	0.2507	5.4916	11.0184	1.8538	5.8142
CF4	1.1908	0.0860	0.1025	0.1859	0.7038	0.3881	8.9780	10.6129	2.6703	11.4445
CF5	0.6284	0.0083	0.0859	0.1994	1.3207	0.5691	8.9115	5.4652	1.0529	5.2813
CF6	3.5900	0.8575	0.1351	0.1845	0.1894	0.1387	6.0728	6.5480	1.0337	5.7116
CF7	1.9018	0.6327	0.0458	0.0817	0.4475	0.2508	6.4878	8.8275	2.0026	19.8526
CF8	1.3615	0.7105	0.0697	0.1441	0.8054	0.3895	8.2403	9.0216	1.2988	11.1380

CF9	1.1464	0.0502	0.2067	0.2909	0.3500	0.2487	7.2184	9.8424	0.7688	2.7407
CF10	1.4238	0.2120	0.1622	0.2381	0.4682	0.3189	7.6940	7.0594	12.2317	51.3714
CF11	2.3465	0.7733	0.0587	0.0696	0.1856	0.1565	4.0413	10.8300	1.7465	25.1003
CF12	2.7360	1.4280	0.0931	0.1305	0.4016	0.2865	9.6233	10.1446	3.0078	23.0438
CF13	2.2215	0.8756	0.1997	0.2649	0.3266	0.2462	8.2669	7.5362	2.0960	7.9123

The results of the LOPCOW algorithm, obtained by applying Eqs. (2-6), are shown in Table 3.

Table 3 Findings of LOPCOW Algorithm

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
σ	0.2622	0.2877	0.3418	0.3001	0.2754	0.2729	0.2794	0.3053	0.2617	0.2735
PV_{ij}	59.121	47.721	54.312	67.266	104.835	96.054	83.902	74.739	11.339	25.739
w_j	0.0946	0.0763	0.0869	0.1076	0.1677	0.1537	0.1342	0.1196	0.0181	0.0412
Ranking	6	8	7	5	1	2	3	4	10	9

3.2 Results of MSD Procedure

In the second section of the assessment process, objective weight coefficients were calculated for the chosen financial performance indicators based on the MSD algorithm. Eqs. (7-10) were employed in the process of determining the criteria weights according to the MSD methodology. The findings arrived at by applying these equations are displayed in Table 4.

Table 4 Findings of MSD Algorithm

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
σ	0.2163	0.2860	0.2661	0.2283	0.2787	0.2340	0.1621	0.1631	0.2453	0.2589
w_j	0.0775	0.1380	0.0802	0.0658	0.1000	0.0745	0.0386	0.0383	0.2179	0.1691
Ranking	6	3	5	8	4	7	9	10	1	2

3.3 Results of Final Weighting Algorithm

In this section of the implementation procedure, the objective importance weights of the performance indicators are derived by means of the LOPCOW and MSD methodologies and combined in accordance with Eq. (11). The final criteria weights calculated for each performance indicator are shown in Table 5.

Table 5 Findings of Final Weighting

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
w_j^{LOPCOW}	0.0946	0.0763	0.0869	0.1076	0.1677	0.1537	0.1342	0.1196	0.0181	0.0412
w_j^{MSD}	0.0775	0.1380	0.0802	0.0658	0.1000	0.0745	0.0386	0.0383	0.2179	0.1691
w_j^{FINAL}	0.0907	0.1303	0.0862	0.0876	0.2075	0.1417	0.0641	0.0566	0.0489	0.0862
Ranking	4	3	6	5	1	2	8	9	10	7

The findings regarding the final importance weights given in Table 5 indicate that the three performance indicators that most affect the financial performance of cement industry firms in 2023 are P5 (total debt to total equity), P6 (total debt to total assets) and P2 (cash ratio), respectively. Conversely, the three indicators with the least impact on firm performance during the analysis period are P9 (market value to book value), P8 (inventory turnover ratio) and P7 (receivables turnover ratio), respectively.

3.4 Results of CRADIS Algorithm

The present section of the research deals with the calculation of the success rankings of the cement firms for the period 2023 based on the CRADIS algorithm, considering the final importance weights of the performance indicators. To this end, the relevant Eqs. (12-21) were applied to the initial matrix. The results of these calculations are reported in Table 6, together with the CRADIS firms performance rankings.

Table 6 Findings of CRADIS *Algorithm*

	S_i^+	K_i^+	S_i^-	K_i^-	Q_i	Ranking
CF1	1.3937	0.7717	0.6742	0.6793	0.7255	2
CF2	1.6164	0.6653	0.4515	0.4549	0.5601	9
CF3	1.5794	0.6809	0.4885	0.4922	0.5866	7
CF4	1.6963	0.6340	0.3716	0.3745	0.5042	12
CF5	1.8024	0.5967	0.2654	0.2675	0.4321	13
CF6	1.3777	0.7806	0.6902	0.6954	0.7380	1
CF7	1.6403	0.6557	0.4276	0.4309	0.5433	10
CF8	1.6864	0.6377	0.3814	0.3844	0.5110	11
CF9	1.5833	0.6792	0.4845	0.4882	0.5837	8
CF10	1.5222	0.7065	0.5457	0.5499	0.6282	6
CF11	1.4531	0.7401	0.6148	0.6195	0.6798	3
CF12	1.4762	0.7286	0.5917	0.5962	0.6624	5
CF13	1.4736	0.7298	0.5943	0.5988	0.6643	4
S_0^+	1.0755	S_0^-	0.9924			

3.5 Results of MOOSRA Algorithm

At this phase in the research, the financial success rankings of the cement industry firms examined in the framework of the current study were based on the MOOSRA methodology. Eqs. (22-23) were used with the initial matrix to perform the calculations related to the MOOSRA procedure. The outcome is displayed in Table 7.

Table 7 Findings of MOOSRA *Algorithm*

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	$\sum \max_{ij}$	$\sum \min_{ij}$	S_i	Ranking
CF1	0.0251	0.0286	0.0328	0.0272	0.0177	0.0190	0.0160	0.0156	0.0035	0.0056	0.1544	0.0367	4.2059	2
CF2	0.0186	0.0296	0.0186	0.0187	0.0433	0.0382	0.0178	0.0199	0.0061	0.0143	0.1436	0.0814	1.7639	10
CF3	0.0212	0.0148	0.0296	0.0280	0.0343	0.0323	0.0131	0.0187	0.0066	0.0073	0.1392	0.0666	2.0891	7
CF4	0.0153	0.0047	0.0181	0.0233	0.0722	0.0500	0.0214	0.0180	0.0095	0.0143	0.1246	0.1222	1.0191	12
CF5	0.0081	0.0005	0.0152	0.0250	0.1356	0.0733	0.0212	0.0093	0.0037	0.0066	0.0895	0.2088	0.4287	13
CF6	0.0460	0.0466	0.0239	0.0231	0.0194	0.0179	0.0144	0.0111	0.0037	0.0071	0.1760	0.0373	4.7192	1
CF7	0.0244	0.0344	0.0081	0.0102	0.0459	0.0323	0.0154	0.0150	0.0071	0.0248	0.1395	0.0782	1.7827	9

CF8	0.0175	0.0386	0.0123	0.0181	0.0827	0.0502	0.0196	0.0153	0.0046	0.0139	0.1399	0.1328	1.0534	11
CF9	0.0147	0.0027	0.0366	0.0365	0.0359	0.0320	0.0172	0.0167	0.0027	0.0034	0.1305	0.0680	1.9205	8
CF10	0.0182	0.0115	0.0287	0.0299	0.0481	0.0411	0.0183	0.0120	0.0435	0.0641	0.2262	0.0891	2.5384	6
CF11	0.0301	0.0420	0.0104	0.0087	0.0191	0.0202	0.0096	0.0184	0.0062	0.0313	0.1568	0.0392	3.9983	3
CF12	0.0351	0.0776	0.0165	0.0164	0.0412	0.0369	0.0229	0.0172	0.0107	0.0288	0.2251	0.0781	2.8818	5
CF13	0.0285	0.0476	0.0353	0.0332	0.0335	0.0317	0.0197	0.0128	0.0075	0.0099	0.1944	0.0652	2.9803	4

3.6 Results of MAIRCA Algorithm

Another decision-making procedure utilized in calculating the financial performance rankings of firms in the cement industry is the MAIRCA methodology. This procedure involved the use of Eqs. (24-30) to rank the respective firms. MAIRCA method results obtained as a result of the assessments are given in Table 8.

Table 8 Findings of MAIRCA *Algorithm*

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	U_i	Ranking
CF1	0.0039	0.0064	0.0009	0.0022	0.0000	0.0002	0.0026	0.0018	0.0037	0.0064	0.0280	4
CF2	0.0050	0.0062	0.0042	0.0043	0.0035	0.0040	0.0019	0.0000	0.0035	0.0054	0.0380	9
CF3	0.0046	0.0082	0.0016	0.0021	0.0023	0.0028	0.0037	0.0005	0.0034	0.0062	0.0353	8
CF4	0.0057	0.0095	0.0043	0.0032	0.0074	0.0063	0.0006	0.0008	0.0031	0.0054	0.0463	11
CF5	0.0070	0.0100	0.0050	0.0028	0.0160	0.0109	0.0006	0.0044	0.0037	0.0063	0.0666	13
CF6	0.0000	0.0040	0.0029	0.0032	0.0002	0.0000	0.0031	0.0036	0.0037	0.0062	0.0271	3
CF7	0.0040	0.0056	0.0066	0.0064	0.0038	0.0028	0.0028	0.0020	0.0034	0.0043	0.0417	10
CF8	0.0053	0.0051	0.0056	0.0045	0.0088	0.0064	0.0012	0.0019	0.0036	0.0055	0.0478	12
CF9	0.0058	0.0097	0.0000	0.0000	0.0025	0.0028	0.0021	0.0013	0.0038	0.0066	0.0346	7
CF10	0.0051	0.0086	0.0018	0.0016	0.0041	0.0046	0.0017	0.0032	0.0000	0.0000	0.0308	5
CF11	0.0029	0.0046	0.0061	0.0067	0.0002	0.0005	0.0049	0.0006	0.0034	0.0036	0.0336	6
CF12	0.0020	0.0000	0.0047	0.0049	0.0032	0.0037	0.0000	0.0011	0.0030	0.0039	0.0265	2
CF13	0.0032	0.0039	0.0003	0.0008	0.0021	0.0027	0.0012	0.0029	0.0033	0.0059	0.0264	1

3.7 Results of Borda Count Algorithm

In this section of the present case analysis, the Borda Counting methodology was utilized to aggregate the different success rankings obtained within the CRADIS, MOOSRA and MAIRCA procedures. The fundamental objective of the Borda Counting procedure is to identify the most financially successful alternative by objectively ranking the decision alternatives. The Borda Counting algorithm is predicated on the following methodology: the lowest ranked alternative is given a point value of 0 and the highest ranked alternative is given a point value of m-1 (m=number of alternatives) to calculate the final ranking of the cement firms. In the end stage of the decision process, the Borda scores were summed up and the total Borda score was calculated for each alternative. The results of the calculation of the Borda Counting algorithm are reported in Table 9.

Table 9 Findings of Borda Count *Algorithm*

	CRADIS Ranking	Borda Point	MOOSRA Ranking	Borda Point	MAIRCA Ranking	Borda Point	Total Borda Point	Ranking
CF1 (AFYON)	2	11	2	11	4	9	31	2

CF2 (AKCNS)	9	4	10	3	9	4	11	9
CF3 (BASCM)	7	6	7	6	8	5	17	7
CF4 (BTCIM)	12	1	12	1	11	2	4	12
CF5 (BSOKE)	13	0	13	0	13	0	0	13
CF6 (BUCIM)	1	12	1	12	3	10	34	1
CF7 (CMENT)	10	3	9	4	10	3	10	10
CF8 (CIMSA)	11	2	11	2	12	1	5	11
CF9 (GOLTS)	8	5	8	5	7	6	16	8
CF10 (KONYA)	6	7	6	7	5	8	22	6
CF11 (NIBAS)	3	10	3	10	6	7	27	4
CF12 (NUHCM)	5	8	5	8	2	11	27	4
CF13 (OYAKC)	4	9	4	9	1	12	30	3

The financial success rankings of the cement firms whose shares are listed on BIST, as shown in Table 9, indicate that CF6 (BUCIM), CF1 (AFYON) and CF13 (OYAKC) are the three firms that will be more financially successful than other firms in 2023. On the other hand, CF5 (BSOKE), CF4 (BTCIM) and CF8 (CIMSA) are the three firms that will be financially more less successful than other cement firms in the same period.

4. Sensitivity Analysis

This section involves the implementation of various sensitivity analyses, with the objective of assessing the reliability of the proposed decision algorithm, in line with the scope of the study. In the initial stage of the sensitivity analyses, the impact of changing the weight coefficients on the final ranking is examined. In the subsequent stage, the impact of reversing the ranking on the final ranking was examined.

4.1 Assessment of the Effect of Changes in Final Criterion Weights on the Ranking of Alternatives

In any decision-making analysis, testing the validity of weighting and ranking results through various scenarios is of great importance for the reliability and effectiveness of the analysis results. A number of approaches have been applied in the literature to check the weights of the criteria [43], [44], [33]. In the current work, in order to investigate the effect of criterion weight values on the first ranking results, 20 scenarios were formed in which the most effective criterion was decreased by 2% in each scenario and the other 9 criteria were increased proportionally. Afterwards, the computed weight values were imported into the CRADIS, MOOSRA and MAIRCA methodologies, respectively, and the new rankings obtained were combined according to the Borda counting procedure. The ranking results obtained under 20 different scenarios are present in Figure 2. The findings of Figure 2 indicate that there are no important changes in the final rankings of the cement firms.

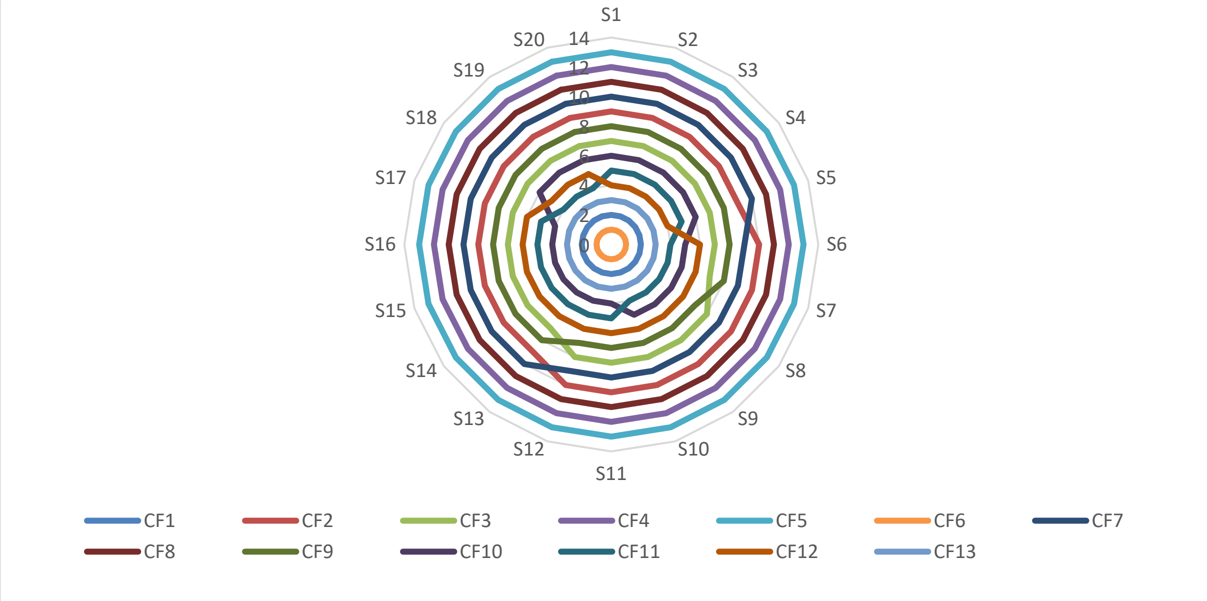

Figure 2 Analysis of the effect of changes in the weighting of criteria on the ranking of firms

4.2 Analyzing the Effect of Ranking Reversal on Final Ranking

In the second and final section of the sensitivity analysis, the effect of the ranking reversal phenomenon on the final ranking, as recommended by Zolfani *et al.,* [45], was analyzed. In this context, considering the ranking results obtained from the Borda Count procedure, the most unsuccessful cement firm in terms of financial performance was excluded from the analysis in each scenario until the most successful firm remained. The results of 13 different scenarios are illustrated in Figure 3. The findings of Figure 3 demonstrate that the elimination of the most successful company from the study does not lead to significant changes in the final ranking.

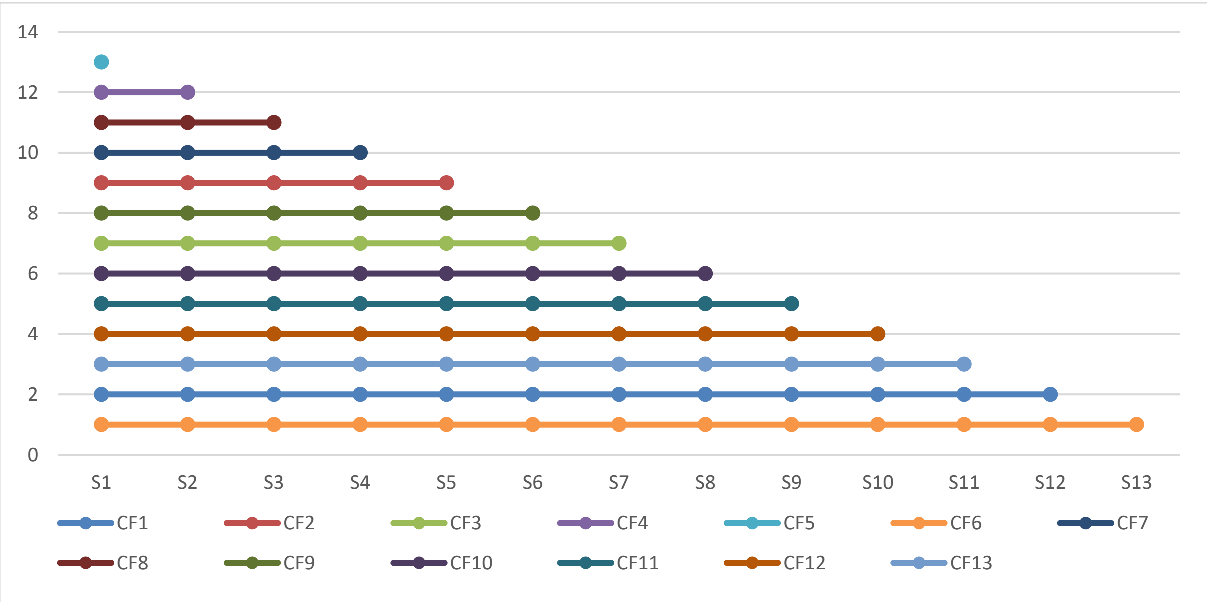

Figure 3 Ranking of findings based on excluding the best alternative from the assessment

5. Conclusions

The cement industry, which is one of the main components of the economic development of countries, is of strategic importance for the implementation of infrastructure projects, the satisfaction of real estate requirements and industrial investments. Given the capital-intensive nature of the cement industry, its significant energy consumption, its dependence on natural resources and its detrimental impact on the environment, the financial performance assessments to be conducted for this sector are critical to the sustainability and competitive advantage of firms. The performance measurements to be performed for the industry in question help internal and external stakeholders to implement more successful policies on issues such as liquidity, profitability, market success, cost efficiency and debt management. Given the cement sector's vulnerability to economic changes, economic fluctuations, abrupt changes in exchange rates and significant regulatory constraints, performance measurement becomes an even more important issue for the sector. The regular, objective assessment of financial performance will help both internal and external stakeholders to make more informed decisions, optimize resource costs and achieve a sustainable competitive advantage in the sector. In light of the aforementioned reasons, this research presents a new integrated decision making algorithm to decision makers for the comparative assessment of firm performance. The decision-making algorithm proposed consists of the integration of LOPCOW, MSD, CRADIS, MOOSRA, MAIRCA and Borda Counting techniques. Of these, LOPCOW and MSD procedures are preferred for the objective weighting of the performance indicators chosen to assess the firm's performance. The CRADIS, MOOSRA, MAIRCA and Borda Count approaches were applied to rank the decision alternatives analyzed in the research. In order to test the effectiveness and applicability of the integrated algorithm presented for decision makers in the present paper, a real-time case study was executed. The focus of this case study is the financial performance of 13 cement firms whose stocks are listed on the BIST for the year 2023.

In the first part of the analysis process, the final criteria weights calculated within the framework of the LOPCOW and MSD algorithms show that the three performance criteria that have the most significant impact on the financial performance of cement firms in 2023 are ratio of total debt to total equity, ratio of total debt to total assets and cash ratio. On the other hand, it is found that the three performance criteria that have the least impact on the financial performance of cement firms in the same period are market value to book value ratio, inventory turnover ratio and receivables turnover ratio.

In the second section of the assessment process, CRADIS, MOOSRA and MAIRCA algorithms were employed to identify the cement firms' performance rankings. The different ranking results obtained by these decision algorithms were integrated using the Borda counting algorithm. This approach yielded a more objective financial success ranking for each firm. The empirical findings obtained according to the Borda Counting procedure indicate that BUCIM is the most financially successful cement industry company in 2023. Nevertheless, the findings indicated that this firm is followed by AFYON > OYAKC > NUHCM = NIBAS > KONYA > BASCM > GOLTS > AKCNS > CMENT > CIMSA > BTCIM > BSOKE, respectively.

The current paper proposes a structured conceptual framework that can support data-driven decision making for both internal and external stakeholders and other interest groups. The empirical findings of this paper provide important insights for investors, firm managers, decision makers, policy makers, financial analysts, etc. The empirical findings of this paper provide important insights for investors, firm managers, decision makers, policy makers, financial analysts, etc. For investors, by applying the data obtained from the study, investors can make more informed investment decisions. The decision algorithm suggested in the research will allow investors to include more financially strong firms in their existing portfolios. This approach enables the optimization of portfolios and the balancing of risk and return. With regard to the role of firm managers and the decision-making processes within firms, the study's findings can serve as a guide for these mechanisms in the identification of firms' strengths and weaknesses. Furthermore, the findings of the study can be utilized in developing new financial strategies, increasing the efficiency level of the firm and monitoring the practices of leading firms in the industry. In addition, firms with lower financial performance in comparison to other firms can use the results of the study to make improvements in various areas such as profitability, leverage, liquidity and market performance and help the firm to gain a sustainable competitive advantage in the sector. Consequently, the findings of the present case study can be utilized as a reference point for assessing the performance of the industry and in the process of identifying the current situation of the firms by financial analysts and researchers.

In the end, the study, which focuses on analyzing the financial performance of firms in the BIST cement industry, has some limitations. These limitations are as follows: the dataset preferred, the time period of analysis and the sample in the current case study. Additionally, the exclusive utilization of objective weighting algorithms and classical ranking algorithms in the study can be described as a limitation. Thus, taking into account these issues, the existing literature can be enriched by selecting different time periods, different industries and different samples in future studies. The incorporation of subjective weighting algorithms, fuzzy sets and decision-making procedures based on grey system theory has the potential to further contribute to the existing literature.

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Conflicts of Interest
“The author/s declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper”.

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References

[1] Eleren, A. & Karagül, M. (2008). 1986-2006 Türkiye ekonomisinin performans değerlendirmesi. *Yönetim ve Ekonomi Dergisi*, *15*(1), 1-14.
[2] Ulusoy, A., & Kara, D. (2017). Kamu borç yönetiminin maliye ve para politikası ile uyum sorunu: Türkiye pratiği. *Maliye Araştırmaları Dergisi*, *3*(1), 29-38.
[3] Rezaie, K., Ramiyani, S. S., Nazari-Shirkouhi, S. & Badizadeh, A. (2014). Evaluating performance of Iranian cement firms using an integrated fuzzy AHP–VIKOR method, *Applied Mathematical Modelling*, 38, 5033-5046. https://doi.org/10.1016/j.apm.2014.04.003

[4] Ershad, S., Uddin, M., & Faruk, M. (2021). Analysis on the financial performance of selected cement industries of bangladesh. International *Journal of Finance Research, 2*(1), 46-57. https://doi.org/10.47747/ijfr.v2i1.334

[5] Mizan, A. N. K. and Hossain, M. (2014). Financial soundness of cement industry of bangladesh: an empirical investigation using z-score. *American Journal of Trade and Policy, 1*(1), 16. https://doi.org/10.15590/ajtp/2014/v1i1/54044

[6] Rezina, S., Ashraf, A., & Khan, M. (2020). An inferential study on the profitability determinants of the cement industry in bangladesh. *Asian Finance & Banking Review, 4*(2), 8-21. https://doi.org/10.46281/asfbr.v4i2.684

[7] Durastanti, C. and Moretti, L. (2020). Environmental impacts of cement production: a statistical analysis. *Applied Sciences, 10*(22), 8212. https://doi.org/10.3390/app10228212

[8] Davidová, V., David, T., & Reiterman, P. (2024). Utilization of high fly ash dosage to reduce cement consumption in concrete formulations. *Acta Polytechnica Ctu Proceedings*, 47, 15-18. https://doi.org/10.14311/app.2024.47.0015

[9] Al-Bakri, A., Ahmed, H., & Hefni, M. (2022). Cement kiln dust (ckd): potential beneficial applications and eco-sustainable solutions. *Sustainability, 14*(12), 7022. https://doi.org/10.3390/su14127022

[10] Jia, X. and Luo, X. (2023). Residents' health effect of environmental regulations in coal-dependent industries: empirical evidence from china's cement industry. *Sustainability, 15*(3), 2512. https://doi.org/10.3390/su15032512

[11] Esbouei, S. K., Ghadikolaei, A. S., & Antucheviciene, J. (2014). Using FANP and Fuzzy VIKOR for ranking manufacturing companies based on their financial performance. *Economic Computation & Economic Cybernetics Studies & Research, 48*(3), 141-162.

[12] Moghimi, R. and Anvari, A. (2014). An integrated Fuzzy MCDM approach and analysis to evaluate the financial performance of Iranian cement companies. The International Journal of Advanced Manufacturing Technology, *71*(1-4), 685-698. https://doi.org/10.1007/s00170-013-5370-6

[13] Safaei Ghadikolaei, A., Khalili Esbouei, S., & Antucheviciene, J. (2014). Applying fuzzy MCDM for financial performance evaluation of Iranian companies. *Technological and Economic Development of Economy*, *20*(2), 274-291. http://dx.doi.org/10.3846/20294913.2014.913274

[14] Tavana, M.,Khalili-Damghani, K., Rahmatian, R. (2015). A hybrid fuzzy MCDM method for measuring the performance of publicly held pharmaceutical companies. *Annals of Operations Research, 226*(1), 589-621. https://doi.org/10.1007/s10479-014-1738-8

[15] Shaverdi, M., Ramezani, I., Tahmasebi, R., & Rostamy, A. A. A. (2016). Combining fuzzy AHP and fuzzy TOPSIS with financial ratiosto design a novel performance evaluation model. *International Journal of Fuzzy Systems, 18*(2), 248- 262. https://doi.org/10.1007/s40815-016-0142-8

[16] Anthony, P., Behnoee, B., Hassanpour, M., &Pamucar, D. (2019). Financial performance evaluation of seven Indian chemical companies. *Decision Making: Applications in Management and Engineering, 2*(2), 81-99. https://doi.org/10.31181/dmame1902021a

[17] Işık, Ö. (2019). Entropi ve TOPSIS yöntemleriyle finansal performans ile pay senedi getirileri arasındaki ilişkinin incelenmesi. *Kent Akademisi*, *12*(1), 200-213.

[18] Aydın, Y. (2020) Finansal performans ile pay senedi getirisi arasındaki ilişkinin Entropi ve MAUT ÇKKV teknikleriyle değerlendirilmesi: BİST kimya, petrol, kauçuk ve plastik ürünler sektörü firmalarından kanıtlar. *Bilecik Şeyh Edebali Üniversitesi Sosyal Bilimler Dergisi*, TBMM 100. Yıl Özel Sayısı,164-185. https://doi.org/10.33905/bseusbed.773541

[19] Deng, Y., Zou, S., & You, D. (2020). Financial performance evaluation of nuclear power-related enterprises from the perspective of sustainability. *Environmental Science and Pollution Research*, *27*, 11349-11363. https://doi.org/10.1007/s11356-019-07545-1

[20] Işık, Ö., & Koşaroğlu, Ş. M. (2020). Analysis of the financial performance of Turkish listed oil companies through the application of SD and MAUT methods. *Third Sector Social Economic Review*, *55*(3), 1395-1411. http://dx.doi.org/10.15659/3.sektor-sosyal-ekonomi.20.06.1378

[21] Bozdoğan, T., Odabas, A., & Çetin, Ö. O. (2023). Financial performance of BIST-Cement companies analysis by TOPSIS and ELECTRE methods. Dumlupınar Üniversitesi Sosyal Bilimler Dergisi, (78), 491-510. https://doi.org/10.51290/dpusbe.1368085

[22] Lukic, R., Kljenak, D. V., & Anđelić, S. (2020). Analyzing financial performances and efficiency of the retail food in Serbia by using the AHP–TOPSIS method. *Економика пољопривреде*, *67*(1), 55-68. doi:10.5937/ekoPolj2001055L

[23] Akbulut, O. Y. (2020). Finansal performans ile pay senedi getirisi arasındaki ilişkinin bütünleşik CRITIC ve MABAC ÇKKV teknikleriyle ölçülmesi: Borsa İstanbul çimento sektörü firmaları üzerine ampirik bir uygulama. *Pamukkale Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, (40), 471-488. https://doi.org/10.30794/pausbed.683330

[24] Ban, A. I., Ban, O. I., Bogdan, V., Popa, D. C. S., & Tuse, D. (2020). Performance evaluation model of Romanian manufacturing listed companies by fuzzy AHP and TOPSIS. *Technological and Economic Development of Economy*, *26*(4), 808-836. https://doi.org/10.3846/tede.2020.12367

[25] Akbulut, O. Y. & Hepşen, A. (2021). Finansal performans ve pay senedi getirileri arasındaki ilişkinin Entropi ve CoCoSo ÇKKV teknikleriyle analiz edilmesi. *Ekonomi Politika ve Finans Araştırmaları Dergisi*, *6*(3), 681-709. https://doi.org/10.30784/epfad.945770

[26] Pala, O., Atçeken, Ö., Omurtak, H., & Şimşir, B. (2024). BİST çimento sektöründe LODECI ve CRADIS ile finansal performans analizi. *Alanya Akademik Bakış*, *8*(3), 956-970. https://doi.org/10.29023/alanyaakademik.1452960

[27] Ecer, F., & Pamucar, D. (2022). A novel LOPCOW-DOBI multi-criteria sustainability performance assessment methodology: An application in developing country banking sector. *Omega*, 112, 102690. https://doi.org/10.1016/j.omega.2022.102690

[28] Işık, Ö., Shabir, M., & Moslem, S. (2024). A hybrid MCDM framework for assessing urban competitiveness: A case study of European cities. *Socio-Economic Planning Sciences*, *96*, 102109. https://doi.org/10.1016/j.seps.2024.102109

[29] Puška, A., Nedeljković, M., Šarkoćević, Ž., Golubović, Z., Ristić, V., & Stojanović, I. (2022). Evaluation of agricultural machinery using multi-criteria analysis methods. Sustainability, 14(14), 8675. https://doi.org/10.3390/su14148675

[30] Puška, A., Stević, Ž., & Pamučar, D. (2022). Evaluation and selection of healthcare waste incinerators using extended sustainability criteria and multi-criteria analysis methods. *Environment, Development and Sustainability*, 1-31. https://doi.org/10.1007/s10668-021-01902-2

[31] Akbulut, O. Y. & Aydın, Y. (2024). A hybrid multidimensional performance measurement model using the MSD-MPSI-RAWEC model for Turkish banks. J*ournal of Mehmet Akif Ersoy University Economics and Administrative Sciences Faculty, 11*(3), 1157- 1183. https://doi.org/10.30798/makuiibf.1464469

[32] Yazdani M, Pamucar D, Chatterjee P, Torkayesh AE (2022) A multi-tier sustainable food supplier selection model under uncertainty. *Oper Manag Res 15*(1),116–145. https://doi.org/10.1007/s12063-021-00186-z

[33] Akbulut, O. Y. (2024). Assessing the environmental sustainability performance of the banking sector: A novel integrated grey Multi-Criteria Decision-Making (MCDM) approach, *International Journal of Knowledge and Innovation Studies 2*(4). 239–258. https://doi.org/10.56578/ijkis020404

[34] Işık, Ö., Shabir, M., Demir, G., Puska, A., & Pamucar, D. (2025). A hybrid framework for assessing Pakistani commercial bank performance using multi-criteria decision-making. *Financial Innovation, 11*(1), 38. https://doi.org/10.1186/s40854-024-00728-x

[35] Puška, A., & Stojanović, I. (2022). Fuzzy multi-criteria analyses on green supplier selection in an agri-food company. *J. Intell. Manag. Decis*, *1*(1), 2-16. https://doi.org/10.56578/jimd010102

[36] Işık, Ö., & Adalar, İ. (2025). A multi-criteria sustainability performance assessment based on the extended CRADIS method under intuitionistic fuzzy environment: a case study of Turkish non-life insurers. *Neural Computing and Applications*, *37*(5), 3317-3342. https://doi.org/10.1007/s00521-024-10803-0

[37] Das, M. C., Sarkar, B., & Ray, S. (2012). Decision making under conflicting environment: a new MCDM method. *International Journal of Applied Decision Sciences,* 5(2), 142-162. https://doi.org/10.1504/IJADS.2012.046505

[38] Jagadish, J., & Ray, A. (2014). Green cutting fluid selection using MOOSRA method. *International Journal of Research in Engineering and Technology*, *3*(3), 559-563.

[39] Pamučar, D., Vasin, L., & Lukovac, V. (2014). Selection of railway level crossings for investing in security equipment using hybrid DEMATEL-MARIC model. In XVI International Scientifcexpert Conference on Railways, Railcon, Niš (pp. 89–92). https://doi.org/10.13140/2.1.2707. 6807

[40] Akbulut, O. Y., & Gümüskaya, T. (2022). Hayat dışı sigorta sektöründe finansal performansın bütünleşik AHP-SV ve MAIRCA yöntemleri ile analizi. *Third Sector Social Economic Review*, *57*(3), 2426-2448. http://dx.doi.org/10.15659/3.sektor-sosyal-ekonomi.22.09.1941

[41] Işık, Ö., Çalık, A., & Shabir, M. (2025). A consolidated MCDM framework for overall performance assessment of listed insurance companies based on ranking strategies. *Computational Economics*, 65, 271–312. https://doi.org/10.1007/s10614-024-10578-5

[42] De Borda, J. C. (1781). M'emoire sur les' elections au scrutin. Histoire de l'Acad'emie Royale des Sciences.

[43] Božanić, D., Milić, A., Tešić, D., Salabun, W., & Pamučar, D. (2021). D numbers–FUCOM–fuzzy RAFSI model for selecting the group of construction machines for enabling mobility. *Facta Universitatis, Series: Mechanical Engineering*, *19*(3), 447-471. https://doi.org/10.22190/FUME210318047B.

[44] Işık, Ö., Shabir, M., & Belke, M. (2023). Is there a causal relationship between financial performance and premium production? Evidence from Turkish insurance industry. Journal of Mehmet Akif Ersoy University Economics and Administrative Sciences Faculty, 10(2), 1388-1412.

[45] Zolfani, S. H., Görçün, Ö. F., & Küçükönder, H. (2021). Evaluating logistics villages in Turkey using hybrid improved fuzzy SWARA (IMF SWARA) and fuzzy MABAC techniques. *Technological and Economic Development of Economy, 27*(6), 1582-1612. https://doi.org/10.3846/tede.2021.16004