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CRiterion Importance Based on SUm of Squares (CRISUS): A Novel Objective Weighting Method and Its Implementation in Multidimensional Sustainability Performance Measurement

Abstract. *Analysing multidimensional corporate sustainability performance is a highly complex and critical decision-making challenge that requires consideration of multiple and often conflicting performance criteria. To address this challenge, a novel methodological approach that integrates the CRiterion Importance based on the SUm of Squares (CRISUS) procedure and the Root Assessment Method (RAM) procedure has been proposed in the present research. The proposed framework employs a newly developed weighting technique, CRISUS, to ascertain the objective importance weights of performance criteria and the RAM algorithm to rank the performance of decision alternatives. To demonstrate the applicability and aptness of the proposed decision-making methodology, a real case study involving seven BIST-listed food and beverage (F&B) firms and seven assessment criteria based on financial, environmental, social, and governance indicators is selected. Lastly, the robustness check conducted to ascertain the validity of the developed hybrid framework has confirmed the accuracy and stability of the outputs produced by the model.*

Keywords: *CRISUS, corporate sustainability, performance measurement, RAM, food and beverage industry.*

JEL Classification: C44, C63, D80, Q56, L20.

Received: 30 January 2025	Revised: 24 May 2025	Accepted: 12 June 2025

1. Introduction

Performance analysis is a pivotal and intricate process, entailing the evaluation and measurement of a firm's performance in relation to established goals, criteria, and standards (Hsu et al., 2024). This process encompasses the gathering, analysis, and interpretation of data, with the objective of determining whether or to what extent the firm has achieved its predefined goals.

A performance analysis based on financial metrics provides important insights into a firm's financial stability, competitiveness, efficiency, profitability, growth strategy, and overall financial condition for a range of stakeholders, including

DOI: 10.24818/18423264/59.2.25.13

financial analysts, investors, shareholders, and executive management. Measuring firm performance through financial ratios also plays a critical role in identifying potential risks related to liquidity, debt, and market conditions (Hoang et al., 2024). However, firm performance assessment is a multifaceted process, influenced by a range of financial and non-financial variables. Gauging firm's performance based solely on financial indicators is not sufficient for a comprehensive assessment and may lead to a one-sided and incomplete assessment, as it ignores crucial non-financial factors that influence long-term success and sustainability.

In the contemporary business environment, which is characterised by intense competition and rapid technological change, firms must employ a combination of financial and non-financial performance indicators to enhance the efficiency of their business processes and develop resilient business models. Considering non-financial metrics such as environmental, social, and governance (ESG) indicators in gauging firm performance provides a more holistic view of a firm's overall health and sustainability. This approach not only improves traditional financial performance, assessment but also aligns business practices with wider societal and environmental aims. Additionally, the measurement, analysis, and assessment of a firm's performance, encompassing both financial and non-financial aspects, is an important opportunity for the firm to develop and grow and to gain a competitive advantage. However, performance analysis is a highly complicated and critical decision-making problem that requires a multitude of factors and a reliable assessment framework.

MCDM (Multiple Criteria Decision Making) is a subdiscipline of operational research that handles decision problems in which there are multiple and potentially conflicting decision criteria. It offers a powerful methodological framework for resolving the inherent multi-objective nature of the performance measurement problem. Hence, the multi-dimensional, intricate, and conflicting nature of firm performance necessitates the utilisation of MCDM methodologies in the performance measurement process.

MCDM methodologies provide a systematic and objective approach to the assessment of multiple firms based on a set of performance metrics. It utilises simple and trustworthy soft computational techniques that have minimal complexity and offers a sound and efficient framework for decision-making (Hsu et al., 2024).

Multi-criteria decision support algorithms facilitate the transformation of data comprising multiple and potentially conflicting metrics into a single performance assessment score, thereby ensuring a more consistent and rational evaluation of organisational performance. Furthermore, they provide a decision support system for decision-makers (DMs) and practitioners in formulating pragmatic decision-making processes. Additionally, they present an effective and well-organised assessment framework that simplifies comparisons between firms.

The present paper aims to address the issue of performance evaluation. It puts forth a novel multi-criteria decision model for the analysis of the multi-dimensional performance based on financial, environmental, social, and governance indicators. The developed decision model comprises two decision-making algorithms. In this context, the CRiterion Importance based on SUm of Squares (CRISUS) procedure,

which was developed in the present work, is used to ascertain the objective importance weights of the criteria. Subsequently, the alternatives within the decision problem are ranked in accordance with the predetermined performance criteria using the Root Assessment Method (RAM) approach, which was recently introduced to the literature by Sotoudeh-Anvari (2023). To demonstrate the practical application of the developed evaluation framework, a real-world case study of food and beverage (F&B) firms listed on Borsa Istanbul (BIST) is considered based on the data set from Refinitiv Eikon.

The first rationale for the selection of F&B companies with BIST-listed shares as a case study is their indispensable role within the Turkish economy, as well as their substantial contributions to the country's GDP and employment. The second motivation can be associated with the fact that the F&B sector has a significant environmental and social footprint. Key issues such as resource use, waste management, labour, and governance practices are of critical importance to this sector, which makes it an important focal point for a holistic performance analysis. A further rationale for selecting these companies, which play an important role in both local and global supply chains, is the absence of a study within the MCDM literature that gauges and assesses the financial, environmental, social, and governance performance of these companies.

One of the most critical calculations in MCDM problems is the weight determination process. Any computational error, subjectivity, or inconsistency in this process may result in decisions that are unreasonable and inappropriate for DMs and practitioners. In this context, the present study introduces a new objective weighting method called CRISUS, which is straightforward to use, easy to understand, and comparable to other well-known MCDM algorithms for determining the weights of predetermined criteria.

The remaining sections of the present manuscript are structured as follows. In Section 2, following a detailed literature review, the gaps of past works in the existing literature are identified. The introduced hybrid framework and its basic procedure are described in detail in Section 3. In Section 4, the developed decision-making methodology is applied to a case study of F&B firms to assess their overall sustainability performance. In Section 5, a robustness analysis is carried out to verify whether the model yields dependable and effective outcomes. Section 6 presents the managerial implications and theoretical contributions considering the findings of the current research. Finally, Section 7 concludes the existing research, points out the research's limitations, and makes recommendations for future research regarding performance measurement.

2. Literature review

The literature section is divided into two sub-sections. Firstly, a detailed review of past studies focused on solving the firm performance measurement problem with various MCDM approaches is provided. Secondly, the research gaps identified in preceding literature are discussed, and the motivation behind the study is explained.

2.1 Studies applying MCDM approaches for firm performance assessment

To date, a number of studies have attempted to solve the problem of measuring firm performance with MCDM methodologies using various performance indicators in various economic industries. Some of these recent studies are summarised below.

Katrancı et al. (2025) developed an integrated methodology covering the indifference threshold-based attribute ratio analysis (ITARA) and cost estimation, benchmarking, and risk assessment (COBRA) techniques for the financial performance assessment of firms listed on BIST (Borsa İstanbul). Ergülen and Çalık (2024) introduced a hybrid approach combining the Fuzzy Best-Worst Method (F-BWM) and Measurement Alternatives and Ranking According to Compromise Solution (MARCOS) to address the performance measurement of Turkish industrial firms. Hoang et al. (2024) presented a new decision-making methodology by integrating Analytic Hierarchy Process (AHP) and Weighted Aggregated Sum Product Assessment (WASPAS) techniques in a spherical fuzzy context to assess the ESG performance of global electronics companies. Alsanousi et al. (2024) compared the financial performance of Saudi Arabian firms using a novel hybrid model combining the BWM and the order preference by similarity to ideal solution (TOPSIS) approaches. Hsu et al. (2024) analysed the sustainability performance of Taiwanese foundry firms based on environmental, social, economic and institutional performance metrics using a hybrid model including trapezoidal fuzzy ITARA and trapezoidal fuzzy reference ideal method (RIM) methods. Kaya et al. (2024) used the full consistency method (FUCOM) and nine MCDM approaches to assess the financial performance of Turkish firms listed on the BIST sustainability index, considering accounting and market-based financial metrics. Kara et al. (2024) suggested a novel single-valued neutrosophic the criteria importance assessment (CIMAS)-the criteria importance through intercriteria correlation (CRITIC)-the reference-based normalisation alternative ranking (RBNAR) hybrid methodology for the financial performance analysis of Turkish technology firms.

2.2 Research gap analysis and the motivation of the work

A detailed examination of prior studies on firm performance measurement yields the following findings: (i) Most articles in the preceding literature typically employed subjective weighting techniques to compute the criteria weights. In these studies, the weights were predominantly estimated employing AHP or its extensions based on various fuzzy sets. It is widely acknowledged that the most significant drawback associated with subjective weighting methodologies is the inconsistency observed between the opinions of experts who possess disparate levels of knowledge and experience, (ii) Only three of past studies employed objective methodologies, namely Entropy, SD, CRITIC, and LOPCOW, to ascertain the weights, (iii) The majority of past articles adopted traditional MCDM methods like TOPSIS, VIKOR, WASPAS, etc. in determining the success ranking of firms. However, these methods, like AHP, were frequently criticised by researchers on account of its structural

problems, and (iv) The decision-making approaches proposed in past studies were implemented in a variety of real case studies for the purpose of analysing the performance of firms operating in disparate sectors across different countries.

Given the aforementioned findings, several research gaps emerge that require further investigation. Firstly, while subjective weighting techniques, such as AHP, are commonly utilised, their dependence on expert judgments can result in inconsistency across performance evaluation outcomes. On the contrary, objective methodologies can provide DMs with more standardised and reliable outcomes; however, the number of objective techniques is relatively limited compared to the number of subjective techniques. Furthermore, their usage in the existing literature is very scarce. To address these gaps, the current research has developed a novel objective weighting technique, which we call CRISUS, as a novel mathematical tool. In addition, we have presented a new hybrid framework for the assessment of multidimensional sustainability performance by integrating our newly developed CRISUS technique with the RAM technique, which is responsible for determining company rankings. This integrated framework provides DMs and practitioners with a robust, practical, and effective mathematical tool to reach more reasonable and realistic conclusions. Second, an in-depth analysis of the preceding studies, reveals that these studies presented a series of frameworks to evaluate firm performance. This outcome indicates that there was no consensus among researchers on the selection of appropriate performance criteria. In other words, there is no commonly accepted or employed criterion set for gauging firm performance in the earlier literature. To address the second critical research gap, the present research proposes a novel set of criteria, which is derived from the Refinitive database and includes financial, environmental, social, and governance data.

3. Methodological framework

This work proposes a novel hybrid multi-criteria decision support framework for the comparative assessment of the multidimensional sustainability performance of BIST-listed F&B firms. This framework follows a two-stage integrated approach: in Stage 1, the CRISUS is employed to prioritize the evaluation criteria, ensuring an objective weighting mechanism. In Stage 2, the RAM is applied to assess and rank the firms based on the predetermined criteria. The detailed methodological steps involved in the implementation of this hybrid approach are outlined below.

3.1 The CRiterion Importance based on SUm of Squares (CRISUS) procedure

The CRISUS methodology is designed for the purpose of calculating objective weighting coefficients of the performance criteria in the decision problem. It is an analytical technique that utilises the principles of Statistical Variance (Rao and Patel, 2010) and Entropy (Shannon, 1948) weighting methods. Additionally, the CRISUS, which is based on a two-stage normalisation procedure, estimates the objective

weights with the aid of a sum-of-squares operator. The implementation steps for the CRISUS procedure are outlined below:

Step 1. Form initial performance matrix $\tilde{X}$. This matrix includes m alternatives, $A_1, \ldots, A_m$ based on the n criteria, $C_1, \ldots, C_n$.

$$\tilde{X} = \left(\begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \ldots & \tilde{x}_{mn} \end{bmatrix} \right) \quad (1)$$

Step 2. Compute the first normalised matrix $X = (x_{ij})$.

The initial performance matrix is normalised by vector normalisation based on the sum of the Euclidean distances (Van Delft and Nijkamp, 1977). Eqs. (2) and (3) are employed for the benefit and cost-oriented criteria, respectively.

$$x_{ij} = \frac{\tilde{x}_{ij}}{\sqrt{\sum_{i=1}^{m} \tilde{x}_{ij}^2}} \quad (2)$$

$$x_{ij} = 1 - \frac{\tilde{x}_{ij}}{\sqrt{\sum_{i=1}^{m} \tilde{x}_{ij}^2}} \quad (3)$$

Step 3. Obtain the second normalised matrix $S = (s_{ij})$.

The second normalised matrix is formed by converting all elements of the matrix normalised in the preceding step into the interval [0,1] via Eq. (4).

$$s_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (4)$$

Step 4. Find the sum of squares for each criterion.

The $(\rho_j,\ j = 1,2, \ldots, n)$ values, which represent the sum of squares of each criterion in the matrix created in the second normalisation, are found with the aid of Eq. (5):

$$\rho_j = \sum_{i=1}^{m} s_{ij}^2 \quad (5)$$

Step 5. Calculate the standard deviations of each criterion

The standard deviations $(\sigma_j,\ j = 1,2, \ldots, n)$ of each criterion in the matrix generated during the first normalisation process is calculated.

Step 6. Identify the weight coefficients of the criteria

The weight coefficients w_j of the criteria are found through Eq. (6).

$$w_j = \frac{\sigma_j \rho_j}{\sum_{j=1}^{n} \sigma_j \rho_j} \quad (6)$$

3.2 Additional comments about the association between the CRISUS approach and other well-known weighting approach

This section examines the relationship between the CRISUS algorithm and other well-known weighting methods.

The rationale behind the utilisation of the ρ_j observed in step 4 of the CRISUS method is derived from the classical weighting methods such as Statistical Variance and Entropy. The CRISUS method exhibits a high degree of correlation with both of the other two methods. This relationship can be demonstrated mathematically as follows:

(i) The objective criterion weight estimation process proposed by Rao and Patel (2010) is based on the variance seen in Eq. (7).

$$V_j = \sigma_j \sigma_j \tag{7}$$

Here, $\sigma_j = \left(\frac{\sum_{i=1}^{m}(s_{ij}-\bar{s})^2}{m}\right)^{1/2}$ and $\bar{s}$ is arithmetic mean.

On the other hand, when we expand the equation $\left(\sum_{i=1}^{m}(s_{ij}-\bar{s})^2\right)^{\alpha}$ to a binomial series of order ½ (Abramowitz and Stegun 1972: 15), the following expression is obtained.

$$\left(\sum_{i=1}^{m}(s_{ij}-\bar{s})^2\right)^{1/2} = 1 + \frac{\left[\sum_{i=1}^{m}(s_{ij}-\bar{s})^2 - 1\right]}{2} - \cdots$$

$$= 1 + \frac{\left[\sum_{i=1}^{m} s_{ij}^2 - \frac{1}{m} - 1\right]}{2} - \cdots \tag{8}$$

As seen in Eq. (8), the main determining factor in the calculation of σ_j's is ρ_j values. Because, as the number m increases, other non-constant terms in the binomial series expansion converge to 0 much faster and can be neglected.

Accordingly, the criteria weights can be computed by replacing one of the standard deviations seen in Eq. (7) with ρ_j. As a result, the resulting $\sigma_j \rho_j$ values in CRISUS will approach V_j.

(ii) When the Entropy technique is applied to decision-making problems, Eq. (9) is utilised to estimate the objective weights of the criteria.

$$E_j = 1 + k\sum_{i=1}^{m} s_{ij}\ln(s_{ij}) \tag{9}$$

Here, k is the positive constant.

For $|s| < 1$, the expression $\ln(s_{ij})$ is expanded into the Maclaurin series (see: Abramowitz and Stegun 1972: 14), as follows:

$$\ln(s_{ij}) = (s_{ij}-1) - \frac{(s_{ij}-1)^2}{2} + \frac{(s_{ij}-1)^3}{3} - \cdots \tag{10}$$

If Eq. (10) is substituted for the expression $\ln(s_{ij})$ in Eq. (9), the expansion of the series in Eq. (11) is obtained.

$$E_j = 2k\sum_{i=1}^{m} s_{ij}^2 + 1 - \frac{3k}{2} + \cdots \tag{11}$$

As can be seen from Eq. (11), the main role in the calculation of E_j is played by the expression ρ_j . The number k, introduced as Boltzman's constant in thermodynamics is chosen as $1/\ln(m)$ in the implementation of decision making problems. This indicates that the same k number is employed for each criterion. Whereas, to gauge the uncertainty in decision-making problems more precisely and accurately, it can be suggested that the number k should be a variable number according to each criterion. Thus, when the number $2k$ in Eq. (11) is replaced by the standard deviations found for each criterion, the values of $\sigma_j \rho_j$ are very close to the values of E_j.

3.3 Root Assessment Method (RAM)

The RAM method, which employs an aggregation function based on root evaluation to ascertain the order of decision alternatives, was developed by Sotoudeh-Anvari (2023)**.** The steps of the RAM method are as follows.

Step 1. Construct the initial performance matrix presented in Eq. (1).

Step 2. Form the normalised performance matrix with the aid of Eq. (12).

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{12}$$

Step 3. Obtain the weighted normalised performance matrix via Eq. (13).

$$z_{ij} = r_{ij} w_j \tag{13}$$

Step 4. Find the sums of the weighted normalised values of the beneficial criteria and non-beneficial criteria for each alternative using Eqs. (14) and (15), respectively. In the following equations, U_i and L_i denote the sum of the weighted normalised values of beneficial and non- beneficial criteria, respectively.

$$U_i = \sum_{j=1}^{n} z_{ij}, for\ benefical\ criteria \tag{14}$$

$$L_i = \sum_{j=1}^{n} z_{ij}, for\ non-benefical\ criteria \tag{15}$$

Step 5. Compute the final ranking score of each alternative with the help of the following aggregating function:

$$P_i = \sqrt[2+L_i]{2+U_i} \tag{16}$$

Here, P_i denotes final ranking scores for alternatives. The alternative with the greatest value of P_i is identified as the best option.

4. Case study

To provide a practical illustration of the developed integrated MCDM model, this section conducts a case study analyzing select F&B firms traded on the BIST. It

includes three sub-sections: the first outlines the criteria, the second introduces the firms, and the final applies the model and presents the results.

4.1 Definition of criteria

Environmental performance (C_1) represents a firm's ability to leverage environmental opportunities and implement best management practices aimed at mitigating environmental risks. It is assessed based on three subcategories: resource use, emissions, and product innovation.

Social performance (C_2) which encompasses four subcategories: product responsibility, human rights, labour, and community, is a measure of a firm's reputation and responsibility.

Corporate governance performance (C_3) which encompasses three subcategories such as corporate social responsibility strategy, shareholder relations, and management practices, refers to a firm's capacity to follow the best corporate governance principles.

The market-to-book ratio (C_4) represents a significant financial indicator, calculated as the ratio of market capitalisation to total book value. A high value for this ratio may be indicative of an overvaluation of the company or the presence of significant intangible assets, such as brand reputation or intellectual property. Conversely, a low value for this ratio may be indicative of an undervalued company or one experiencing financial distress.

The ratio of earnings before interest, taxes, depreciation, and amortisation to total assets (C_5) is an accounting-based financial metric used to assess a firm's operating performance. This ratio measures the company's profitability before the influence of non-operating expenses such as interest, taxes, depreciation, and amortisation, thus providing insight into the company's ability to generate profits from its core operations.

The ratio of total liabilities to total assets (C_6) is an accounting-based financial indicator that provides insight into a firm's financial leverage and overall risk. It demonstrates what proportion of a firm's assets are financed by liabilities (i.e., debts). A higher liability-asset ratio suggests that a larger portion of the firm's assets is financed through debt, which can imply higher financial risk. Conversely, a lower liability-asset ratio indicates that a greater portion of the firm's assets is funded by equity, suggesting a more stable financial structure.

Price volatility (C_7) is a market-based financial measure of the average annual price movement of a stock from the average price to the high and low for each year.

4.2 Definition of alternative firms

The existing research utilises financial and non-financial criteria for the multidimensional sustainability performance measurement of F&B companies. In this context, a set of seven performance indicators derived from the Refinitiv Eikon database is employed as assessment criteria. The first five of these criteria are

categorised as benefit-based, while the remaining two are delineated as cost-based criteria. These performance criteria are explained in detail below.

The firm included in the case study are among the leading players in Turkey's F&B sector, and their stocks are listed on BIST. These companies, which dominate their markets with a wide range of products and strong brand recognition, are distinguished entities such as Anadolu Efes (A_1), BİM (A_2), Coca-Cola İçecek (A_3), Migros (A_4), ŞOK Marketler (A_5), Tat Gıda (A_6), and Ülker (A_7). The financial and non-financial performance data pertaining to these firms were sourced from the Refinitiv Eikon database in 2022.

4.3 Application and results of newly developed method based on CRISUS and RAM prosecutes

4.3.1 Determining the criterion objective weights via CRISUS method

In this part, the results of the weight determination process using CRISUS are presented. The decision problem contains seven performance criteria and seven decision alternatives. All criteria except C6 and C7 are benefit-oriented criteria. Table 1 shows the initial performance matrix. The first normalised performance matrix is constructed by applying Eqs. (2) and (3). This matrix is shown in Table 2. The second normalised matrix is obtained with the aid of Eq. (4) and are provided in Table 3. The sum of the squares of the criteria (ρ_j) in the matrix constructed during the second normalisation process is obtained with Eq. (5). In the next step, the standard deviations of each criterion (σ_j) is computed. In the last step of the CRISUS procedure, the objective weight values of the criteria are found via Eq. (6). The ρ_j, σ_j, and w_j values for each criterion are given in Table 4.

The CRISUS model yielded the following results: C4 (market-to-book ratio) was identified as the most critical performance criterion, exerting a significant influence on the multidimensional performance of firms. In contrast, C7 (price volatility) was determined to be the least important criterion for multidimensional performance. The order of importance, from the most significant to the least, is as follows: C4, C5, C1, C6, C3, C2, and C7.

Table 1. The initial performance matrix

Firm	Indicator						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	59.34	86.04	59.04	93.71	8.79	52.62	22.53
A_2	42.13	68.35	70.56	482.65	21.63	74.08	20.71
A_3	85.74	89.43	42.93	172.53	16.09	53.88	25.26
A_4	92.5	94.78	62.34	1260.45	11.88	96.99	32.07
A_5	51.72	59.54	45.62	1553.92	18.6	94.78	25.8
A_6	47.41	72.84	56.29	183.75	13.16	45.32	30.91
A_7	88.25	89.76	41.6	199.59	3.71	83.36	23.89

Source: Data set obtained from Refinitiv Eikon.

Table 2. The first normalised matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.3222	0.4013	0.4057	0.0449	0.2286	0.7320	0.6746
A_2	0.2288	0.3188	0.4849	0.2315	0.5626	0.6227	0.7009
A_3	0.4656	0.4171	0.2950	0.0827	0.4185	0.7256	0.6352
A_4	0.5023	0.4421	0.4284	0.6044	0.3090	0.5060	0.5369
A_5	0.2808	0.2777	0.3135	0.7452	0.4838	0.5173	0.6274
A_6	0.2574	0.3398	0.3868	0.0881	0.3423	0.7692	0.5536
A_7	0.4792	0.4187	0.2859	0.0957	0.0965	0.5754	0.6550

Source: authors' own calculations.

Table 3. The second normalised matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.1270	0.1534	0.1560	0.0237	0.0937	0.1646	0.1539
A_2	0.0902	0.1219	0.1865	0.1223	0.2304	0.1400	0.1599
A_3	0.1836	0.1595	0.1135	0.0437	0.1714	0.1631	0.1449
A_4	0.1980	0.1690	0.1648	0.3194	0.1266	0.1138	0.1225
A_5	0.1107	0.1062	0.1206	0.3937	0.1982	0.1163	0.1431
A_6	0.1015	0.1299	0.1488	0.0466	0.1402	0.1729	0.1263
A_7	0.1889	0.1601	0.1099	0.0506	0.0395	0.1294	0.1494

Source: authors' own calculations.

Table 4. The results of CRISUS technique

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
ρ_j	0.1554	0.1462	0.1479	0.2792	0.1678	0.1464	0.1440
σ_j	0.1076	0.0570	0.0697	0.2641	0.1457	0.0999	0.0562
$\rho_j\sigma_j$	0.0167	0.0083	0.0103	0.0737	0.0244	0.0146	0.0081
w_j	0.1070	0.0533	0.0660	0.4719	0.1564	0.0936	0.0518
Rank	3	6	5	1	2	4	7

Source: authors' own calculations.

4.3.2 Ranking the firm alternatives via RAM method

Once the initial performance matrix has been obtained, Eqs. (12) and (13) are employed to derive the normalised performance matrix and the weighted normalised performance matrix, respectively. Subsequently, the U_i and L_i values (Table 5) are calculated with the aid of Eqs. (14) and (15), respectively. Lastly, the final ranking scores of the firm alternatives are obtained through Eq. (16). The ranking outcomes of the RAM procedure are presented in Table 5. Based on the results obtained, it is concluded that A5 is the alternative with the best ranking position. The remaining alternatives are ranked as A4≻A2≻A3≻A6≻A7≻A1, respectively.

Table 5. Ranking results of performance measurement problem by RAM

	A_1	A_2	A_3	A_4	A_5	A_6	A_7
U_i	0.0579	0.1222	0.0831	0.2116	0.2423	0.0715	0.0661
L_i	0.0163	0.0198	0.0173	0.0273	0.0251	0.0173	0.0224
P_i	14304	14514	14388	14792	14900	14348	14316
Rank	7	3	4	2	1	5	6

Source: authors' own calculations.

5. Robustness check

This section aims to perform a robustness analysis in two stages to validate the suggested decision-making approach and its outcomes. In the first stage, the outputs of the developed objective weighting approach are compared with the results of different well-known objective weighting techniques. In the second stage, the results of the developed decision-making approach are analysed comparatively with the outcomes of popular MCDM tools.

5.1 A comparison of CRISUS results with those of other well-known objective weighting approaches

This subsection aims to evaluate the methodological robustness, practicality, and stability of the CRISUS model. To this end, the outputs of the CRISUS are compared with the outputs of several traditional objective weighting approaches. The traditional weighting approaches included in the comparative analysis are CRiteria Importance Through Intercriteria Correlation (CRITIC) (Diakoulaki et al. 1995), Standard Deviation (SD) (Diakoulaki et al. 1995), and Statistical Variance (SV) (Rao and Patel 2010) algorithms. The modified standard deviation (MSD) (Puška et al. 2022), Symmetry Point of Criterion (SPC) (Z. Gligorić et al. 2023), Modified Preference Selection Index (MPSI) (M. Gligorić et al. 2022), MEthod based on the Removal Effects of Criteria (MEREC) (Keshavarz-ghorabaee et al. 2021), and MAXimum of Criterion (MAXC) algorithms (Z. Gligorić et al. 2024), which are considered relatively novel objective weighting approaches, were also deployed in the comparative analysis. Furthermore, as in past MCDM studies, a linear normalisation technique is employed to ensure greater consistency in the results of conventional weighting approaches, such as SV, SD, and CRITIC, which are susceptible to diverse normalisation procedures. The weight values obtained from each objective weighting approach and the related Pearson correlation coefficients (r) are provided in Table 6.

Table 6. The weights and correlation coefficients of the comparative analysis

Criteria	Objective weighting methods									
	CRISUS	CRITIC	Entropy	MAXC	MEREC	MPSI	MSD	SD	SPC	SV
C_1	0.1070	0.1535	0.0671	0.1006	0.1054	0.1397	0.1206	0.1514	0.0780	0.0639
C_2	0.0533	0.0880	0.0182	0.0477	0.0719	0.0506	0.0619	0.0911	0.0375	0.0169
C_3	0.0660	0.0910	0.0267	0.0796	0.0588	0.0630	0.0762	0.1017	0.0424	0.0256
C_4	0.4719	0.2628	0.6645	0.4575	0.3260	0.3826	0.3967	0.2505	0.6446	0.6924
C_5	0.1564	0.1746	0.1487	0.1597	0.2915	0.2041	0.1696	0.1830	0.0954	0.1266
C_6	0.0936	0.1472	0.0579	0.0925	0.0895	0.1176	0.1163	0.1389	0.0682	0.0595
C_7	0.0518	0.0829	0.0169	0.0623	0.0568	0.0424	0.0586	0.0834	0.0338	0.0151
r (*p < 0.01)		0.9292*	0.9981*	0.9987*	0.8414*	0.9684*	0.9954*	0.9195*	0.9890*	0.9959*

Source: authors' own calculations.

A detailed examination of the r values given at the bottom of Table 6 reveals that CRISUS exhibits a high degree of correlation with other conventional or novel weighting procedures. The findings from Table 6 confirm the CRISUS model's reliability and practicality.

As shown in Table 7, the ranking positions of C1, C4, C5, and C6 remain unchanged under all weighting methods, while minor shifts in C2, C3, and C7 are observed under MAXC and MEREC. However, these minor changes do not significantly alter the overall assessment. These findings confirm the methodological stability of the proposed weighting framework.

Table 7. Criteria rankings for comparative analysis

Criteria	Criteria ranks									
	CRISUS	**CRITIC**	**Entropy**	**MAXC**	**MEREC**	**MPSI**	**MSD**	**SD**	**SPC**	**SV**
C_1	3	3	3	3	3	3	3	3	3	3
C_2	6	6	6	7	5	6	6	6	6	6
C_3	5	5	5	5	6	5	5	5	5	5
C_4	1	1	1	1	1	1	1	1	1	1
C_5	2	2	2	2	2	2	2	2	2	2
C_6	4	4	4	4	4	4	4	4	4	4
C_7	7	7	7	6	7	7	7	7	7	7

Source: authors' own calculations.

5.2 Comparative analysis with popular MCDM ranking methods

In the second stage of the validation process, a comparison is made between the RAM model and seven other MCDM tools, including Additive Ratio ASsessment (ARAS) (Zavadskas and Turskis, 2010), Evaluation Based On Distance from Average Solution (EDAS) (Keshavarz Ghorabaee et al., 2015), MARA (M. Gligorić et al., 2022), Measurement of alternatives and ranking according to Compromise solution (MARCOS) (Stević et al., 2020), Objective Pairwise Adjusted Ratio Analysis (OPARA) (Keshavarz-Ghorabaee et al., 2024), Simple Additive Weighting (SAW) (MacCrimmon, 1968), and Weighted Aggregated Sum Product ASsessment (WASPAS) (Chakraborty and Zavadskas, 2014). The outcomes regarding the comparative analysis are depicted in Table 8. Table 8 demonstrates that the rankings of A2, A3, A4, A5, and A6 have remained consistent across all implemented MCDM frameworks. Furthermore, minor alterations have been observed in the sorting positions of the remaining two firm alternatives (A1 and A7). Despite a slight shift in the ranking outcomes, it can be concluded that the initial ranking (i.e., A5, A4, A2, A3, A6, A7, and A1) is valid and endorsed.

Table 8. Final rank of firm alternatives according to the implemented MCDM tools

Firm	Alternative MCDM ranking procedures															
	RAM	Rank	ARAS	Rank	EDAS	Rank	MARA	Rank	MARCOS	Rank	OPARA	Rank	SAW	Rank	WASPAS	Rank
A_1	1.4304	7	0.2741	7	0.0055	7	0.3038	6	0.3433	6	0.0782	7	0.1024	6	0.2178	6
A_2	1.4514	3	0.5029	3	0.4370	3	0.2174	3	0.4944	3	0.1444	3	0.1475	3	0.3330	3
A_3	1.4388	4	0.3666	4	0.1646	4	0.2602	4	0.4195	4	0.1023	4	0.1251	4	0.2718	4
A_4	1.4792	2	0.8211	2	0.8569	2	0.1178	2	0.6687	2	0.2307	2	0.1995	2	0.4579	2
A_5	1.4900	1	0.9083	1	0.9509	1	0.0856	1	0.7249	1	0.2671	1	0.2162	1	0.4958	1
A_6	1.4348	5	0.3228	5	0.1084	5	0.2862	5	0.3741	5	0.0956	5	0.1116	5	0.2442	5
A_7	1.4316	6	0.3220	6	0.0852	6	0.3127	7	0.3277	7	0.0817	6	0.0978	7	0.2136	7

Source: authors' own calculations.

6. Discussion, managerial implications and theoretical contributions

When the practical outcomes of the implementation of the MCDM approach developed in the present research are carefully assessed, it has been observed that

that the market-to-book ratio (C_4) is the most critical criterion influencing the multidimensional sustainable performance of F&B firms. As for the ranking of listed firms, the findings indicate that ŞOK Marketler (A_5) is the most successful firm in the F&B sector with regard to multi-dimensional corporate sustainability performance.

Overall, the executive implications of the existing work can be outlined as follows: (i) the implementation of the mathematical tool, as put forward in the present study, enables the monitoring of performance levels across a range of criteria by those in senior management positions. This facilitates the identification of potential areas for development and allows for the acquisition of competitive power over rivals in a rapidly changing business environment. Furthermore, through a holistic sustainable performance measurement and assessment, firms can identify and mitigate potential financial, environmental, social, and governance risks and improve overall resilience by considering multiple sustainability criteria, (ii) through a comprehensive sustainable performance analysis, investors can more effectively assess the risk profiles of firms. The contemporary investment climate is characterised by an increased focus on ESG risks, and the developed decision-making framework can provide investors with valuable information to make well-balanced and informed investment decisions in this context, (iii) an exhaustive assessment of corporate sustainability performance, incorporating both financial and ESG elements, can offer a comprehensive view of a company's capacity to generate long-term value for existing shareholders. Furthermore, such a holistic performance assessment can assist existing shareholders in grasping the potential sustainability risks that could influence future profitability and reputation, including environmental liabilities or inadequate governance practices, and (iv) the case study's findings pertaining to performance benchmarking provide a foundation for regulatory bodies to develop regulations and incentives that foster the implementation of superior ESG practices within the F&B industry.

In addition to the managerial implications, this manuscript's most important theoretical contribution is the introduction of a novel objective weighting methodology (i.e., CRISUS) for the estimation of the relative importance of corporate sustainable performance measures that influence the overall performance of the F&B companies. The advantages of utilising the CRISUS method, which incorporates the beneficial aspects of Statistical Variance and Entropy weighting methods, can be summarised as follows: (i) its computational steps are straightforward, and it has a basic algorithm that is simple for DMs to use and it requires neither software nor high user knowledge and skills for the calculation of objective weights, (ii) it is not affected by the large number of alternatives in the decision problem, (iii) it performs the normalisation of the criteria in two stages, taking into account their cost and benefit characteristics, (iv) it is characterised by its robust computational ability and minimal computational time, (v) it does not suffer from the inconsistencies regarding experts' judgments that are inherent to subjective weighting models, and (vi) in comparison to alternative weighting

methodologies, the sum of squares operation inherent to the CRISUS method offers a more straightforward approach to weight calculation.

On the other hand, the developed mathematical tool based on CRISUS and RAM to measure and benchmark multi-dimensional corporate sustainable performance is a novel MCDM model. This decision model combines the strengths of the CRISUS and RAM approaches, providing a reliable and robust methodological framework to meet the performance evaluation needs of all stakeholders associated with the sector. Additionally, the combination of CRISUS and RAM can facilitate a comprehensive and multifaceted understanding of corporate sustainability performance, encompassing the intricate interconnections and interdependencies inherent in various indicators. Besides, the developed hybrid approach resists the rank reversal paradox. Moreover, the findings from the sensitivity tests demonstrate that the developed framework is capable of producing maximally consistent and stable outputs, even in situations where conditions are subject to change.

7. Conclusions

The introduced approach is based on a hybrid decision-making framework that integrates two newly developed decision-making algorithms. The first component of the newly formulated framework is the CRISUS model, which is utilised in the calculation of the objective weight values for the performance criteria in the present decision problem. Another component is the RAM, which is used in prioritising the firm alternatives in accordance with predetermined criteria. CRISUS-based results point out that the market-to-book ratio is the factor that has the most critical impact on the multi-dimensional sustainability performance of F&B firms. Furthermore, the outcomes obtained by implementing RAM demonstrate that ŞOK Marketler is the company with the highest multi-dimensional corporate sustainability performance in relation to other companies within the industry.

As with every research study, this research is not without its limitations. The results reached in this research for the F&B sector cannot be generalised for other economic sectors. The CRISUS is designed by considering the crisp value of the criteria. Hence, it does not work in an environment where the criterion value is imprecise, uncertain, or incomplete. Future research could modify CRISUS by utilising theories such as rough sets, fuzzy sets, or grey sets within environments where the values of performance indicators are incomplete, imprecise, or vague. Additionally, the algorithm of the CRISUS can be modified by using different types of normalisation. Further, the CRISUS-RAM hybrid model, which has proven to be a powerful and effective mathematical tool based on robustness tests, can be utilised to address decision-making problems confronted in diverse fields, including engineering, logistics, banking, and supply chain management, among others.

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