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Assessing the Environmental Sustainability Performance of the Banking Sector: A Novel Integrated Grey Multi-Criteria Decision-Making (MCDM) Approach

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Abstract: The objective of this work is to analyze the environmental sustainability performance of deposit banks traded in Borsa Istanbul (BIST) through the application a novel integrated grey Multi-Criteria Decision-Making (MCDM) approach. The grey combined model proposed for the assessment of environmental performance in the banking sector integrates the Logarithmic Objective Weighting Based on Percentage Change (LOPCOW) and Proximity Indexed Value (PIV) algorithms. In the first stage, the importance weights of the criteria were determined using the Grey LOPCOW objective weighting technique, which enables a comprehensive and robust weighting system. Following this, the Grey PIV method was employed to assess the banks' environmental sustainability performance. To demonstrate the robustness and applicability of the suggested MCDM framework, several sensitivity analyses and comparative assessments were conducted. The empirical findings imply that the most significant environmental performance indicator affecting the environmental sustainability performance of deposit banks is "amount of disposed waste". Moreover, Yapı Kredi was identified to be the bank with the highest environmental sustainability performance compared to its competitors in the BIST banking industry. The findings obtained through sensitivity and comparative analyses indicate that the introduced hybrid decision model in the existing work constitutes a robust, defendable, and effective framework for assessing the environmental sustainability performance of banking institutions. Lastly, the findings have important implications for bank management, regulators, and policymakers, offering valuable insights for the enhancement of sustainability practices within the banking industry. This work contributes to the growing body of literature on environmental performance measurement in the financial sector and provides a methodological foundation for future sustainability assessments in similar contexts.

Keywords: Banking sector; Environmental sustainability; Grey MCDM; Grey LOPCOW; Grey PIV; Sustainability performance; Borsa Istanbul (BIST)

1 Introduction

The financial system plays a pivotal role in the economic landscape, facilitating the efficient allocation of resources among economic agents and contributing to the growth and development of the economy. Key institutions within the financial system include investment trusts, insurance companies, asset management companies, and banks, which play a crucial role in ensuring the effective operation of the financial system. In comparison to alternative financial intermediaries, banks are the paramount financial intermediaries supporting sustainable economic growth worldwide and ensuring the efficient allocation of financial resources among economic agents [1]. Banks are one of the most crucial financial intermediary institutions that meet the financing needs of firms and individuals by making the deposits they collect from savers available as loans to those who demand funds. This intermediation function enables banks to stimulate economic activities by encouraging investment and consumption activities [2]. Especially in developing countries, banks support economic development and contribute to poverty reduction by facilitating the financial access of economic agents [3]. In addition, the banking sector also plays an important role in ensuring economic stability. With the financing support provided to small and medium-sized firms, banks can help both the growth of firms and the decrease in unemployment rates by providing diversity in the economy [4]. In addition, banks have a critical role in economic development activities by providing a balance between investments and loans [5].

The concept of sustainability can be most simply defined as the practice of not destroying the natural resources required for use by future generations, while simultaneously meeting the needs and expectations of those involved in the firm, including employees, shareholders, customers and investors [6]. Sustainability represents long-term prosperity by balancing the environmental, social and institutional impacts of economic growth activities [7, 8]. The concept of sustainability has three main dimensions: environmental, social and institutional. However, the environmental sustainability dimension is of greater importance than the other dimensions. This is because this dimension is more prominent than the other dimensions in issues that require a global struggle, such as global warming or climate change [9]. Global issues such as the accelerated depletion of natural resources, the precipitous decline in biodiversity, the deterioration of ecological balance and the surge in environmental pollution have a profound negative impact on both human activities and the planet. Consequently, the concept of environmental encompasses the endeavors to minimize the detrimental effects of these activities on natural resources while pursuing robust activities [10]. Considering the problems occurring in the ecosystem, it is necessary for banks, like all other firms, to take environmental issues into account, especially when realizing their long-term goals [11]. On the other hand, banks that integrate environmental activities will gain a significant competitive advantage by becoming more resistant to regulatory pressures [12]. In light of the aforementioned considerations, it can be stated with a priori clarity that the environmental dimension stands out more than other dimensions [13].

In the 21st century, which is called the century of the environment, the concept of the environment has become one of the most important issues in the banking sector, as in all other sectors. The increasing concerns about changing climates and increasing environmental problems have led firms and banks to implement policies to reduce their harmful effects on the environment [14]. The banking sector has many opportunities to lead society towards sustainability, especially through the so-called green banking initiatives [15]. Consequently, banking activities conducted in accordance with sustainability principles not only minimize environmental risks but also contribute to the enhancement of corporate reputation and performance [16]. On the other hand, by adopting sustainability principles, banks can encourage innovation in the economy and support global efforts in sustainable development [17]. To this end, the present work develops an integrated Grey MCDM model to gauge the environmental sustainability performance of banks. In the developed model, LOPCOW and PIV approaches were integrated with interval grey numbers. The fundamental rationale for employing grey numbers is their capacity to facilitate flexible decision-making in complex scenarios. In comparison to fuzzy sets, grey numbers offer a more effective utilization of grey theory, particularly in circumstances where data is limited, restricted, or partial [18]. In accordance with the suggested approach, Grey LOPCOW has the responsibility of computing the weights of the criteria, while Grey PIV serves to rank the performance of the banking institutions. A real case study was performed, consisting of 7 experts, 13 environmental performance criteria and 6 deposit banks. The objective of the case study was to demonstrate the applicability and suitability of the newly introduced grey-based hybrid decision-making framework.

In general, with the help of the presented MCDM framework, this research aims to answer the following research questions:

• RQ1. Why is it important to analyze the environmental performance of banks?

• RQ2. Which assessment criteria should be used to analyze the environmental performance of the banking sector?

• RQ3. What is the most important indicator of environmental performance in the banking sector?

• RQ4. Which of the commercial banks listed on the BIST is more successful than its competitors in terms of environmental performance?

Through research questions aimed at filling gaps in previous studies, bank managers and other decision makers in the banking sector can identify a practical and reliable methodological approach to analyze the environmental performance of banks in detail. The contributions of the proffered decision support tool to the past literature are as follows:

√ The existing work presents a methodological framework for solving environmental performance measurement problems for decision-makers in the banking industry.

√ The Grey LOPCOW approach is employed to compute the weight coefficients of the environmental performance criteria.

√ The Grey PIV procedure, which is a relatively new ranking technique, is implemented for the first time in the MCDM literature to rank banks' environmental performance.

√ To investigate the sustainable environmental performance of banks, a case study was conducted employing 13 environmental performance measures. This is the first study to examine the environmental performance of banks via an integrated decision methodology.

√ Managerial implications are provided for baking decision-makers to improve and sustain the environmental performance of the banking sector.

√ A comprehensive sensitivity and benchmarking analysis is conducted to test the validity of the proposed decision-making process.

The following section of the study is organized as follows: The second section contains a literature review and explains how the study will fill the gaps in the literature. In the third section, the proposed MCDM methods are discussed from a theoretical perspective. Then, in the fourth section, the case analysis conducted within the scope of the study is presented, and in the fifth section, the results of the proposed model for the evaluation of the environmental performance of selected banks are shared. In the sixth section, sensitivity analyses and related validation analyses are presented. In the seventh section, practical and managerial implications are discussed. Finally, the eighth section summarizes the results obtained and provides recommendations for future work.

2 Research Background

This section is divided into two sub-sections. The first section presents a summary of the sustainability studies conducted in the banking sector employing MCDM methodologies. The second subsection addresses research gaps regarding previous studies in the banking industry.

2.1 Sustainability Studies in the Banking Sector with MCDM Approaches

Since banks are the most vital institutions of the financial system, there are many studies in the earlier literature focusing on gauging their performance from diverse perspectives. This subsection presents a comprehensive overview of extant studies within the banking industry that concentrate on measuring and assessing the bank's performance. The studies outlined in Table 1 concentrate on multidimensional performance or sustainability performance, as opposed to those that focus on one-dimensional performance, specifically financial performance analysis.

Table 1. Literature review

Study	Sample	Technique	Finding
Özçelik and Avci Öztürk [19]	3 banks in Turkey	GIA	In terms of sustainable performance, TSKB was ranked first, followed by Garanti Bank and Akhonk.
Rebai et al. [20]	3 banks operating in France	AHP	The result of the study conducted to evaluate the sustainability performance of banks was reported that the banks included in the amalysis were far from being sustainable.
Işık [21]	Turkish participation banking industry	MEREC, PSI and MAIRCA	The empirical findings of the paper, covering quarterly data between March 2019 and December 2020, show that the most successful period for the participation banking sector was December 2020, while the most unsuccessful period was March 2019.
Aras et al. [22]	7 banks in Turkey	Extropy and TOPSTS	The findings demonstrate that there is no meaningful diversity between the performances of traditional banks and participation banks in terms of sustaimability dimensions.
Raut et al. [23]	6 large Indian commercial banks	Fuzzy AHP and Fuzzy TOPSIS	It has been observed that the enviromentally friendly management system is in the background compared to other criteria. In addition, it was also stated that the concept of corporate social responsibility is insufficient to solve emviromental problems.
Ömürbek et al. [24]	7 largest Turkish banks by asset gize	Entropy, ARAS, MOOSRA and COPRAS	The evaluation criteria with the highest impact on the sustainability performance of the banks was determined as scope 2 emissions. Additionally, according to the three methods used, Ziraat Bank has the highest sustainability performance and Vakıfbank has the lowest performance.
Işık [25]	3 state-owned development and investment banks	SD, MABAC and WASPAS	According to the empirical findings for the period 2014-2018, Turk Eximbank was identified as the most financially successful bank in all periods.

Study	Sample	Technique	Finding
Aras et al. [26]	8 banks in Turkey	Extropy and TOPSIS	A Spearman rank correlation test was conducted to determine whether there is any relationship between sustainability performance scores and market values of banks. The results of the correlation analysis reveal that there is a significant and positive relationship between sustainable performance and market value in the long term.
Korzeb and Samaniego-Medina [27]	14 commercial banks operating in Poland	TOPSTS	In the study conducted to analyze sustainable performance in the period 2015-2017, the authors revealed that state-owned banks attach more importance to sustainability activities compared to foreign banks.
Kestane and Kurnaz [28]	Turkish banking sector	GIA	It is stated that Akbank shows the best perfomance in environmmental tenms, while İşbank shows the best performance in financial terms.
Esec [29]	5 private Turkish deposit banks	Entropy and ARAS	The social dimension is the most important factor affecting the sustainable performance of private equity deposit banks. In addition, banks that want to maximize their sustainable performance should first reduce their staff turnover rates and then reduce greenhouse gas consumption.
Nosratabadi et al. [30]	16 banks in 8 European countries	AHP	The study analyses the sustainable performance of the country banks. In line with the analyses, it has been determined that the performance of Norwegian and German banks is higher than that of the other country banks.
Eş and Kamacı [31]	Turkish banking sector	Entropy, ARAS and EDAS	In the study analyzing the social, environmental and economic performance of banks, İşbank has shown the most successful performance.
Oral and Geçdoğan [32]	Turkish banking sector	AHP and TOPSIS	In the study investigating sustainable performance, it was found that banks are stable in their activities not only in economic or financial terms but also in environmental and social terms.
Yarlıkaş and Öztürk [33]	5 Turkish deposit banks	CRITIC and MOORA	The most important factor affecting bank performance is return on equity. It is also reported that banks comply with selected indicators in terms of sustainability.
Doğan and Kılıç [34]	6 banks in Turkey	Entropy and GIA	The social, environmental, corporate and financial sustainability performances of the banks were analyzed for the 2019-2020 period. The evaluations show that Garanti Bank is more successful than other banks in terms of performance.
Bektaş [35]	3 public Turkish deposit banks	MEREC and ARAS	The study conducted for the 2014-2021 period identified scope 1 emissions as the most significant factor affecting sustainability. Conversely, in terms of sustainability, the most successful bank is Vakıfbank.
Chaudhuri et al. [36]	10 private Indian banks	DEA	Within the context of the study in which the additives of banks to environmental sustainability were analyzed, it was concluded that City Union and HDFC made the highest contribution to environmental sustainability.
Terzioğlu et al. [37]	9 banks in Turkey	Entropy, MOORA, OCRA and GLA	The results of the study, which aimed to assess financial and environmental sustainability performance, indicated that Vakıfbank was the most sustainable bank according to the MOORA and GIA methods, while Ziraat Bank was the most sustainable bank according to the OCRA method.

Study	Sample	Technique	Finding
Quynh [38]	4 public banks in Vietnam	AHP and TOPSIS	The study proposed a novel model for measuring multidimensional sustainable performance in banks. The findings demonstrated that the model could be used to assess both efficiency and versatility in this domain.
Bektaş [39]	Akbank	LOPCOW and CoCoSo	The economic, social and environmental performance of Akbank has been investigated for the period 2009-2021. The analyses reveal that the bank has a more successful performance in 2014, 2017 and 2018 compared to other years.
Sharma and Kumar [40]	Indian banking sector	Entropy, TOPSIS and VIKOR	The researchers aimed to make a multidimensional performance evaluation for the banking sector. The evaluations indicate that banks give more importance to environmental sustainability than financial sustainability.
Işık [41]	Turkish commercial banking sector	Entropy and ARAS	As a result of the assessments conducted for the period 2008-2017, the most successful year for the sector was identified as 2010. In addition, the year 2015 has been determined as the most unsuccessful year of the sector.
Akbulut and Aydın [42]	6 banks traded on BIST	MSD, MPSI and RAWEC	According to the study, which analyzed the environmental performance of the banking sector, Garanti BBVA was found to have the best performance.
Işık et al. [43]	15 listed Pakistan deposit banks	Fuzzy LBWA, Fuzzy LMAW, and MARCOS	The results demonstrate that the monthly returns indicator is the vital driver of multidimensional bank performance.

2.2 Research Gap Analysis

The general outputs of the previous study pointed to two critical gaps in the literature regarding the research topic. There exist no generally accepted criteria in the current industry for assessing the environmental performance of banks. Some prior papers have presented some assessment criteria, but it is unclear how these criteria are identified. Hence, the first critical research gap can be related to the lack of a set of criteria that evaluates comprehensive environmental performance in preceding studies. To fill this gap, unlike previous studies, this research proffers a comprehensive and up-to-date set of criteria that includes 13 criteria in 5 main dimensions to assess the bank's environmental performance. The second critical gap pertains to the methodological framework that can be applied in assessing bank environmental performance.

As seen in Table 1, past studies mostly prefer traditional methods in evaluating bank performance. However, these approaches, such as AHP, Entropy, TOPSIS, VIKOR, GIA, ARAS, and DEA etc., have many drawbacks and structural problems. Consequently, owing to their inherent restrictions, they are unable to satisfy the requirements of decision-makers in the banking industry with regard to environmental performance analysis and evaluation. To fill the second research gap, this research proposes a dependable, applicable and robust mathematical tool as a methodological framework for assessing banks' environmental performance by integrating MCDM techniques with grey systems theory. In this context, the developed methodology utilizes extended versions of two very recent techniques such as the LOPCOW and PIV based on the utilization of interval grey numbers.

In comparison to fuzzy numbers, grey interval numbers possess several important advantages. First, it allows DMs to reduce the possible inconsistencies resulting from sophisticated circumstances and ambiguities associated with the decision problem by employing interval numbers. Second, the lower computational complexity allows DMs to make more effective decisions. Third, using this approach facilitates achieving more robust, durable and reliable results when dealing with limited, uncertain, and small data [41–48].

The developed decision-making framework combines the advantages of the LOPCOW and PIV algorithms for gauging the alternative banks' environmental performance. The following are the primary advantages of the LOPCOW method. Firstly, it has the capacity to decrease the discrepancies between the weight values of the most and least important criteria. Secondly, it possesses significant computational capability and requires a comparatively brief computational time. Thirdly, the system's unique algorithm enables the elimination of any discrepancy resulting from variations in data size. Besides, criteria with negative values can be incorporated directly into the analysis, without the need for any transformation [49]. As for PIV methodology, this methodology is notable for its simple algorithm, which is easily comprehensible and can be readily implemented by decision-makers. Thus, this algorithm offers DMs a practical, powerful and systematic approach to problem-solving. Moreover, the algorithm's notable resistance to the rank reversal issue is a significant advantage over its counterparts [44].

3 Methodology

This section explains the integrated model consisting of Grey LOPCOW and Grey PIV techniques proposed to solve the environmental sustainable performance decision-making problem for the banking sector, as shown in Figure 1.

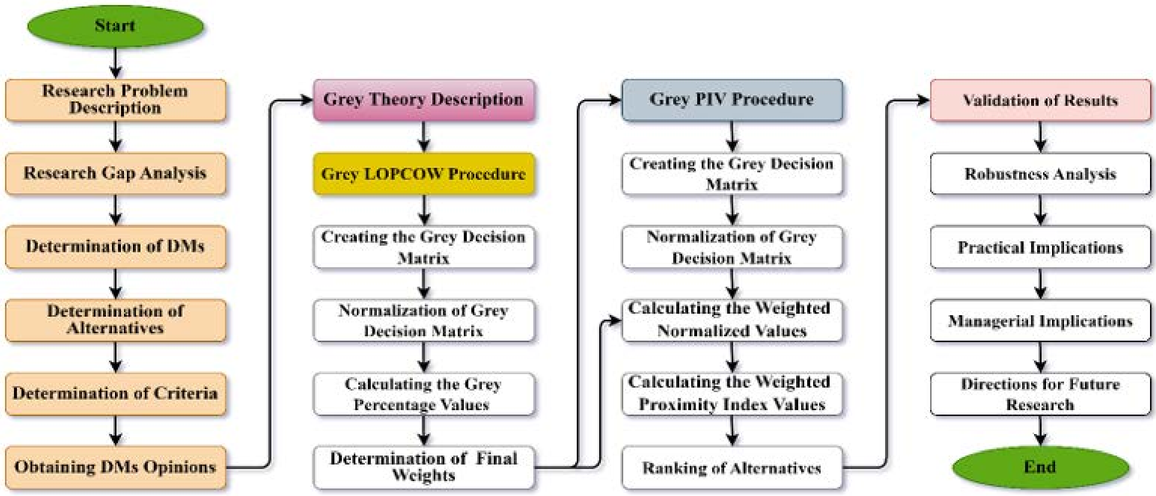

Figure 1. Proposed model

3.1 Grey Theory Description

The theoretical framework of grey system theory, along with the concept of interval grey numbers, was structured by Deng [50]. This theoretical paradigm posits that systems that contain incomplete information or are not clearly understood are designated as grey systems. A significant aspect of the grey system logic is its role as an effective methodological framework for the resolution of uncertain problems characterized by incomplete information. In the context of grey theory, grey numbers serve as instruments for addressing the management of incomplete information within the problem structure. These numbers are characterized by their ability to represent unknown values, while simultaneously operating within a defined and known bound. Furthermore, numerical data may also present variations of grey numbers as black and white numbers. The presence of a black number indicates that the analyzed data contains no meaningful information, whereas a white number signifies that the data is fully understood [45]. Due to this reason, grey numbers are defined as numbers that are expressed within a certain range but whose exact numerical values are unknown [46]. A grey number can be represented as $\otimes Z$ and Z^1 and Z^u represent the lower and upper bounds of a grey number, respectively [47, 48]. Thus, a grey number is defined as; $\otimes \mathrm{Z} \in \left[\mathrm{Z}^{\mathrm{l}}, \mathrm{Z}^{\mathrm{u}}\right], \mathrm{Z}^{\mathrm{l}} \leq \mathrm{Z}^{\mathrm{u}}$. According to Li et al. [51], the arithmetic of grey numbers is typically similar to that of interval values. Furthermore, the mathematical operation rules of grey numbers can be expressed as the operation rules of real numbers [47, 48]. In consequence, the mathematical operations for two grey numbers ($\otimes \mathrm{Z}_1$ and $\otimes \mathrm{Z}_2$) are performed in accordance with the following Eqs. (1)-(4).

$$\otimes \mathrm{Z}_1 + \otimes \mathrm{Z}_2 = \left[\mathrm{Z}_1^{\mathrm{l}} + \mathrm{Z}_2^{\mathrm{l}}, \mathrm{Z}_1^{\mathrm{u}} + \mathrm{Z}_2^{\mathrm{u}}\right] \tag{1}$$

$$\otimes \mathrm{Z}_1 - \otimes \mathrm{Z}_2 = \left[\mathrm{Z}_1^{\mathrm{l}} - \mathrm{Z}_2^{\mathrm{u}}, \mathrm{Z}_1^{\mathrm{u}} - \mathrm{Z}_2^{\mathrm{l}}\right] \tag{2}$$

$$\otimes \mathrm{Z}_1 \times \otimes \mathrm{Z}_2 = \left[\mathrm{Min}\left\{\mathrm{Z}_1^{\mathrm{l}} \cdot \mathrm{Z}_2^{\mathrm{l}}, \mathrm{Z}_1^{\mathrm{l}} \cdot \mathrm{Z}_2^{\mathrm{u}}, \mathrm{Z}_1^{\mathrm{u}} \cdot \mathrm{Z}_2^{\mathrm{l}}, \mathrm{Z}_1^{\mathrm{u}} \cdot \mathrm{Z}_2^{\mathrm{u}}\right\}, \mathrm{Max}\left\{\mathrm{Z}_1^{\mathrm{l}} \cdot \mathrm{Z}_2^{\mathrm{l}}, \mathrm{Z}_1^{\mathrm{l}}, \mathrm{Z}_2^{\mathrm{u}}, \mathrm{Z}_1^{\mathrm{u}} \cdot \mathrm{Z}_2^{\mathrm{l}}, \mathrm{Z}_1^{\mathrm{u}} \cdot \mathrm{Z}_2^{\mathrm{u}}\right\}\right] \tag{3}$$

$$\otimes \mathrm{Z}_1 \div \otimes \mathrm{Z}_2 = \left[\mathrm{Min}\left\{\mathrm{Z}_1^{\mathrm{l}}/\mathrm{Z}_2^{\mathrm{l}}, \mathrm{Z}_1^{\mathrm{l}}/\mathrm{Z}_2^{\mathrm{u}}, \mathrm{Z}_1^{\mathrm{u}}/\mathrm{Z}_2^{\mathrm{l}}, \mathrm{Z}_1^{\mathrm{u}}/\mathrm{Z}_2^{\mathrm{u}}\right\}, \mathrm{Max}\left\{\mathrm{Z}_1^{\mathrm{l}}/\mathrm{Z}_2^{\mathrm{l}}, \mathrm{Z}_1^{\mathrm{l}}/\mathrm{Z}_2^{\mathrm{u}}, \mathrm{Z}_1^{\mathrm{u}}/\mathrm{Z}_2^{\mathrm{l}}, \mathrm{Z}_1^{\mathrm{u}}/\mathrm{Z}_2^{\mathrm{u}}\right\}\right] \tag{4}$$

The distance between two grey numbers is calculated according to Eq. (5).

$$\mathrm{L}(\otimes \mathrm{Z}) = \mathrm{Z}^{\mathrm{u}} - \mathrm{Z}^{\mathrm{l}} \tag{5}$$

The grey probability degree, which was developed by Li et al. [51] and introduced to the literature, is used to compare grey number values with each other. The grey degree of likelihood shows the magnitude or smallness of two grey numbers relative to each other [52]. Therefore, the degree of probability of two grey numbers is determined in Eq. (6).

$$P\{\otimes \mathrm{Z}_1 \leq \otimes \mathrm{Z}_2\} = \frac{\max(0,\ \mathrm{L}(\otimes \mathrm{Z}_1) + \mathrm{L}(\otimes \mathrm{Z}_2) - \max(0, \mathrm{Z}_1^{\mathrm{u}} - \mathrm{Z}_2^{\mathrm{u}}))}{\mathrm{L}(\otimes \mathrm{Z}_1) + \mathrm{L}(\otimes \mathrm{Z}_2)} \tag{6}$$

Based on Eq. (6), the comparison of two grey numbers can yield four distinct results.

$$\text{If } \otimes Z_1 = \otimes Z_2 \text{ then } P\{\otimes Z_1 \leq \otimes Z_2\} = 0,5 \text{ if } P\{\otimes Z_1 > \otimes Z_2\} \text{ then } P\{\otimes Z_1 \leq \otimes Z_2\} = 1$$
$$If \otimes \mathrm{Z}_1 < \otimes \mathrm{Z}_2 then\{\otimes \mathrm{Z}_1 \leq \otimes \mathrm{Z}_2\} = 0$$
$$\text{If P}\{\otimes \mathrm{Z}_1 \leq \otimes \mathrm{Z}_2\} > 0,5 \text{ then } \otimes \mathrm{Z}_2 > \otimes \mathrm{Z}_1$$
$$\text{Otherwise if } P\{\otimes \mathrm{Z}_1 \leq \otimes \mathrm{Z}_2\} < 0,5 \text{ then } \otimes \mathrm{Z}_2 < \otimes \mathrm{Z}_1$$

3.2 Grey LOPCOW Procedure

The LOPCOW method, introduced to the literature by Badi and Pamucar [46], provides an objective weighting methodology for decision-makers. The LOPCOW method differs from the other MCDM methods in that it also takes into account the correlation coefficients and standard deviation values between the criteria when calculating the weight scores. Furthermore, the method enables the difference between the most and least important criteria to be reduced to a reasonable level by calculating the criteria weights with a logarithmic function [53, 54]. Furthermore, the fact that the method is not influenced by negative data provides researchers with a significant advantage over other methods. The application procedure of the method consists of four steps, as described below [55].

Step 1: In the implementation stages, the initial step is to create the grey decision matrix ($\otimes$Z), which contains the evaluation criteria and decision alternatives, in accordance with Eq. (7). Subsequently, the experts consider the language values provided in Table 2 when making their decisions.

$$\otimes \mathrm{Z} = [\otimes \mathrm{z}_{\mathrm{ij}}]_{\mathrm{m} \times \mathrm{n}} \tag{7}$$

In the equation, $\mathrm{z}_{\mathrm{ij}} = [\mathrm{z}_{\mathrm{ij}}^{\mathrm{l}}, \mathrm{z}_{\mathrm{ij}}^{\mathrm{u}}]$, as shown in the grey matrix, it represents the value of the i-th alternative as regards the j-th criterion.

Table 2. The grey linguistic values and the equivalent numbers

Linguistic Values	Abbreviation	Related Grey Numbers
Very bad	VB	$(1 - 10)$
Bad	B	$(11 - 20)$
Moderately bad	MB	$(21 - 30)$
Fair	F	$(31 - 40)$
Moderately good	MG	$(41 - 50)$
Good	G	$(51 - 60)$
Very good	VG	$(61 - 70)$

Adapted from Pamucar et al. [56]

Step 2: The initial grey matrix, which is initially created within the scope of DMs evaluations, is normalized at this stage by taking into account the non-beneficial and beneficial characteristics. Accordingly, the normalization process is carried out using the following Eq. (8) for non-beneficial criteria and Eq. (9) for beneficial criteria.

$$\otimes \mathrm{c}_{\mathrm{ij}} = \frac{\max(\otimes \mathrm{z}_{\mathrm{ij}}) - \otimes \mathrm{z}_{\mathrm{ij}}}{\max(\otimes \mathrm{z}_{\mathrm{ij}}) - \min(\otimes \mathrm{z}_{\mathrm{ij}})} = \left[\frac{\max(\mathrm{z}_{\mathrm{ij}}^{\mathrm{u}}) - \mathrm{z}_{\mathrm{ij}}^{\mathrm{u}}}{\max(\mathrm{z}_{\mathrm{ij}}^{\mathrm{u}}) - \min(\mathrm{z}_{\mathrm{ij}}^{\mathrm{l}})}\right], \left[\frac{\max(\mathrm{z}_{\mathrm{ij}}^{\mathrm{u}}) - \mathrm{z}_{\mathrm{ij}}^{\mathrm{l}}}{\max(\mathrm{z}_{\mathrm{ij}}^{\mathrm{u}}) - \min(\mathrm{z}_{\mathrm{ij}}^{\mathrm{l}})}\right] \tag{8}$$

$$\otimes \mathrm{c}_{\mathrm{ij}} = \frac{\otimes \mathrm{z}_{\mathrm{ij}} - \min(\otimes \mathrm{z}_{\mathrm{ij}})}{\max(\otimes \mathrm{z}_{\mathrm{ij}}) - \min(\otimes \mathrm{z}_{\mathrm{ij}})} = \left[\frac{\mathrm{z}_{\mathrm{ij}}^{\mathrm{l}} - \min(\mathrm{z}_{\mathrm{ij}}^{\mathrm{l}})}{\max(\mathrm{z}_{\mathrm{ij}}^{\mathrm{u}}) - \min(\mathrm{z}_{\mathrm{ij}}^{\mathrm{l}})}\right], \left[\frac{\mathrm{z}_{\mathrm{ij}}^{\mathrm{u}} - \min(\mathrm{z}_{\mathrm{ij}}^{\mathrm{l}})}{\max(\mathrm{z}_{\mathrm{ij}}^{\mathrm{u}}) - \min(\mathrm{z}_{\mathrm{ij}}^{\mathrm{l}})}\right] \tag{9}$$

Step 3: The $\otimes PV_{ij}$ values, expressed as grey percentage values for the assessment criteria, are computing employing Eq. (10).

$$\otimes PV_{ij} = [PV_{ij}^{l}, PV_{ij}^{u}] = \left[\left|\ln\left(\frac{\sqrt{\frac{\sum_{i=1}^{m}(c_{ij}^{\mathrm{l}})^2}{m}}}{\sigma^{\mathrm{l}}}\right) \times 100\right|, \left|\ln\left(\frac{\sqrt{\frac{\sum_{i=1}^{m}(c_{\mathrm{ij}}^{\mathrm{u}})^2}{\mathrm{m}}}}{\sigma^{\mathrm{u}}}\right) \times 100\right|\right] \tag{10}$$

Step 4: In the final stage, the grey weight scores ($\otimes w_{jLOP}$) for each chosen assessment criterion are determined by employing Eq. (11).

$$\otimes w_{jLOP} = \left[w_{jLOP,}^{l} w_{jLOP}^{u}\right] = \left[\min\left(\frac{PV_{ij}^{l}}{\sum_{j=1}^{n} PV_{ij}^{l}}, \frac{PV_{ij}^{u}}{\sum_{j=1}^{n} PV_{ij}^{u}}\right), \max\left(\frac{PV_{ij}^{l}}{\sum_{j=1}^{n} PV_{ij}^{l}}, \frac{PV_{ij}^{u}}{\sum_{j=1}^{u} PV_{ij}^{u}}\right)\right] \quad (11)$$

In the final stage of this methodology, crisp weights are identified by averaging the weights generated for each assessment criterion.

3.3 Grey PIV Procedure

The PIV technique, introduced in the literature by Mufazzal and Muzakkir [44], is a mathematical tool often preferred by researchers. The implementation procedure of this technique consists of 5 steps [57].

Step 1: As in all other MCDM algorithms, the first step of the Grey PIV technique starts with the grey decision matrix formed in Eq. (7).

Step 2: Grey decision matrix values are normalized with the aid of Eq. (12).

$$\otimes \mathrm{e_{ij}} = \left[\mathrm{e_{ij}^{l}}, \mathrm{e_{ij}^{u}}\right] = \frac{\otimes \mathrm{z_{ij}}}{\sqrt{\sum_{\mathrm{i=1}}^{\mathrm{m}} \left(\otimes \mathrm{z_{ij}}\right)^{2}}}$$
$$= \left[\frac{\mathrm{z_{ij}}}{\sqrt{\sum_{\mathrm{i=1}}^{\mathrm{m}} \left(\mathrm{z_{ij}^{u}}\right)^{2} + \sum_{\mathrm{i=1}}^{\mathrm{m}} \left(\mathrm{z_{ij}^{l}}\right)^{2}}}, \frac{\mathrm{z_{ij}^{u}}}{\sqrt{\sum_{\mathrm{i=1}}^{\mathrm{m}} \left(\mathrm{z_{ij}^{u}}\right)^{2} + \sum_{\mathrm{i=1}}^{\mathrm{m}} \left(\mathrm{z_{ij}^{l}}\right)^{2}}}\right] \quad (12)$$

Step 3: The weight scores computing employing the Grey LOPCOW method are incorporated into the Grey PIV approach in this step, and a weighted normalized matrix is then computed in accordance with Eq. (13).

$$\otimes \mathrm{t_{ij}} = \left[\mathrm{t_{ij}^{l}}, \mathrm{t_{ij}^{u}}\right] = \otimes \mathrm{w_i} \times \otimes \mathrm{e_{ij}} = \left[\mathrm{w_i^{l}} \times \mathrm{e_{ij}^{l}}, \mathrm{w_i^{u}} \times \mathrm{e_{ij}^{u}}\right] \quad (13)$$

Step 4: In this phase, the $\otimes g_{ij}$ values, which are expressed as a grey weighted proximity index, are computed by considering the non-beneficial and beneficial characteristics of the chosen assessment criteria. In this context, Eq. (14) is used for non-beneficial criteria and Eq. (15) is used for beneficial criteria.

$$\otimes \mathrm{g_{ij}} = \left[\mathrm{g_{ij}^{l}},\ \mathrm{g_{ij}^{u}}\right] = \otimes \mathrm{t_{ij}} - \min\left(\otimes \mathrm{t_{ij}}\right) = \left[\mathrm{t_{ij}^{l}} - \min\left(\mathrm{t_{ij}^{u}}\right), \mathrm{t_{ij}^{u}} - \min\left(\mathrm{t_{ij}^{l}}\right)\right] \quad (14)$$

$$\otimes \mathrm{g_{ij}} = \left[\mathrm{g_{ij}^{l}}\ \mathrm{g_{ij}^{u}}\right] = \max\left(\otimes \mathrm{t_{ij}}\right) - \otimes \mathrm{t_{ij}} = \left[\max\left(\mathrm{t_{ij}^{l}}\right) - \mathrm{t_{ii}^{u}}, \max\left(\mathrm{t_{ij}^{u}}\right) - \mathrm{t_{ij}^{l}}\right] \quad (15)$$

Step 5: In the final stage of the method, grey $\otimes d_i$ and crisp d_i values, which are expressed as overall proximity index values for ranking decision alternatives, are determined according to Eq. (16) and Eq. (17).

$$\otimes d_i = \left[d_i^{l}, d_i^{u}\right] = \sum_{j=1}^{n} \otimes g_{ij} = \left[\sum_{j=1}^{n} g_{ij}^{l}, \sum_{j=1}^{n} g_{ij}^{u}\right] \quad (16)$$

$$\mathrm{d_i} = \frac{\mathrm{d_i^{l}} + \mathrm{d_i^{u}}}{2} \quad (17)$$

When ranking the decision alternatives, the alternative with the smallest $\mathrm{d_i}$ value is considered the most successful, while the alternative with the largest $\mathrm{d_i}$ value is considered the most unsuccessful.

4 A Real-Case Application of Environmental Performance Assessment for Banks

The banking industry plays a pivotal role in the financial system, providing a variety of financial services and intermediation functions to its stakeholders. It is of great importance to analyze the financial and sustainability performance of the banking sector and the banks operating within it. This is necessary for the system to continue its activities in a stable manner and to gain competitive power. To this end, the existing work aims to propound a novel hybrid MCDM framework for the evaluation of environmental performance in the banking industry. The present work focuses on a case study involving 6 deposit banks whose shares are listed on BIST and which regularly publish sustainability reports. The names and market shares of the alternative banks included in the existing work are provided in Table 3. Additionally, Table 4 presents the assessment criteria chosen to analyze the environmentally sustainable performance of the banks.

Table 3. The alternative banks

Code	Alternative	Market Share (%)
A1	Akbank	0.0820
A2	Garanti	0.0879
A3	Halk	0.1061
A4	Şekerbank	0.0048
A5	Vakıflar	0.1282
A6	Yapı ve Kredi	0.0845

Table 4. The environmental performance indicators

Category	Code	Definition	Optimization	References
Energy	EI1	Fuel Consumption	Min	[39, 58]
	EI2	Electricity Consumption (Renewable)	Max	[49, 58, 59]
	EI3	Electricity Consumption (Non-Renewable)	Min	[49, 58, 59]
Air Release	EI4	Direct Emissions	Min	[8, 60–62]
	EI5	Indirect Emissions	Min	[8, 60–62]
Waste and Recycling	EI6	Hazardous Waste	Min	[58, 59, 63]
	EI7	Non-Hazardous Waste	Max	[58, 59, 63]
	EI8	Amount of Recycled Waste	Max	[58, 59, 64]
	EI9	Amount of Disposed Waste	Min	[58, 59, 63, 64]
Water	EI10	Water Consumption	Min	[39, 61, 65]
	EI11	Water Withdrawal	Min	[66, 67]
	EI12	Discharged Water	Min	[47, 64]
Employee Training	EI13	Environmental Education	Max	[64, 68, 69]

5 Implementation of the Grey LOPCOW-PIV MODEL

This section of the study presents the findings of the application of the decision framework for measuring the environmental performance of the selected banks.

5.1 Results of the Grey LOPCOW Procedure

The Grey LOPCOW procedure was preferred in determining the importance weights of the selected environmental performance indicators. A committee was established to assess the environmental performance indicators. A face-to-face interview was conducted with the members of this committee. This committee consists of experts who have been selected for their experience and knowledge in the field. The committee members include four board members, two branch managers, and one regional manager. Additionally, these individuals have at least 15 years of experience in evaluating banking activities and their environmental impacts. Table 5 shows the details of seven sector professionals who have been identified as evaluators.

Table 5. Details of DMs

DM	Duty	Experience (Years)	Graduation
DM-I	Member of Board	20	Master's Degree
DM-II	Member of Board	25	Master's Degree
DM-III	Member of Board	22	Master's Degree
DM-IV	Member of Board	26	PhD Degree
DM-V	Branch Manager	15	Bachelor's Degree
DM-VI	Regional Manager	28	Bachelor's Degree
DM-VII	Branch Manager	18	Bachelor's Degree

Each DM opinion was obtained in accordance with the grey linguistic values given in Table 2. The linguistic data obtained on the basis of the DM opinions are given in Table 6.

The linguistic data obtained within the framework of the DM opinions have been converted into quantitative values by means of the grey numbers shown in Table 2. The quantitative data for each of the DM opinions are presented in Table 7.

Table 6. The linguistics assessments of DMs for the alternatives

	DMs	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9	EI10	EI11	EI12	EI13
	DM1	MG	B	F	VB	VB	G	MB	MB	VB	F	MB	MB	VB
	DM2	F	B	MB	VB	MB	VB	MB	B	F	B	VB	B	VB
	DM3	VB	MB	F	F	VB	VB	B	MG	MB	VB	F	VB	VB
A1	DM4	B	MB	F	VG	G	VB	VB	VB	MB	VB	MB	B	B
	DM5	G	B	F	VB	G	F	B	B	MB	F	B	VB	VB
	DM6	MB	MB	GV	VB	MB	G	F	F	F	VB	G	MG	B
	DM7	F	MB	VB	B	B	G	B	VB	G	B	F	G	B
	DM1	MG	B	G	MG	MB	VG	G	MG	MG	VB	B	MB	G
	DM2	VG	MB	MG	G	MG	G	VG	MB	MG	F	F	G	F
	DM3	VG	MG	MB	MB	MG	MB	G	MB	MG	G	MG	MG	MB
A2	DM4	G	MG	MG	F	F	F	G	MG	VG	MB	MB	B	F
	DM5	B	F	MG	G	MB	VB	MB	MB	F	G	G	G	MB
	DM6	VG	F	MG	G	MG	MB	MG	MB	VB	MG	F	MB	MB
	DM7	MG	MB	F	B	G	MB	G	VG	VG	F	MG	B	MB
	DM1	G	B	F	G	G	F	G	VG	VG	G	MB	MG	B
	DM2	VG	MG	MB	VG	VG	B	F	MG	B	G	MG	VG	F
	DM3	G	MG	MB	B	G	VG	VG	MB	VG	B	B	BG	MG
A3	DM4	VG	MB	MB	F	MG	MG	MB	G	F	G	F	VG	G
	DM5	MB	MB	MG	MG	G	MG	MG	MG	MB	MG	VG	B	VG
	DM6	F	G	MB	MG	MB	VG	B	B	G	G	VG	F	MB
	DM7	MG	MB	MG	VG	MG	VG	VG	G	MB	MB	MB	F	MG
	DM1	VB	G	VG	G	G	B	B	F	G	VG	MG	G	MG
	DM2	G	G	G	VG	F	MG	MB	MG	G	VG	MG	G	VG
	DM3	VG	G	VG	MB	G	VG	G	MG	F	MG	VG	VG	VG
A4	DM4	G	G	VG	G	VB	MG	VG	G	MB	VG	G	G	VG
	DM5	VG	MG	G	VG	MB	B	MG	MG	F	G	G	MG	VG
	DM6	MB	MG	G	MB	G	MB	G	MG	G	G	F	B	G
	DM7	G	VG	MG	MB	VG	MB	G	VG	MG	MG	VG	VG	MG
	DM1	B	VG	VG	G	G	F	G	VG	VG	G	MG	VG	MG
	DM2	MB	G	VG	F	VG	MG	VG	VG	VG	MG	VG	MG	G
	DM3	F	VG	MG	VG	VG	VG	MG	VG	VG	MG	VG	VG	VG
A5	DM4	MG	G	G	G	MB	VG	VG	G	VG	G	VG	G	MG
	DM5	VG	G	VG	VG	VG	VG	VG	VG	VG	MB	MG	MG	VG
	DM6	VG	VG	VG	VG	MB	MB	VG	VG	MG	G	VG	VG	VG
	DM7	VG	MG	VG	MB	VG	G	MG	MG	VG	G	G	MG	VG
	DM1	B	G	MG	VG	MB	MG	F	MG	G	MB	B	VG	VG
	DM2	B	G	G	G	MG	VG	G	VG	MB	G	MG	F	VG
	DM3	MB	MG	G	MB	G	G	F	VG	MG	VG	BM	F	VG
A6	DM4	F	G	VG	MG	VG	MG	MB	VG	G	F	VG	F	G
	DM5	G	VG	MB	G	MG	VG	VG	VG	G	F	F	VG	G
	DM6	G	MG	MG	F	G	G	MB	VG	MG	VG	MB	B	G
	DM7	MB	VG	MG	G	MB	MB	F	MB	MB	VG	G	G	VG

The data based on the DM opinions shown in Table 7 are integrated within the framework of Eq. (7) and the grey initial decision matrix is created as shown in Table 8.

Each value in the grey decision matrix is normalized by taking into account the characteristics of the non-beneficial and beneficial. The normalized values are calculated using Eq. (8) for the non-beneficial environmental performance indicators and Eq. (9) for the beneficial environmental performance indicators. The resulting normalized values are shown in Table 9.

In the final stage of the proposed approach, the grey percentage values ($\otimes PV_{ij}$) of the evaluation criteria were initially calculated by utilizing Eq. (10). Subsequently, the grey objective importance weights of each evaluation criterion were determined using Eq. (11). The findings and crisp weights obtained from these calculations are presented in Table 10.

The findings of the Grey LOPCOW method, as presented in Table 10, indicate that the three evaluation criteria with the most significant impact on the environmental performance of the selected banks are EI9 (amount of disposed waste), EI7 (non-hazardous waste) and EI8 (amount of recycled waste), respectively. On the other hand, the three evaluation criteria that have the least impact on the environmental performance of banks are EI4 (direct emissions), EI10 (water consumption) and EI1 (fuel consumption), respectively.

Table 7. The quantitative assessments of DMs for the alternatives

	DMs	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9	EI10	EI11	EI12	EI13
	DM1	[41-50]	[11-20]	[31-40]	[1-10]	[1-10]	[51-60]	[21-30]	[21-30]	[1-10]	[31-40]	[21-30]	[21-30]	[1-10]
	DM2	[31-40]	[11-20]	[21-30]	[1-10]	[21-30]	[1-10]	[21-30]	[11-20]	[31-40]	[11-20]	[1-10]	[11-20]	[1-10]
	DM3	[1-10]	[21-30]	[31-40]	[31-40]	[1-10]	[1-10]	[11-20]	[41-50]	[21-30]	[1-10]	[31-40]	[1-10]	[1-10]
A1	DM4	[11-20]	[21-30]	[21-30]	[61-70]	[51-60]	[1-10]	[1-10]	[1-10]	[21-30]	[1-10]	[21-30]	[11-20]	[11-20]
	DM5	[51-60]	[11-20]	[31-40]	[1-10]	[51-60]	[31-40]	[11-20]	[11-20]	[21-30]	[31-40]	[11-20]	[1-10]	[1-10]
	DM6	[21-30]	[21-30]	[61-70]	[1-10]	[21-30]	[51-60]	[31-40]	[31-40]	[31-40]	[1-10]	[51-60]	[41-50]	[11-20]
	DM7	[31-40]	[21-30]	[1-10]	[11-20]	[11-20]	[51-60]	[11-20]	[1-10]	[51-60]	[11-20]	[31-40]	[51-60]	[11-20]
	DM1	[41-50]	[11-20]	[51-60]	[41-50]	[21-30]	[61-70]	[51-60]	[41-50]	[41-50]	[1-10]	[11-20]	[21-30]	[51-60]
	DM2	[61-70]	[21-30]	[21-30]	[51-60]	[41-50]	[51-60]	[61-70]	[21-30]	[41-50]	[31-40]	[31-40]	[51-60]	[31-40]
	DM3	[61-70]	[41-50]	[21-30]	[21-30]	[41-50]	[21-30]	[51-60]	[21-30]	[41-50]	[51-60]	[41-50]	[41-50]	[21-30]
A2	DM4	[51-60]	[41-50]	[41-50]	[31-40]	[31-40]	[31-40]	[51-60]	[41-50]	[61-70]	[21-30]	[21-30]	[11-20]	[31-40]
	DM5	[11-20]	[31-40]	[41-50]	[51-60]	[21-30]	[1-10]	[21-30]	[21-30]	[31-40]	[51-60]	[51-60]	[51-60]	[21-30]
	DM6	[61-70]	[31-40]	[41-50]	[51-60]	[41-50]	[21-30]	[41-50]	[21-30]	[1-10]	[41-50]	[31-40]	[21-30]	[21-30]
	DM7	[41-50]	[21-30]	[31-40]	[11-20]	[51-60]	[21-30]	[51-60]	[61-70]	[61-70]	[31-40]	[41-50]	[11-20]	[21-30]
	DM1	[51-60]	[11-20]	[31-40]	[51-60]	[51-60]	[31-40]	[51-60]	[61-70]	[61-70]	[51-60]	[21-30]	[41-50]	[11-20]
	DM2	[61-70]	[41-50]	[21-30]	[61-70]	[61-70]	[11-20]	[31-40]	[41-50]	[11-20]	[51-60]	[41-50]	[61-70]	[31-40]
	DM3	[51-60]	[41-50]	[21-30]	[11-20]	[51-60]	[61-70]	[61-70]	[21-30]	[61-70]	[11-20]	[11-20]	[21-30]	[41-50]
A3	DM4	[61-70]	[21-30]	[21-30]	[31-40]	[41-50]	[41-50]	[21-30]	[51-60]	[31-40]	[51-60]	[31-40]	[61-70]	[51-60]
	DM5	[21-30]	[21-30]	[41-50]	[41-50]	[51-60]	[41-50]	[41-50]	[41-50]	[21-30]	[41-50]	[61-70]	[11-20]	[61-70]
	DM6	[31-40]	[51-60]	[21-30]	[41-50]	[21-30]	[61-70]	[11-20]	[11-20]	[51-60]	[51-60]	[61-70]	[31-40]	[21-30]
	DM7	[41-50]	[21-30]	[41-50]	[61-70]	[41-50]	[61-70]	[61-70]	[51-60]	[61-70]	[61-70]	[21-30]	[31-40]	[41-50]
	DM1	[1-10]	[51-60]	[61-70]	[51-60]	[51-60]	[11-20]	[11-20]	[31-40]	[51-60]	[61-70]	[41-50]	[51-60]	[41-50]
	DM2	[51-60]	[51-60]	[51-60]	[61-70]	[31-40]	[41-50]	[21-30]	[41-50]	[51-60]	[61-70]	[41-50]	[51-60]	[61-70]
	DM3	[61-70]	[51-60]	[61-70]	[21-30]	[51-60]	[61-70]	[51-60]	[41-50]	[31-40]	[41-50]	[61-70]	[61-70]	[61-70]
A4	DM4	[51-60]	[51-60]	[61-70]	[51-60]	[1-10]	[41-50]	[61-70]	[51-60]	[21-30]	[61-70]	[51-60]	[51-60]	[61-70]
	DM5	[61-70]	[41-50]	[51-60]	[61-70]	[21-30]	[11-20]	[41-50]	[41-50]	[31-40]	[51-60]	[51-60]	[41-50]	[61-70]
	DM6	[21-30]	[41-50]	[51-60]	[21-30]	[51-60]	[21-30]	[51-60]	[41-50]	[51-60]	[51-60]	[31-40]	[11-20]	[51-60]
	DM7	[51-60]	[61-70]	[41-50]	[21-30]	[61-70]	[21-30]	[51-60]	[61-70]	[41-50]	[41-50]	[61-70]	[61-70]	[41-50]
	DM1	[11-20]	[61-70]	[61-70]	[51-60]	[51-60]	[31-40]	[51-60]	[61-70]	[61-70]	[51-60]	[41-50]	[61-70]	[41-50]
	DM2	[21-30]	[51-60]	[61-70]	[31-40]	[61-70]	[41-50]	[61-70]	[61-70]	[61-70]	[41-50]	[61-70]	[41-50]	[51-60]
	DM3	[31-40]	[61-70]	[41-50]	[61-70]	[61-70]	[61-70]	[41-50]	[61-70]	[61-70]	[41-50]	[61-70]	[61-70]	[61-70]
A5	DM4	[41-50]	[51-60]	[51-60]	[51-60]	[21-30]	[61-70]	[61-70]	[51-60]	[51-60]	[51-60]	[61-70]	[51-60]	[41-50]
	DM5	[61-70]	[51-60]	[61-70]	[61-70]	[61-70]	[61-70]	[61-70]	[61-70]	[61-70]	[21-30]	[41-50]	[41-50]	[61-70]
	DM6	[61-70]	[61-70]	[61-70]	[61-70]	[21-30]	[21-30]	[61-70]	[61-70]	[41-50]	[51-60]	[61-70]	[61-70]	[61-70]
	DM7	[61-70]	[41-50]	[61-70]	[21-30]	[61-70]	[51-60]	[41-50]	[41-50]	[61-70]	[51-60]	[51-60]	[41-50]	[61-70]
	DM1	[11-20]	[51-60]	[41-50]	[61-70]	[21-30]	[41-50]	[31-40]	[41-50]	[51-60]	[21-30]	[11-20]	[61-70]	[61-70]
	DM2	[11-20]	[51-60]	[51-60]	[51-60]	[41-50]	[61-70]	[51-60]	[61-70]	[21-30]	[51-60]	[41-50]	[31-40]	[61-70]
	DM3	[21-30]	[41-50]	[51-60]	[21-30]	[51-60]	[51-60]	[31-40]	[61-70]	[41-50]	[61-70]	[21-30]	[31-40]	[61-70]
A6	DM4	[31-40]	[41-50]	[61-70]	[41-50]	[61-70]	[41-50]	[21-30]	[61-70]	[51-60]	[31-40]	[61-70]	[31-40]	[51-60]
	DM5	[51-60]	[61-70]	[21-30]	[51-60]	[41-50]	[61-70]	[61-70]	[61-70]	[51-60]	[31-40]	[31-40]	[61-70]	[51-60]
	DM6	[51-60]	[41-50]	[41-50]	[31-40]	[51-60]	[51-60]	[21-30]	[61-70]	[41-50]	[61-70]	[21-30]	[11-20]	[51-60]
	DM7	[21-30]	[61-70]	[41-50]	[51-60]	[21-30]	[21-30]	[31-40]	[21-30]	[21-30]	[61-70]	[51-60]	[51-60]	[61-70]

Table 8. The grey decision matrix

	A1	A2	A3	A4	A5	A6
EI1	[26.71, 35.71]	[46.71, 55.71]	[45.29, 54.29]	[42.43, 51.43]	[41.00, 50.00]	[28.14, 37.14]
EI2	[16.71, 25.71]	[28.14, 37.14]	[29.57, 38.57]	[49.57, 58.57]	[53.86, 62.86]	[51.00, 60.00]
EI3	[29.57, 38.57]	[35.29, 44.29]	[28.14, 37.14]	[53.86, 62.86]	[56.71, 65.71]	[43.86, 52.86]
EI4	[15.29, 24.29]	[36.71, 45.71]	[42.43, 51.43]	[41.00, 50.00]	[48.14, 57.14]	[43.86, 52.86]
EI5	[22.43, 31.43]	[35.29, 44.29]	[45.29, 54.29]	[38.14, 47.14]	[48.14, 57.14]	[41.00, 50.00]
EI6	[26.71, 35.71]	[29.57, 38.57]	[43.86, 52.86]	[29.57, 38.57]	[46.71, 55.71]	[46.71, 55.71]
EI7	[15.29, 24.29]	[46.71, 55.71]	[39.57, 48.57]	[41.00, 50.00]	[53.86, 62.86]	[35.29, 44.29]
EI8	[16.71, 25.71]	[32.43, 41.43]	[39.57, 48.57]	[43.86, 52.86]	[56.71, 65.71]	[52.43, 61.43]
EI9	[25.29, 34.29]	[39.57, 48.57]	[36.71, 45.71]	[39.57, 48.57]	[58.14, 67.14]	[39.57, 48.57]
EI10	[12.43, 21.43]	[32.43, 41.43]	[39.57, 48.57]	[52.43, 61.43]	[43.86, 52.86]	[45.29, 54.29]
EI11	[23.86, 32.86]	[32.43, 41.43]	[35.29, 44.29]	[48.14, 57.14]	[53.86, 62.86]	[33.86, 42.86]
EI12	[19.57, 28.57]	[29.57, 38.57]	[36.71, 45.71]	[46.71, 55.71]	[51.00, 60.00]	[39.57, 48.57]
EI13	[5.29, 14.29]	[28.14, 37.14]	[36.71, 45.71]	[53.86, 62.86]	[53.86, 62.86]	[56.71, 65.71]

Table 9. The grey normalized matrix

	A1	A2	A3	A4	A5	A6
EI1	[0.6897, 1.0000]	[0.0000, 0.3103]	[0.0493, 0.3596]	[0.1478, 0.4581]	[0.1970, 0.5074]	[0.6404, 0.9507]
EI2	[0.0000, 0.1950]	[0.2477, 0.4427]	[0.2786, 0.4737]	[0.7121, 0.9071]	[0.8050, 1.0000]	[0.7430, 0.9381]
EI3	[0.7224, 0.9620]	[0.5703, 0.8099]	[0.7605, 1.0000]	[0.0760, 0.3156]	[0.0000, 0.2395]	[0.3422, 0.5817]
EI4	[0.7850, 1.0000]	[0.2730, 0.4881]	[0.1365, 0.3515]	[0.1706, 0.3857]	[0.0000, 0.2150]	[0.1024, 0.3174]
EI5	[0.7407, 1.0000]	[0.3704, 0.6296]	[0.0823, 0.3416]	[0.2881, 0.5473]	[0.0000, 0.2593]	[0.2058, 0.4650]
EI6	[0.6897, 1.0000]	[0.5911, 0.9015]	[0.0985, 0.4089]	[0.5911, 0.9015]	[0.0000, 0.3103]	[0.0000, 0.3103]
EI7	[0.0000, 0.1892]	[0.6607, 0.8498]	[0.5105, 0.6997]	[0.5405, 0.7297]	[0.8108, 1.0000]	[0.4204, 0.6096]
EI8	[0.0000, 0.1837]	[0.3207, 0.5044]	[0.4665, 0.6501]	[0.5539, 0.7376]	[0.8163, 1.0000]	[0.7289, 0.9125]
EI9	[0.7850, 1.0000]	[0.4437, 0.6587]	[0.5119, 0.7270]	[0.4437, 0.6587]	[0.0000, 0.2150]	[0.4437, 0.6587]
EI10	[0.8163, 1.0000]	[0.4082, 0.5918]	[0.2624, 0.4461]	[0.0000, 0.1837]	[0.1749, 0.3586]	[0.1458, 0.3294]
EI11	[0.7692, 1.0000]	[0.5495, 0.7802]	[0.4762, 0.7070]	[0.1465, 0.3773]	[0.0000, 0.2308]	[0.5128, 0.7436]
EI12	[0.7774, 1.0000]	[0.5300, 0.7527]	[0.3534, 0.5760]	[0.1060, 0.3286]	[0.0000, 0.2226]	[0.2827, 0.5053]
EI13	[0.0000, 0.1489]	[0.3783, 0.5272]	[0.5201, 0.6690]	[0.8038, 0.9527]	[0.8038, 0.9527]	[0.8511, 1.0000]

Table 10. The Grey LOPCOW results

	$\otimes PV_{ij}$	$\otimes w_{jLOP}$	**Crisp** w_j	**Rank**
EI1	[36.9245, 87.2664]	[0.0511, 0.0741]	0.0626	11
EI2	[60.3546, 87.2503]	[0.0740, 0.0835]	0.0788	6
EI3	[53.5720, 87.9048]	[0.0741, 0.0746]	0.0744	7
EI4	[32.6256, 72.3424]	[0.0452, 0.0614]	0.0533	13
EI5	[43.3816, 90.4329]	[0.0600, 0.0767]	0.0684	9
EI6	[39.5323, 85.7607]	[0.0547, 0.0728]	0.0637	10
EI7	[78.4209, 105.7824]	[0.0898, 0.1085]	0.0992	2
EI8	[71.5288, 97.8219]	[0.0830, 0.0990]	0.0910	3
EI9	[76.5400, 110.1423]	[0.0935, 0.1059]	0.0997	1
EI10	[42.3154, 74.6314]	[0.0586, 0.0633]	0.0610	12
EI11	[62.6899, 98.1841]	[0.0833, 0.0868]	0.0850	5
EI12	[50.4857, 87.5485]	[0.0699, 0.0743]	0.0721	8
EI13	[74.1232, 93.2592]	[0.0791, 0.1026]	0.0909	4

5.2 The Results of Grey PIV Procedure

In the subsequent stage of the analytical process, the environmental performance of the bank was appraised through the implementation of the Grey PIV methodology. The initial step within the Grey PIV method involves the formulation of the Grey initial decision matrix. This matrix is obtained by means of Eq. (7) and is presented in Table 8. In the second step of the proposed method, all values for the criteria in the grey initial matrix are normalized using Eq. (12). The normalized grey values are reported in Table 11.

Table 11. The normalized grey decision matrix

	A1	A2	A3	A4	A5	A6
EI1	[0.1759, 0.2351]	[0.3076, 0.3668]	[0.2981, 0.3574]	[0.2793, 0.3386]	[0.2699, 0.3292]	[0.1853, 0.2445]
EI2	[0.1070, 0.1646]	[0.1801, 0.2377]	[0.1893, 0.2469]	[0.3173, 0.3749]	[0.3447, 0.4023]	[0.3264, 0.3840]
EI3	[0.1805, 0.2354]	[0.2154, 0.2703]	[0.1718, 0.2267]	[0.3287, 0.3836]	[0.3462, 0.4011]	[0.2677, 0.3226]
EI4	[0.1004, 0.1595]	[0.2411, 0.3002]	[0.2786, 0.3377]	[0.2692, 0.3284]	[0.3162, 0.3753]	[0.2880, 0.3471]
EI5	[0.1475, 0.2066]	[0.2320, 0.2912]	[0.2977, 0.3569]	[0.2508, 0.3099]	[0.3165, 0.3757]	[0.2695, 0.3287]
EI6	[0.1801, 0.2408]	[0.1994, 0.2600]	[0.2957, 0.3563]	[0.1994, 0.2600]	[0.3149, 0.3756]	[0.3149, 0.3756]
EI7	[0.0981, 0.1559]	[0.2998, 0.3576]	[0.2540, 0.3118]	[0.2632, 0.3209]	[0.3457, 0.4034]	[0.2265, 0.2842]
EI8	[0.1029, 0.1582]	[0.1996, 0.2549]	[0.2435, 0.2989]	[0.2699, 0.3253]	[0.3490, 0.4044]	[0.3226, 0.3780]
EI9	[0.1602, 0.2172]	[0.2507, 0.3077]	[0.2326, 0.2896]	[0.2507, 0.3077]	[0.3683, 0.4254]	[0.2507, 0.3077]
EI10	[0.0810, 0.1397]	[0.2113, 0.2700]	[0.2579, 0.3165]	[0.3417, 0.4003]	[0.2858, 0.3445]	[0.2951, 0.3538]
EI11	[0.1572, 0.2165]	[0.2136, 0.2729]	[0.2325, 0.2918]	[0.3172, 0.3765]	[0.3548, 0.4141]	[0.2231, 0.2823]
EI12	[0.1307, 0.1909]	[0.1975, 0.2576]	[0.2452, 0.3054]	[0.3120, 0.3722]	[0.3407, 0.4008]	[0.2643, 0.3244]
EI13	[0.0321, 0.0868]	[0.1710, 0.2257]	[0.2231, 0.2778]	[0.3273, 0.3820]	[0.3273, 0.3820]	[0.3446, 0.3993]

The weighted normalized matrix created using Eq. (13) is given in Table 12.

The grey weighted proximity index values (g_{ij}) were calculated using Eq. (14) and Eq. (15) with consideration for the non-beneficial/beneficial characteristics of the criteria. The findings obtained by using Eq. (14) for nonbeneficial criteria and Eq. (15) for beneficial criteria are shown in Table 13.

In the final step of the Grey PIV procedure, firstly, the general proximity index values (d_i^l, d_i^u) utilized for the purpose of ranking the decision alternatives were calculated by Eq. (16). Subsequently, the success scores (d_i) of the banks were determined according to Eq. (17). The findings of these calculations and the results of the success rankings of the banks are presented in Table 14.

The findings presented in Table 14 demonstrate that, within the context of the banks whose shares are listed on BIST, the Yapı ve Kredi Bank stands out as a leader in environmentally sustainable performance. The subsequent banks in order of environmental sustainable performance are Akbank, Garanti Bank, Şekerbank, Halkbank and Vakıfbank, respectively.

Table 12. The weighted normalized matrix

	A1	**A2**	**A3**	**A4**	**A5**	**A6**
EI1	[0.0090, 0.0174]	[0.0157, 0.0272]	[0.0152, 0.0265]	[0.0143, 0.0251]	[0.0138, 0.0244]	[0.0095, 0.0181]
EI2	[0.0079, 0.0137]	[0.0133, 0.0199]	[0.0140, 0.0206]	[0.0235, 0.0313]	[0.0255, 0.0336]	[0.0242, 0.0321]
EI3	[0.0134, 0.0176]	[0.0160, 0.0202]	[0.0127, 0.0169]	[0.0244, 0.0286]	[0.0257, 0.0299]	[0.0198, 0.0241]
EI4	[0.0045, 0.0098]	[0.0109, 0.0184]	[0.0126, 0.0207]	[0.0122, 0.0202]	[0.0143, 0.0230]	[0.0130, 0.0213]
EI5	[0.0089, 0.0159]	[0.0139, 0.0223]	[0.0179, 0.0274]	[0.0151, 0.0238]	[0.0190, 0.0288]	[0.0162, 0.0252]
EI6	[0.0099, 0.0175]	[0.0109, 0.0189]	[0.0162, 0.0259]	[0.0109, 0.0189]	[0.0172, 0.0273]	[0.0172, 0.0273]
EI7	[0.0088, 0.0169]	[0.0269, 0.0388]	[0.0228, 0.0338]	[0.0236, 0.0348]	[0.0310, 0.0438]	[0.0203, 0.0309]
EI8	[0.0085, 0.0157]	[0.0166, 0.0252]	[0.0202, 0.0296]	[0.0224, 0.0322]	[0.0290, 0.0400]	[0.0268, 0.0374]
EI9	[0.0150, 0.0230]	[0.0234, 0.0326]	[0.0217, 0.0307]	[0.0234, 0.0326]	[0.0344, 0.0451]	[0.0234, 0.0326]
EI10	[0.0047, 0.0088]	[0.0124, 0.0171]	[0.0151, 0.0200]	[0.0200, 0.0254]	[0.0167, 0.0218]	[0.0173, 0.0224]
EI11	[0.0131, 0.0188]	[0.0178, 0.0237]	[0.0194, 0.0253]	[0.0264, 0.0327]	[0.0296, 0.0359]	[0.0186, 0.0245]
EI12	[0.0091, 0.0142]	[0.0138, 0.0191]	[0.0171, 0.0227]	[0.0218, 0.0277]	[0.0238, 0.0298]	[0.0185, 0.0241]
EI13	[0.0025, 0.0089]	[0.0135, 0.0232]	[0.0177, 0.0285]	[0.0259, 0.0392]	[0.0259, 0.0392]	[0.0273, 0.0410]

Table 13. The grey weighted proximity index

	A1	**A2**	**A3**	**A4**	**A5**	**A6**
EI1	[-0.0084, 0.0084]	[-0.0017, 0.0182]	[-0.0022, 0.0175]	[-0.0031, 0.0161]	[-0.0036, 0.0154]	[-0.0079, 0.0091]
EI2	[0.0118, 0.0257]	[0.0057, 0.0203]	[0.0049, 0.0196]	[-0.0058, 0.0101]	[-0.0081, 0.0081]	[-0.0066, 0.0094]
EI3	[-0.0035, 0.0048]	[-0.0009, 0.0074]	[-0.0042, 0.0042]	[0.0075, 0.0159]	[0.0088, 0.0172]	[0.0029, 0.0113]
EI4	[-0.0053, 0.0053]	[0.0011, 0.0139]	[0.0028, 0.0162]	[0.0024, 0.0156]	[0.0045, 0.0185]	[0.0032, 0.0168]
EI5	[-0.0070, 0.0070]	[-0.0019, 0.0135]	[0.0020, 0.0185]	[-0.0008, 0.0149]	[0.0031, 0.0200]	[0.0003, 0.0164]
EI6	[-0.0077, 0.0077]	[-0.0066, 0.0091]	[-0.0013, 0.0161]	[-0.0066, 0.0091]	[-0.0003, 0.0175]	[-0.0003, 0.0175]
EI7	[0.0141, 0.0350]	[-0.0078, 0.0169]	[-0.0028, 0.0210]	[-0.0038, 0.0202]	[-0.0128, 0.0128]	[0.0002, 0.0235]
EI8	[0.0133, 0.0315]	[0.0037, 0.0235]	[-0.0006, 0.0198]	[-0.0032, 0.0176]	[-0.0111, 0.0111]	[-0.0085, 0.0133]
EI9	[-0.0080, 0.0080]	[0.0004, 0.0176]	[-0.0013, 0.0157]	[0.0004, 0.0176]	[0.0114, 0.0301]	[0.0004, 0.0176]
EI10	[-0.0041, 0.0041]	[0.0035, 0.0124]	[0.0063, 0.0153]	[0.0112, 0.0206]	[0.0079, 0.0171]	[0.0084, 0.0177]
EI11	[-0.0057, 0.0057]	[-0.0010, 0.0106]	[0.0006, 0.0122]	[0.0076, 0.0196]	[0.0108, 0.0228]	[-0.0002, 0.0114]
EI12	[-0.0050, 0.0050]	[-0.0004, 0.0100]	[0.0030, 0.0136]	[0.0076, 0.0185]	[0.0096, 0.0206]	[0.0043, 0.0150]
EI13	[0.0184, 0.0384]	[0.0041, 0.0274]	[-0.0012, 0.0233]	[-0.0119, 0.0151]	[-0.0119, 0.0151]	[-0.0137, 0.0137]

Table 14. The results of Grey PIV

Bank	d_i^l	d_i^u	d_i	**Ranking**
AKBNK	0.0028	0.1866	0.0947	2
GARAN	-0.0018	0.2007	0.0995	3
HALKB	0.0059	0.2130	0.1094	5
SKBNK	0.0014	0.2109	0.1062	4
VAKBN	0.0084	0.2262	0.1173	6
YKBNK	-0.0173	0.1926	0.0876	1

6 Validation Test

The validity and applicability of the Grey LOPCOW-PIV approach were tested by performing a robustness test consisting of three stages. Firstly, the impact of fluctuations in the weight values of environmental assessment criteria on the ultimate banking ranking was examined through 130 distinct scenarios. Secondly, the resilience of the ranking outcomes to the rank reversal issue was assessed via six scenarios. Finally, the ranking results of the proposed Grey MCDM model were compared with other Grey MCDM methodologies.

6.1 Exploring the Changes in Criteria Weights

In the initial phase of the sensitivity analysis, the impact of each environmental criterion on the ranking position of alternative banks was examined through 130 distinct scenarios. According to the first 10 scenarios, the importance weight of the first evaluation criterion was reduced by 10%, 20%, ..., 100% in each scenario. The weights of the remaining criteria were modified proportionally so that their total weight values would be 1. The same weight calculation process was repeated for the remaining 12 criteria, resulting in a total of 130 scenarios. As a result, thanks to these sensitivity scenarios, all possible effects of changes in criteria weights on the final ranking results can be taken into account [70]. The outcomes concerning the new rankings obtained from 130 scenarios are illustrated in Figure 2. As demonstrated in Figure 2, it is evident that the ranking positions of YKBNK, AKBNK and VAKBN remain constant when the criteria weights are altered. Minor alterations in the ranking positions are observed for the remaining three bank alternatives (i.e., GARAN, SKBNK, and HALKB). However, these minor changes in the rankings are not substantial enough to impact the overall ranking outcome. Consequently, the findings obtained from this analysis indicate that the proposed model produces robust and dependable outcomes.

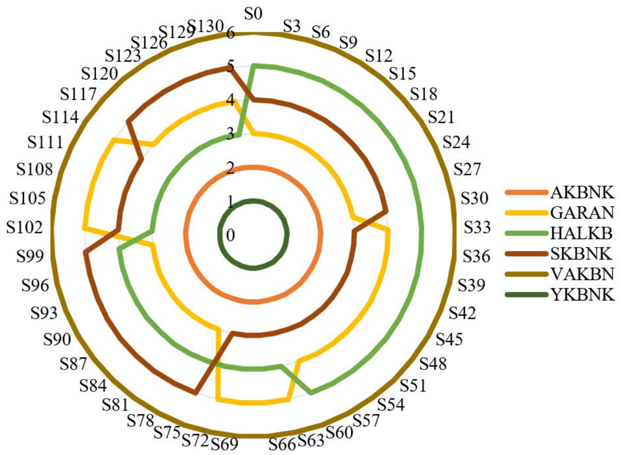

Figure 2. Re-ranking of alternatives based on the new weights for criteria

6.2 Examining the Impact of the Rank Reversal Phenomenon on the Ranking Result

Whether the ranking results are resistant to the order reversal problem was examined with a total of 6 scenarios in which the worst alternatives in the ranking were deleted in order [71, 72]. The ranking results derived from six distinct scenarios are presented in Figure 3. According to Figure 3, the obtained results confirm the initial ranking results and reveal that the bank ranking positions are robust to the rank reversal problem.

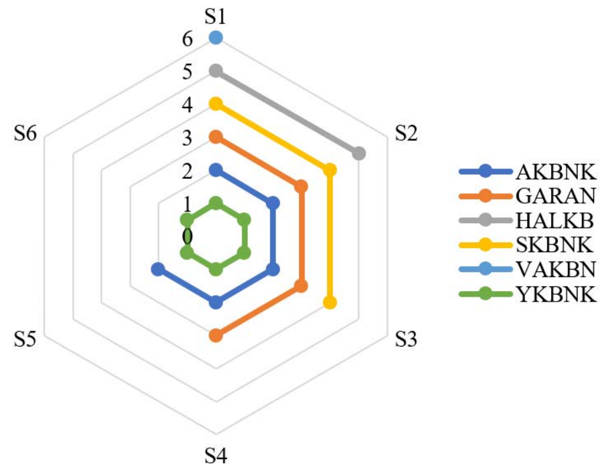

Figure 3. Alternatives' ranking orders based on various scenarios

6.3 Comparison of the Proposed Hybrid Methodology with the Various MCDM Tools Result

In the last stage of robustness analysis, the rankings obtained with Grey PIV were compared with the results of other classical and new Grey MCDM approaches. In this context, the used methods for comparative analysis are Grey SAW [73], Grey EDAS [74], Grey WASPAS [75], Grey MARCOS [76], Grey MACONT [77], and Grey WEDBA [78], respectively. The results of the comparative analysis are demonstrated in Figure 4. Based on Figure 4, no change was observed in the ranking position of the alternative banks, indicating that the ranking results obtained from the proposed grey hybrid approach produce stable and dependable outputs.

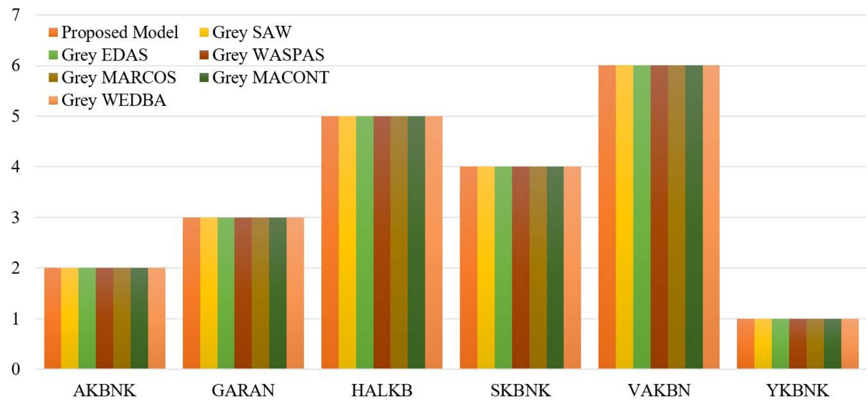

Figure 4. Alternatives' ranking results according to different MCDM tools

7 Discussion and Practical, and Managerial Implications

Banks have a high potential to create environmental impacts through both their lending and investment activities and other financial service activities. Assessing the environmental sustainability performance of the banking sector is critical for effective risk management, strategic planning and ecosystem sustainability. Increasing climate and environmental problems have led banking institutions, like other non-financial firms, to develop policies aimed at reducing their harmful effects on the environment. As a result, banking activities that take environmental issues into account not only serve to minimize environmental risks, but also contribute to improving corporate reputation and long-term performance.

The current study has some practical implications for bank decision-makers as follows:

•A novel and comprehensive decision-making framework for assessing and analysing banks' environmental sustainability performance is proposed in this paper.

•The presented decision-making approach is designed to be simple and straightforward to implement for bank decision-makers who do not possess advanced mathematical skills.

•Integrating LOPCOW approach with interval grey numbers provides significant flexibility to decision-makers in the relevant sector by facilitating the calculation of weights of predetermined criteria.

•Combining the PIV method with interval grey numbers can aid DMs and practitioners in the effective management of processes related to environmental issues, enabling the making of reliable and rational decisions.

The managerial implications of the existing work are as follows:

•The application of Grey LOPCOW and Grey PIV methods in evaluating bank environmental performance can contribute to the existing literature by providing new insights and methodologies. This can pave the way for further research and development in the field of environmental sustainability in the banking industry.

•The usage of MCDM tools assists banks in aligning their operations with broader sustainability goals, such as the United Nations Sustainable Development Goals.

•The utilization of MCDM algorithms in the assessment of environmental performance has the potential to assist banking executives in adhering to prevailing environmental regulations and standards. A structured methodology for evaluating environmental performance can enable comprehensive and transparent sustainability reporting, a prerequisite in the contemporary context where regulators and stakeholders are demanding such information with increased frequency.

•The introduced framework provides a detailed assessment of environmental risks associated with banking activities. By identifying and prioritizing these risks, banks can develop more effective mitigation strategies, thereby reducing potential liabilities and enhancing their resilience to environmental challenges.

•The comparative analysis allows banks to benchmark their performance against peers. This can highlight best practices and areas needing improvement, fostering a culture of continuous improvement in environmental sustainability.

•The empirical findings from the suggested decision-making approach have the potential to guide the board of directors of banks in enhancing their environmental sustainability performance, thereby establishing a sustainable competitive advantage within the industry.

8 Conclusions and Directions for Future Research

Analysing the performance of the banking sector from different perspectives is important for all those involved in banking. To manage risk, comply with regulations, attract investors, enhance reputation, improve operational efficiency, ensure long-term sustainability and build stakeholder confidence, it is essential that banks measure and assess their performance.

Recently, the sustainability performance of financial and non-financial institutions has begun to attract attention from a variety of stakeholders, including regulators, academics, practitioners and policymakers. In this context, sustainability performance is generally analyzed by researchers based on environmental, social and governance indicators. Therefore, the current research aimed to make a comparison between banks by focusing on the environmental performance dimension, which is one of the three dimensions of ESG.

This work puts forward a combined Grey MCDM approach with the aim of addressing the problem of measuring banks' environmental performance. The suggested framework is tested through a case study to analyze the environmental sustainability indicators of six deposit banks whose shares are traded on BIST. In this context, the environmental indicators are weighted employing the Grey LOPCOW approach, while the Grey PIV model is implemented to rank the banks' environmental performance.

Grey LOPCOW results show that the quantity of disposed waste, non-hazardous waste, and amount of recycled waste are the most significant factors influencing the environmental performance of banks. In addition, the three evaluation criteria, such as direct emissions, water consumption, and fuel consumption were found to be the least influential criteria on environmental performance. The findings from the existing work are similar to those obtained in previous studies [24, 31, 34, 35, 39]. However, the results of this paper differ from the findings of other researches [23, 29, 33, 40].

The outcomes obtained from the application of the Grey PIV method show that the Yapı ve Kredi bank is a deposit bank with the highest environmental performance compared to other banks. In the environmental performance ranking, Yapı ve Kredi Bank was followed by Akbank, Garanti Bank, Şekerbank, Halkbank and Vakıfbank, respectively. This finding aligns with the conclusions presented in previous studies [19, 24, 28, 34], while it differs from the findings of other researches [31, 35, 37].

In accordance with the objective of the study, the accuracy and validity of the presented conceptual framework were tested in three stages through sensitivity analyses. In the initial phase of the study, the impact of fluctuations in the weight values of the criteria on the initial ranking of the alternative banks was examined. In the second stage, the robustness of the proposed MCDM model to the problem of ranking reversal was analyzed. In the third and final stage, the outputs of the suggested decision support model are compared with the results of a variety of MCDM techniques. The findings of the sensitivity analysis reveal that the developed MCDM tool in the existing work is a stable, reliable, and robust decision support tool for practitioners and decision makers in the banking industry. Similar to other studies, this research has some limitations. First of all, the evaluation of only 6 deposit banks can be considered a limitation. Secondly, the use of only grey linguistic variables and their corresponding interval grey numbers in this work can be seen as another limitation. In addition, only the LOPCOW method was employed in the assessment of environmental indicators in this research. There are many weighting approaches in the MCDM literature. Hence, considering the critical role of criterion weight values in determining the positions of alternatives, the use of only the LOPCOW technique can be considered as another limitation. Weighting methods such as LBWA, LMAW, SIWEC, RANCOM can be utilized in future studies. Besides, more consistent criterion weights can be obtained by integrating these methods. Moreover, 7 expert opinions were consulted in terms of criteria evaluations in the existing research. Therefore, more experts can be included in the analysis in future studies to generalize the results. Finally, in future studies, researchers can add depth to the analysis by using fuzzy linguistic variables instead of grey linguistic variables. In this context, it may be suggested to use methodologies such as intuitionistic fuzzy numbers, Pythagorean fuzzy numbers, picture fuzzy numbers or spherical fuzzy numbers, which provide significant flexibility to DMs and are frequently employed in the literature for modeling uncertainty.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

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Conflicts of Interest

The author declares that there is no conflict of interest in the study.

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