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Evaluation of Banking Performance of the Balkan Countries in Type-2 Neutrosophic Fuzzy Environment

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ABSTRACT

This paper proposes the PSI & CODAS integrated model based on the Type-2 Neutrosophic Fuzzy Numbers (T2fNNs) to solve the decision-making problems encountered in banking and make performance analyses of banking institutions. The proposed model is also an integrated MCDM approach that can overcome many complex situations and many misevaluations by decision-makers. The Power-Heronian Function is embedded in the weighting process within the PSI method to handle interrelations among criteria effectively and to reduce the influence of extreme and unreasonable values in the decision matrix. Besides, it provides an applicable and stable assessment, as it is not sensitive to the number of criteria and decision alternatives. The T2NN MCDM approach was applied to evaluate the banking performances of banks in Balkan countries after the COVID-19 global pandemic and demonstrate the implementation of the suggested model. Next, a comprehensive robustness check consisting of two stages was performed to test the validation of the suggested MCDM model and its results. According to the study results, A13 Türkiye İş Bankası was the best option for applying the proposed model and has remained the best option for all scenarios. Besides, it has been surveyed that minor alterations did not alter the overall conclusions in the ranking performance of few options. The sensitivity analysis results prove that the proposed PSI & CODAS approach is a powerful and applicable computational tool, and its results are reasonable, realistic, and substantially accurate.

1. Introduction

In recent years, the economies of the Balkan countries have shown notable growth. However, the main driving force of this growth was to provide external financing to respond to the ever-increasing domestic demand [1]. This model has many drawbacks and limitations and cannot meet long-term requirements. Hence, these countries continue to struggle with many financial problems that undermine economic development, and they have not overcome these problems until now.

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Developing the national finance and banking systems may be an optimal way to solve these structural problems.

The efficiency and performance of banks are a vitally important issue [2] for national and regional economies, as well as for international economies and the business world. Continuous measurement of banks' performance in the context of operating on a sound basis is vital for the sustainability of existing financial systems and the stability of global, national, and regional economies. Banks are central to economies and businesses, and a well-functioning banking system is critical to economic growth and development. Examining bank performances provides multidimensional advantages. Not only do banks assess themselves, but they go further and provide extremely valuable information for all stakeholders, such as investors, regulators, and customers. In this context, effective and efficient evaluation of banks to prevent or mitigate the effects of financial crises, to identify risks in advance, and to optimize decision-making processes in the industry in question are among the top priorities.

The fragile economies of the Balkan countries make their banking systems more essential and a priority [3]. First, evaluating the performance of the banks of the Balkan countries can be used as a roadmap that can guide decision-makers in improving the financial structures and economic conditions of the countries in the region. At the same time, studies on this subject can contribute to the literature by eliminating critical research gaps. In general, the banking systems of the Balkan countries have been examined relatively less in the relevant literature than those of developed European countries' banking systems [4]. This situation reveals the problem of the Balkan countries' economic development and development levels, their unique practices, performance differences, and lack of understanding of regional dynamics in the context of their banking performance and regional cultural and social structures. In this context, this study may provide an opportunity to understand better the functioning and structural characteristics of regional banks and stakeholders in the global banking system. In addition, considering the findings, the performance of banks in the Balkan countries can be compared with that of banks in Europe and other geographies, providing valuable insights, including regional similarities and differences.

Since Balkan countries are among the emerging markets [5], examining the performance of banks in this region provides critical information and advantages for investors who want to invest in the region. Based on this study's findings and managerial implications, investors can turn to countries where banks show high performance and make their investments at a lower risk level and high efficiency. The performance analysis results provide critical information about the financial stability, profitability, and suitability of the banks and the countries in which they are located, thus minimizing investment risks. In this context, high-performing banks can attract more capital and investment to the countries and regions where they are located and support economic growth.

Moreover, banks with superior performance can play a pivotal role in various areas, from facilitating financing for local and international businesses to meeting the needs of individual customers in their respective countries. They can also significantly contribute to the economic development of the region. Furthermore, performance evaluation serves as a cornerstone for regulatory agencies, providing them with crucial insights better to manage risks and threats in the banking system. This analysis is instrumental in guiding regulators' financial reforms and policy-making processes.

Lastly, assessing Balkan banks' performance is instrumental in bolstering their integration with the global financial system and enhancing the region's visibility. High-performing banks can act as a conduit for Balkan countries to attract a significant share of international capital flows. Furthermore, such evaluations can aid in formulating strategic development plans by identifying banks' weaknesses, enhancing their competitiveness, and fostering the region's overall economic growth.

To achieve these expected effects, decision-makers, especially investors, should have comprehensive information about the performance of the banking system, and this information should be comparable with the data and information of other banks. Therefore, a feasible and practical methodological framework is one of the primary and major requirements for appraising the performance of banks. When the literature is assessed in detail, the most widely applied multi-objective mathematical model used to assess the performance of banks is the Data Envelopment Analysis technique [6–9].

Even though they are valuable examples in the literature, unfortunately, the contribution of these papers to the literature is limited concerning the technique applied in the paper. As the DEA technique has some limitations, it cannot be used as a methodological frame in the decision-making process related to evaluating banks' performance. As a basis, it is susceptible to the determining the measures, and when the factors are altered, the results achieved may also alter on a large scale. Also, each criterion added or removed may cause severe deviations in the results.

Furthermore, while effective in evaluating efficiency, the DEA technique is fragile in its potential to compare variants. Its application steps and the fundamental procedure are complex and time-consuming. It becomes particularly evident when the number of criteria is high, making the efficiency analysis technique's implementation a complex and lengthy process for decision-makers [10, 11].

Also, other methods preferred by authors in the existing literature are the Analytic Hierarchy Process (AHP) [12–16] and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [9, 15–21] techniques. However, both traditional MCDM approaches have many drawbacks and limitations. Due to these limitations, both are the most criticized methods [22]. First, the AHP technique requires time-consuming pairwise comparisons among all criteria and decision alternatives. Its basic algorithm is very complicated and time-consuming [23]. Furthermore, it is adversely influenced by rank reversal problems and is particularly sensitive to the number of measures and variants. The conclusions may alter dramatically if we add or eliminate a measure.

The same disadvantages are experienced with the TOPSIS technique, which also suffers from the rank reversal problem [24]. These issues lead to unreliable results from both approaches, making it difficult for practitioners to be sure of the correctness and rationality of the results. As a result, neither technique can be used as a methodological frame due to these drawbacks. In addition, the VIKOR [20, 25] 2011) and the ELECTRE [9, 26], COPRAS [27], SAW [20], and ANP [28] are the traditional MCDM techniques used for assessing the performance of the banks in the existing literature.

While MCDM methods such as the VIKOR and Electre techniques offer valuable decision-making tools, they also present practical challenges. The VIKOR technique, for instance, requires an additional weighting technique to identify the criteria weights and can only be applied when the information is sufficient, and the crisp values are collected entirely. Similarly, the Electre technique necessitates a threshold value to evaluate the decision alternatives. However, the process of identifying this value is not clearly defined in the existing literature, and it is possible to encounter non-realistic and unreasonable evaluations depending on the information level of decision-makers.

The SAW method, a potential MCDM approach, may be applied if all the variables are maximized (and transformed into maximizing variables) before analysis. In addition, it requires that all values should be positive. This constraint underscores the challenges in the banking industry, where it is possible to see negative values in the banks' balance sheets, and these variables may not always be positive. Also, results for each alternative may not be reasonable, especially if there are vast differences between variables. However, this is a likely situation for the banking industry.

Some authors have attempted to enhance the AHP and TOPSIS methods using fuzzy set theory [29]. However, in the banking industry, it is rare to encounter situations where only fuzzy data is available, as almost all banks operating on the stock exchange must publish their financial data regularly. It means that uncertainties do not exist in the current industry or are incredibly slight. Therefore, evaluating fuzzy data while crisp values are available in the banking field is unnecessary and unreasonable.

As seen above, there are surprising and serious gaps in the existing literature, and the MCDM frameworks suggested by the earlier works have not been able to handle these gaps due to some structural problems and limitations. The present article proposes a powerful practical tool for solving such decision-making problems. The suggested procedure consists of four phases. In the first phase (in the preparatory process), the researchers identified a set of research questions. Subsequently, a panel of specialists was formed, consisting of four highly experienced and deeply knowledgeable professionals in the banking and independent auditing sector, to obtain more reasonable and realistic results. Then, the selection criteria used in the present article were determined together by these experts at the end of a lengthy deliberation process after an extensive literature review by the researchers, reassuring the audience about the model's foundation. In addition, the experts examined the financial data and reports of forty banks in different Balkan countries, and the researchers determined that 14 banks among them were investable. Accordingly, in the last step of the first stage, the decision-makers determined the data to be used in the analysis, considering the officially published financial reports and balance sheets, using the criteria and decision alternatives in Table 2.

This study introduces the Combinative Distance-based Assessment (CODAS) approach, supported by the Preference Selection Index (PSI) and the Power Heronian operator. In this study, the Power-Heronian operator is utilized within the Preference Selection Index (PSI) method to handle interdependencies between criteria and to reduce the distortion caused by extreme values in the normalized decision matrix. Its integration strengthens the robustness and fairness of the weighting process in the proposed PSI & CODAS hybrid model. This robust model addresses the relevant decision-making problem and produces reliable solutions. Its robustness ensures it can eliminate existing research gaps and theoretical evaluation deficiencies, providing significant advantages to decision-makers.

The proposed hybrid technique enumerates decision alternatives by considering the interrelationships and interactions between criteria. Thus, it can reduce the effects of excessive, unreasonable, and undesirable values in the initial decision matrix. At the same time, it can be applied easily and quickly without requiring advanced mathematical knowledge, such as PSI management, which refers to determining the preference selection index. In the second stage of the proposed model, the criterion weights were determined by following the basic algorithm of the proposed integrated model related to the PSI method. These steps are presented in detail in Section 2. In the next stage, the implementation steps of the CODAS approach are followed, and alternatives are listed.

The main objective of this study is to develop and implement a robust and practical MCDM framework for evaluating the financial performance of banks operating in the Balkan region, particularly in the post-COVID-19 context. The study aims to address the following research questions: RQ-1: How can bank performance in the Balkan region be evaluated effectively under uncertainty? RQ-2: What are the most significant financial criteria in determining the performance of these banks? RQ-3: How do different banks rank based on the proposed PSI & CODAS model integrated with T2NFNs and the Power-Heronian operator? These questions serve as the foundation for the model development and the subsequent application stages in the study.

The rest of the article is organized as follows. Section 2 illustrates the implementation steps of the proposed PSI & CODAS integrated model and presents the model's fundamental procedure. In Section 3, as a numerical illustration, the suggested framework is implemented to solve the decision-making problems related to the evaluation of the performance of Balkan banks. This application is significant as it demonstrates the model's effectiveness in a real-world context. An extensive validity check is then performed to check the proposed model's validity and conclusions. In Section 4, the outcomes of the current investigation are debated, and the management implications of the study are outlined. It also concludes the study, presenting current limitations and recommendations for future studies.

2. Methodology

The suggested integrated fuzzy MCDM procedure and its fundamental algorithm are exhibited here. The application steps and broad structure of the suggested tool are given in Figure 1.

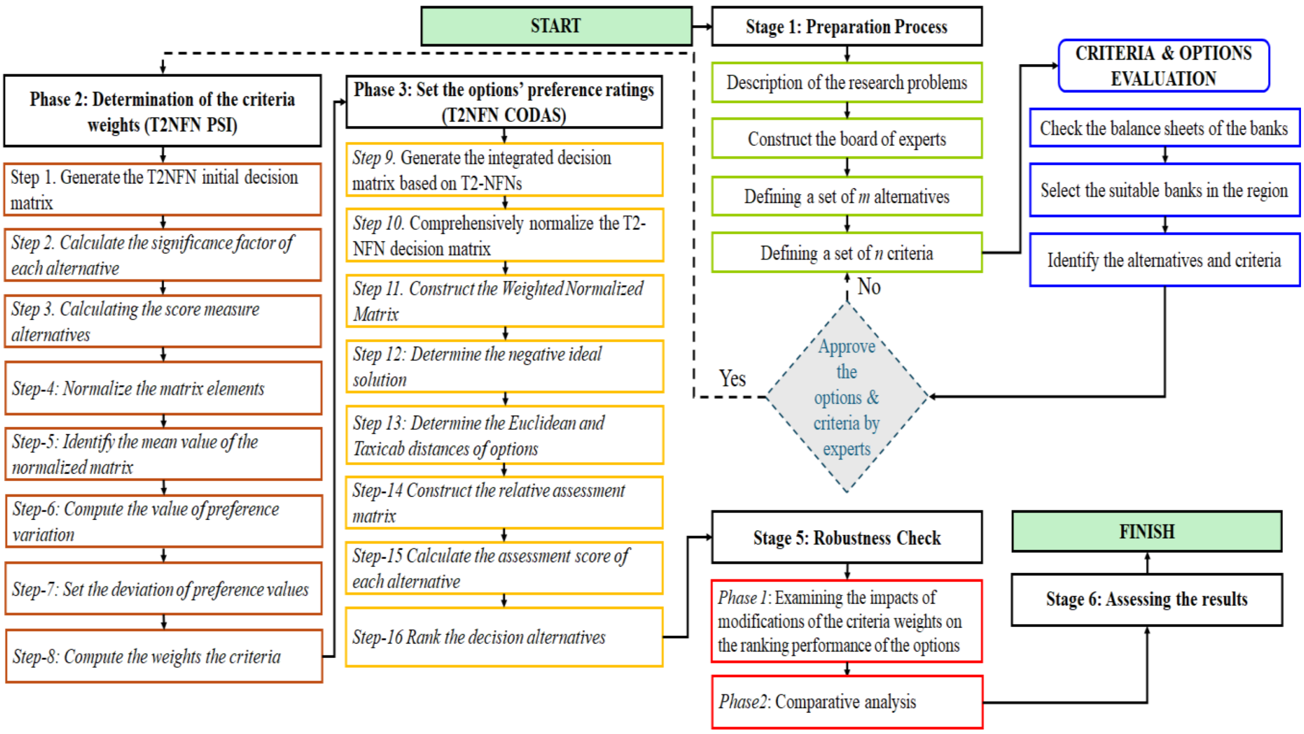

Fig. 1. The suggested PSI & CODAS model and its basic algorithm

1.1 Preliminaries on type-2 neutrosophic fuzzy numbers

Let us examine certain essential notions of the T2NNs for creating a foundation for the integrated procedure.

Definition 1 [30]**:** X is a limited universe of discourse and $F[0,1]$ be a collection of all triangular neutrosophic numbers. Type 2 neutrosophic number set (T2NNS) NN is given by

$$NN = \left(x, T_{NN}(x), I_{NN}(x), F_{NN}(x) \mid x \in X\right) \tag{1}$$

where $T_{NN}(x)$ is the degree of truth, $I_{NN}(x)$ is the degree of indeterminacy, and $F_{NN}(x)$ is the falsity degree.

Here, the authors provide a second level of generalization by considering the grades as T2NNS and hence, $T_{NN}(x) = \left(T_{NN(T)}(x), I_{NN(T)}(x), F_{NN(T)}(x)\right)$; $I_{NN}(x) =$

$\left(T_{NN(I)}(x), I_{NN(I)}(x), F_{NN(I)}(x)\right)$; and $F_{NN}(x) = \left(T_{NN(F)}(x), I_{NN(F)}(x), F_{NN(F)}(x)\right)$. All these grades are in the unit interval.

Remark 1: For ease of use, $NN_i = (T_i, I_i, F_i)$ is called the type 2 neutrosophic number and collection of such numbers for T2NNS.

Definition 2 [30] [30]: Let NN_1 and NN_2 be as before. Some operations with T2NN are given by:

(1) Addition "$\oplus$"

$$NN_1 \oplus NN_2 = \left(\left(\left(T_{1(T)} + T_{2(T)} - T_{1(T)}.T_{2(T)}\right), \left(T_{1(I)} + T_{2(I)} - T_{1(I)}.T_{2(I)}\right), \left(T_{1(F)} + T_{2(F)} - T_{1(F)}.T_{2(F)}\right)\right), \left(I_{1(T)}.I_{2(T)}, I_{1(I)}.I_{2(I)}, I_{1(F)}.I_{2(F)}\right), \left(F_{1(T)}.F_{2(T)}, F_{1(I)}.F_{2(I)}, F_{1(F)}.F_{2(F)}\right)\right) \quad (2)$$

(2) Multiplication "$\otimes$"

$$NN_1 \otimes NN_2 = \left(\left(T_{1(T)}.T_{2(T)}, T_{1(I)}.T_{2(I)}, T_{1(F)}.T_{2(F)}\right), \left(\left(I_{1(T)} + I_{2(T)} - I_{1(T)}.I_{2(T)}\right), \left(I_{1(I)} + I_{2(I)} - I_{1(I)}.I_{2(I)}\right), \left(I_{1(F)} + I_{2(F)} - I_{1(F)}.I_{2(F)}\right)\right), \left(\left(F_{1(T)} + F_{2(T)} - F_{1(T)}.F_{2(T)}\right), \left(F_{1(I)} + F_{2(I)} - F_{1(I)}.F_{2(I)}\right), \left(F_{1(F)} + F_{2(F)} - F_{1(F)}.F_{2(F)}\right)\right)\right) \quad (3)$$

(3) Scalar multiplication, where $\lambda > 0$

$$\lambda NN_1 = \left(\left(\left(1 - \left(1 - T_{1(T)}\right)^{\lambda}\right), \left(1 - \left(1 - T_{1(I)}\right)^{\lambda}\right), \left(1 - \left(1 - T_{1(F)}\right)^{\lambda}\right)\right), \left(I_{1(T)}^{\lambda}, I_{1(I)}^{\lambda}, I_{1(F)}^{\lambda}\right), \left(F_{1(T)}^{\lambda}, F_{1(I)}^{\lambda}, F_{1(F)}^{\lambda}\right)\right) \quad (4)$$

(4) Power, where $\lambda > 0$

$$NN_1^{\lambda} = \left(\left(\left(T_{1(T)}^{\lambda}, T_{1(I)}^{\lambda}, T_{1(F)}^{\lambda}\right)\right), \left(\left(1 - \left(1 - I_{1(T)}\right)^{\lambda}\right), \left(1 - \left(1 - I_{1(I)}\right)^{\lambda}\right), \left(1 - \left(1 - I_{1(F)}\right)^{\lambda}\right)\right), \left(\left(1 - \left(1 - F_{1(T)}\right)^{\lambda}\right), \left(1 - \left(1 - F_{1(I)}\right)^{\lambda}\right), \left(1 - \left(1 - F_{1(F)}\right)^{\lambda}\right)\right)\right) \quad (5)$$

Definition 3 [30] NN_1 is as before. Score and accuracy measures are given by

$$S(NN_1) = \frac{1}{12}\begin{pmatrix} 8 + \left(T_{1(T)} + 2T_{1(I)} + T_{1(F)}\right) - \left(I_{1(T)} + 2I_{1(I)} + I_{1(F)}\right) \\ -\left(F_{1(T)} + 2F_{1(I)} + F_{1(F)}\right) \end{pmatrix} \quad (6)$$

$$A(NN_1) = \frac{1}{4}\left(\left(T_{1(T)} + 2T_{1(I)} + T_{1(F)}\right) - \left(F_{1(T)} + 2F_{1(I)} + F_{1(F)}\right)\right) \quad (7)$$

where $S(NN_1)$ and $A(NN_1)$ are score and accuracy measures.

It must be noted that when the score of a is greater than the score of b, if T2NN $a > b$. If score values are equal, accuracy is calculated, and if the value of a is less than b, then T2NN $a < b$. We break the tie arbitrarily when both elements have equal accuracy values 31].

1.2 T2NFN-Preference Selection Index

A weighting approach was developed by Maniya and Bhatt [32] for calculating criterion weights. The most important advantage of this method is that its basic algorithm is efficient and practical, and its results are consistent and have high accuracy. At the same time, it is mainly resistant to the rank reversal problem compared to the AHP method. In addition, the AHP method does not require many comparisons, which is a critical limitation. Unlike the Best-Worst Method (BWM) and Stepwise Weight Assessment Ratio Analysis (SWARA) methods, there is no loss of information in the evaluation processes. This study proposes an extended version of the PSI with the help of T2NFNs. The basic algorithm of the technique is given as follows [32–35]:

Step 1. Construct the initial T2NFN decision matrix for each expert ($\aleph^b$): the decision-makers assess the alternatives based on a linguistic scale. Subsequently, these evaluations are transformed into the corresponding T2NFNs based on the established scale. Then, each expert is appraisal to the basic decision-matrix $\aleph^b = \left[\overline{\theta}_{ij}^{b}\right]_{m\times n}$,

where $\overline{\theta}_{ij}^{b} = \left[\left(\overline{\theta}_{ij}^{T_T(b)}, \overline{\theta}_{ij}^{T_I(b)}, \overline{\theta}_{ij}^{T_F(b)}\right), \left(\overline{\theta}_{ij}^{I_T(b)}, \overline{\theta}_{ij}^{I_I(b)}, \overline{\theta}_{ij}^{I_F(b)}\right), \left(\overline{\theta}_{ij}^{F_T(b)}, \overline{\theta}_{ij}^{F_I(b)}, \overline{\theta}_{ij}^{F_F(b)}\right)\right], 1 \le b \le e$; *i=1,...,m; j=1,...n*.

Each pair $\overline{\theta}_{ij}^{b}$ takes a value from the predefined Type 2 neutrosophic scale.

Step 2. Identify the significance factor of each variant: The significance factor for each alternative is calculated based on the evaluations provided by the decision-makers. In this step, the relative importance of the alternatives is determined in relation to the decision-makers' assessments, using Eq. (8).

$$\theta_{ij}^{SF} = \left[\begin{array}{l} \left(\frac{\sum_{k=1}^{e}\overline{\theta}_{kij}^{T_T} - \prod_{k=1}^{e}\overline{\theta}_{kij}^{T_T}}{e}, \frac{\sum_{k=1}^{e}\overline{\theta}_{kij}^{T_I} - \prod_{k=1}^{e}\overline{\theta}_{kij}^{T_I}}{e}, \frac{\sum_{k=1}^{e}\overline{\theta}_{kij}^{T_F} - \prod_{k=1}^{e}\overline{\theta}_{kij}^{T_F}}{e}\right), \\ \left(\frac{\sum_{k=1}^{e}\overline{\theta}_{kij}^{I_T} - \prod_{k=1}^{e}\overline{\theta}_{kij}^{I_T}}{e}, \frac{\sum_{k=1}^{e}\overline{\theta}_{kij}^{I_I} - \prod_{k=1}^{e}\overline{\theta}_{kij}^{I_I}}{e}, \frac{\sum_{k=1}^{e}\overline{\theta}_{kij}^{I_F} - \prod_{k=1}^{e}\overline{\theta}_{kij}^{I_F}}{e}\right), \\ \left(\frac{\sum_{k=1}^{e}\overline{\theta}_{kij}^{F_T} - \prod_{k=1}^{e}\overline{\theta}_{kij}^{F_T}}{e}, \frac{\sum_{k=1}^{e}\overline{\theta}_{kij}^{F_I} - \prod_{k=1}^{e}\overline{\theta}_{kij}^{F_I}}{e}, \frac{\sum_{k=1}^{e}\overline{\theta}_{kij}^{F_F} - \prod_{k=1}^{e}\overline{\theta}_{kij}^{F_F}}{e}\right) \end{array}\right] \tag{8}$$

Here, *e* represents the number of experts. As a result, the T2NN matrix for the alternatives, in relation to the criteria, is constructed using Eq. (9).

$$\aleph = \begin{bmatrix} \theta_{11}^{SF} & \theta_{12}^{SF} & \theta_{13}^{SF} & \cdots & \theta_{1n}^{SF} \\ \theta_{21}^{SF} & \theta_{22}^{SF} & \theta_{23}^{SF} & \cdots & \theta_{2n}^{SF} \\ \theta_{31}^{SF} & \theta_{32}^{SF} & \theta_{33}^{SF} & \cdots & \theta_{3n}^{SF} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \theta_{m1}^{SF} & \theta_{m2}^{SF} & \theta_{m3}^{SF} & \cdots & \theta_{mn}^{SF} \end{bmatrix} \tag{9}$$

where $\theta_{ij}^{SF} = \left[\left(\theta_{ij}^{T_T}, \theta_{ij}^{T_I}, \theta_{ij}^{T_F}\right), \left(\theta_{ij}^{I_T}, \theta_{ij}^{I_I}, \theta_{ij}^{I_F}\right), \left(\theta_{ij}^{F_T}, \theta_{ij}^{F_I}, \theta_{ij}^{F_F}\right)\right]$; *i=1,...,m; j=1,..,n*.

Step 3. Calculating the score measure alternatives using equation (6): Thus, we get a matrix of score measures factors, Eq. (10).

$$\overline{\aleph} = \begin{bmatrix} \aleph_{11} & \aleph_{12} & \aleph_{13} & \cdots & \aleph_{1n} \\ \aleph_{21} & \aleph_{22} & \aleph_{23} & \cdots & \aleph_{2n} \\ \aleph_{31} & \aleph_{32} & \aleph_{33} & \cdots & \aleph_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \aleph_{m1} & \aleph_{m2} & \aleph_{m3} & \cdots & \aleph_{mn} \end{bmatrix} \tag{10}$$

Where $\aleph_{ij} = \left(8 + \left(\theta_{ij}^{T_T} + 2\theta_{ij}^{T_I} + \theta_{ij}^{T_F}\right) - \left(\theta_{ij}^{I_T} + 2\theta_{ij}^{I_I} + \theta_{ij}^{I_F}\right) - \left(\theta_{ij}^{F_T} + 2\theta_{ij}^{F_I} + \theta_{ij}^{F_F}\right)\right)/12$; *i=1,...,m; j=1,..,n*.

Step-4: Normalize the matrix elements: The elements of the initial decision matrix are normalized using Eq. (11) as shown below.

$$r_{ij}^{*} = \begin{cases} \dfrac{x_{ij}^{'}}{max\, x_{ij}^{'}}; \; j \in B \\ \dfrac{min\, x_{ij}^{'}}{x_{ij}^{'}}; \; j \in C \end{cases} \tag{11}$$

B is the set of benefit criteria, and C is the cost criteria, which r_{ij}^{*} denotes the normalized score value of alternative *i* with respect to criterion *j*.

Step 5: Identify the mean value of the normalized matrix: The mean value of the normalized matrix is calculated with the help of Eq. (12).

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

Step 6: Compute the value of preference variation: The preference variation value is identified by employing Eq. (13).

$$\phi_j = \sum_{i=1}^{m} \left| r_{ij}^{*} - N \right|^2 \tag{13}$$

The Power-Heronian function is integrated into the PSI weighting process during the normalization and deviation computation stages to strengthen the model's robustness further. Specifically, it is applied when calculating the mean deviation of preference values, which helps to moderate the influence of criteria with extremely high or low normalized values.

Step 7: Set the deviation of preference values: The deviation of preference value is computed by applying Eq. (14).

$$\Omega_j = 1 - \phi_j \tag{14}$$

Step 8: Compute the criteria weights: The weights are calculated using Eq. (15).

$$w_j = \frac{\Omega_j}{\sum_{i=1}^{n} \Omega_j} \tag{15}$$

1.3 The CODAS method

Here, the basic algorithm of the CODAS approach is exhibited.

Step 9: The initial decision matrix was obtained similarly by applying the first steps of the T2NFN-PSI approach. These steps are not shown here to avoid repetition.

Step 10: Construct the Normalized Matrix: In this step, the decision matrix is standardized by performing linear normalization operations with the help of Eq. (16).

$$x_{ij}^{'} = \begin{cases} \frac{x_{ij}^{*}}{\max x_{ij}^{*}} if \ j \in C_b \\ \frac{\min x_{ij}^{*}}{x_{ij}^{*}} if \ j \in C_c \end{cases} \tag{16}$$

While C_b symbolizes the set of benefit criteria, C_c represents the set of cost criteria

Step 11: Construct the Weighted Normalized Matrix: Each performance value of the normalized matrix is weighted using Eq. (17). The weights obtained in the previous stage are used to weight these performance values.

$$r_{ij} = w_j x_{ij}^{'} \tag{17}$$

Step 12: Determine the negative ideal solution: The negative ideal solution is determined with the help of the following equations. These are the minimum values of each row of the weighted normalized matrix.

$$n_s = \left[ns_j \right]_{1xm} \tag{18}$$

$$ns_j = \min x_{ij}^{'} \tag{19}$$

Step 13: Determine the Euclidean and Taxicab distances of options from the negative ideal solution: Euclidean and Taxicab distances are calculated by using Eq. (20) and (21) are given below:

$$E_i = \sqrt{\sum_{j=1}^{m} \left(r_{ij} - n_{sj} \right)^2} \tag{20}$$

$$T_i = \sum_{j=1}^{m} \left| r_{ij} - ns_j \right| \tag{21}$$

Step-14 Construct the relative assessment matrix: The relative assessment matrix is built using Eq. (22) and (23) as follows.

$$Ra = \left[hi_k \right]_{nxn} \tag{22}$$

$$hi_k = \left(E_i - E_k \right) + \left(\left(\psi E_i - E_k \right) . \left(T_i - T_k \right) \right) \tag{23}$$

ψ value is in the range of 0 and 1. Mostly, the value of 0.2 gives excellent results. In the CODAS method, the threshold parameter (τ) is used in the relative assessment matrix to determine the significance of the difference between alternatives based on their Euclidean and Taxicab distances. In this study, τ was set to 0.2, a commonly used value in the literature that ensures effective discrimination among close-ranking alternatives. This parameter helps refine the ranking sensitivity and prevents minor distance differences from leading to unjustified rank changes.

Step-15 Calculate the assessment score of each alternative: The assessment score for each option is computed with the help of Eq. (24). These values are the sum of the relative assessment values of each decision alternative.

$$h_i = \sum_{k=1}^{n} hi_k , \tag{24}$$

where h_i is the overall performance score of alternative *i*, calculated as the sum of the relative assessment values obtained from Euclidean and Taxicab distances.

Step-16 Rank the decision alternatives: All decision options are ranked considering the value of the assessment score (h_i) of options.

3. Results

Here, the suggested model has been applied to solve the decision problem regarding the performance of the banks in the region. In the first stage, the researchers formed a panel of experts consisting of four in-depth and experienced professionals. Table 1 exhibits the experts' profiles.

Table 1
Details of the Experts

DMs	Institutions	Duty	Experience	Graduation
DM-1	Emlak participation bank	Director Commercial Banking	30	Public Adm.
DM-2	ING Bank	Director of Credits	26	Economy
DM-3	Citibank	Marketing Director	15	Economy
DM-4	Emlak participation bank	General Manager	30	Business

With the help of these experts, the financial criteria to be used to examine the performance of the banks were determined. The determination of the criteria listed in Table 2 followed a two-stage process. First, a comprehensive literature review was conducted to identify the most frequently used financial performance indicators in bank evaluation studies. Key sources included traditional and fuzzy MCDM-based evaluations in the banking sector.

Second, expert opinions were collected from four professionals with significant experience in banking and financial auditing (see Table 1 for expert profiles). A series of structured interviews and consensus meetings were held, during which the initial list of criteria derived from the literature was refined based on the experts' practical insights. The final set of criteria—Total Deposits, Total Equity, Labor & Related Expenses, Depreciation Expense, Net Loans, Net Interest Income, and Fees & Commissions from Operations—were selected due to their critical importance in reflecting the financial strength, cost structure, income sources, and operational efficiency of banks. This combined approach ensures that the selected criteria are theoretically sound and practically relevant.

Then, the financial reports and records of 37 banks in the Balkan countries were examined, and the alternatives to be considered were determined. To ensure the validity and reliability of the decision-making process, the expert committee was actively involved in several critical stages of the study. First, they participated in identifying and finalizing evaluation criteria through a structured consensus process. Second, each expert independently evaluated the performance of the alternatives using predefined linguistic scales, and these evaluations were converted into Type-2 Neutrosophic Fuzzy Numbers (T2NFNs). To increase effectiveness and reduce bias, expert judgments were aggregated using an averaging technique applied to the T2NFN matrices, ensuring that each expert's input contributed equally. Additionally, consistency checks were applied during the evaluation stages to ensure that the experts' assessments did not significantly diverge. This structured integration of expert input enhances the final results' robustness, objectivity, and representativeness. Table 2 shows the identified criteria and alternatives.

Table 2
Criteria and Alternatives

Codes	Banks	Codes	Criteria
A1	KIB Banka dd Velika Kladusa	C1	Total Deposits
A2	NLB Banka ad Banja Luka	C2	Total Equity
A3	Erste & Steiermaerkische Bank dd	C3	Labor & Related Expenses
A4	Privredna Banka Zagreb dd	C4	Depreciation Expense
A5	Bank of Greece	C7	Fees & Commissions from Operations
A6	Eurobank Ergasias Services and Holdings SA	C6	Net Interest Income

A7	National Bank of Greece SA	C5	Net Loans
A8	Banca Transilvania SA	C1	Total Deposits
A9	BRD Groupe Societe Generale SA	C2	Total Equity
A10	Komercijalna Banka ad Beograd	C3	Labor & Related Expenses
A11	Nova Ljubljanska Banka dd Ljubljana	C4	Depreciation Expense
A12	Turkiye Halk Bankasi AS	C7	Fees & Commissions from Operations
A13	Turkiye Is Bankasi AS		
A14	Turkiye Vakiflar Bankasi TAO		

After the criteria and alternatives were determined, the experts evaluated each alternative by considering the criteria. Linguistic assessments made by experts considering the linguistic assessment scale presented in Table 3 are shown in Appendix A.

Table 3
T2NFN Linguistic evaluation scale

Linguistic variables	T2FNN
Very Bad (VB)	[(0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70)]
Bad (B)	[(0.35,0.35,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65)]
Medium Bad (MB)	[(0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60)]
Medium (M)	[(0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45)]
Medium Good (MG)	[(0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15)]
Good (G)	[(0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20)]
Very Good (VG)	[(0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05)]

Step 1. Then, these evaluations were converted into T2NFNs corresponding to the linguistic assessment scale shown in Table 3 and T2NFN matrices were created as many as the number of experts.

Step 2. Then, T2NFNs Eq. (8) and the importance of each alternative were calculated within the experts' evaluation framework. The combined T2NFN matrix is then obtained.

Step 3. Next, the score measures of the alternatives were computed with the help of Eq. (6) and the initial decision matrix was constructed as demonstrated in Table 4.

Table 4
The initial decision matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
C1	0.828	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.462	0.462	0.421
C2	0.828	0.517	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.462	0.461	0.462	0.410	0.462
C3	0.828	0.517	0.461	0.461	0.461	0.461	0.461	0.462	0.461	0.461	0.461	0.462	0.462	0.410
C4	0.828	0.517	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.461	0.462	0.462	0.462
C5	0.462	0.461	0.516	0.614	0.791	0.810	0.785	0.516	0.516	0.462	0.516	0.791	0.828	0.828
C6	0.462	0.461	0.516	0.516	0.516	0.692	0.629	0.516	0.516	0.462	0.516	0.810	0.828	0.752
C7	0.462	0.462	0.461	0.516	0.516	0.692	0.692	0.629	0.516	0.462	0.629	0.785	0.828	0.642

Step-4-5: the matrix elements depicted in Table 5 were normalized by using Eq. (11). The mean values of vectors were identified

Table 5
The normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	Av.
C1	0.508	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.911	0.911	1.000	0.890
C2	0.495	0.792	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.887	0.889	0.887	1.000	0.887	0.861
C3	0.495	0.792	0.889	0.889	0.889	0.889	0.889	0.887	0.889	0.889	0.889	0.887	0.887	1.000	0.861

C4	0.557	0.891	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.960
C5	0.558	0.557	0.623	0.742	0.956	0.979	0.949	0.623	0.623	0.558	0.623	0.956	1.000	1.000	0.768
C6	0.558	0.557	0.623	0.623	0.623	0.836	0.760	0.623	0.623	0.558	0.623	0.979	1.000	0.908	0.707
C7	0.558	0.558	0.557	0.623	0.623	0.836	0.836	0.760	0.623	0.558	0.760	0.949	1.000	0.776	0.716

Step-6-8: The preference variation value was identified by employing Eq. (13). Then, the deviation of preference values was computed by applying Eq. (14). Finally, the criteria weights were identified with the help of Eq. (15). Table 6 demonstrates the obtained conclusions regarding these implementation steps.

Table 6
The preference variation matrix and criteria weights

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	Sum	A.V	W
C1	0.146	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.012	0.164	0.836	0.1603
C2	0.134	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.019	0.001	0.166	0.834	0.1598
C3	0.134	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.019	0.166	0.834	0.1598
C4	0.163	0.005	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.186	0.814	0.1560
C5	0.044	0.044	0.021	0.001	0.035	0.045	0.033	0.021	0.021	0.044	0.021	0.035	0.054	0.054	0.473	0.527	0.1010
C6	0.022	0.022	0.007	0.007	0.007	0.017	0.003	0.007	0.007	0.022	0.007	0.074	0.086	0.041	0.329	0.671	0.1286
C7	0.025	0.025	0.025	0.009	0.009	0.015	0.015	0.002	0.009	0.025	0.002	0.054	0.081	0.004	0.298	0.702	0.1346

As can be seen in Table 6, the most important criterion is determined as C1 Total Deposits. The C2 Total Equity criterion follows this. Other criteria are based on importance scores: C3 Labor & Related Expenses > C4 Depreciation Expense > C7 Fees & Commissions from Operations > C6 Net Interest Income > C5 Net Loans. One of the study's important findings regarding the criteria proves that there are no significant differences in relative weight values.

After the criterion weights were determined, the implementation steps of the T2NFN-based CODAS approach were followed in the second stage of the proposed model. The performances of the fourteen banks were examined, and the banks were ranked according to their relative importance scores. Steps 1 to 10 of the proposed model, including the construction and normalization of the decision matrix and the computation of criterion weights using the T2NFN-PSI approach, were completed as described in the Methodology section. T2NFNs were determined depending on expert evaluations, and the first decision matrix was created by following the same implementation procedures. Besides, it uses the same normalization procedure, and the normalized matrix is the same as the normalized matrix formed in the T2NFN-PSI framework. Therefore, the implementation continued from Step 11 of the T2NFN-based CODAS approach, as described in the Methodology section.

Step 11-13: the elements of the normalized decision matrix were weighted by employing Eq. (17). Afterwards, the negative ideal solution was computed by employing Eq. (18). Then, Euclidean and Taxicab distances were computed by using Eq. (20) and (21) The weighted normalized matrix was formed, and the weighted normalized matrix and the computed the negative ideal solution is shown in Table 7.

Table 7
The weighted normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	Min
C1	0.081	0.146	0.146	0.146	0.146	0.146	0.146	0.146	0.146	0.146	0.146	0.146	0.146	0.160	0.081
C2	0.079	0.127	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.160	0.142	0.079

C3	0.079	0.127	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.160	0.079
C4	0.087	0.139	0.156	0.156	0.156	0.156	0.156	0.156	0.156	0.156	0.156	0.156	0.156	0.156	0.087
C5	0.056	0.056	0.063	0.075	0.097	0.099	0.096	0.063	0.063	0.056	0.063	0.097	0.101	0.101	0.056
C6	0.072	0.072	0.080	0.080	0.080	0.107	0.098	0.080	0.080	0.072	0.080	0.126	0.129	0.117	0.072
C7	0.075	0.075	0.075	0.084	0.084	0.113	0.113	0.102	0.084	0.075	0.102	0.128	0.135	0.105	0.075
T_i	0.000	0.212	0.275	0.296	0.318	0.376	0.363	0.302	0.284	0.260	0.302	0.406	0.438	0.411	
E_i	0.202	0.294	0.319	0.324	0.330	0.346	0.343	0.327	0.322	0.316	0.327	0.357	0.369	0.361	

Step-14-16 Considering the distances presented in Table 7, the relative assessment matrix is generated using Eq. (22) and (23). ψ value was identified as 0.2. Then, the assessment score for each option was computed with the help of Eq. (24). Finally, all alternatives were sorted considering the value of the assessment score (h_i) of options. Table 8 demonstrates the conclusions regarding ranking the alternatives.

Table 8
The final assessment scores and ranking of the alternatives

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	h_i	Rank
A1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000	14
A2	0.186	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.1857	13
A3	0.236	0.050	0.000	-0.005	-0.010	0.000	0.000	-0.007	-0.002	0.003	-0.008	0.000	0.000	0.000	0.2568	11
A4	0.245	0.060	0.005	0.000	-0.006	0.000	-0.018	-0.003	0.003	0.008	-0.003	0.000	0.000	0.000	0.2908	9
A5	0.257	0.071	0.010	0.006	0.000	-0.017	-0.013	0.003	0.008	0.014	0.003	0.000	0.000	0.000	0.3421	6
A6	0.290	0.104	0.054	0.045	0.017	0.000	0.004	0.020	0.050	0.061	0.020	-0.010	0.000	-0.015	0.6374	4
A7	0.282	0.097	0.047	0.018	0.013	-0.004	0.000	0.016	0.042	0.053	0.016	-0.014	0.000	-0.018	0.5474	5
A8	0.251	0.065	0.007	0.003	-0.003	-0.020	-0.016	0.000	0.005	0.011	0.000	0.000	0.000	0.000	0.3030	8
A9	0.240	0.054	0.002	-0.003	-0.008	0.000	0.000	-0.005	0.000	0.006	-0.005	0.000	0.000	0.000	0.2811	10
A10	0.229	0.043	-0.003	-0.008	-0.014	0.000	0.000	-0.011	-0.006	0.000	-0.011	0.000	0.000	0.000	0.2203	12
A11	0.251	0.065	0.008	0.003	-0.003	-0.020	-0.016	0.000	0.005	0.011	0.000	0.000	0.000	0.000	0.3042	7
A12	0.310	0.125	0.075	0.065	0.054	0.010	0.014	0.060	0.070	0.081	0.060	0.000	-0.012	-0.004	0.9073	3
A13	0.335	0.149	0.099	0.089	0.078	0.045	0.052	0.084	0.094	0.106	0.084	0.012	0.000	0.008	1.2349	1
A14	0.319	0.133	0.083	0.074	0.062	0.015	0.018	0.068	0.079	0.090	0.068	0.004	-0.008	0.000	1.0053	2

As shown in Table 8, the bank with the highest performance was determined as A13 Turkiye İş Bankasi AS. This is followed by A14 Türkiye Vakiflar Bankasi TAO and A12 Türkiye Halk Bankasi AŞ, respectively. Other alternatives have very low relative importance scores compared to the banks in the top three and are ranked as shown in Table 8 with different values.

A comprehensive robustness test was carried out to test the validity of the proposed model. In the first stage, the criterion weights were changed, and the effects of these changes on the ranking results were examined. For this, by following the approach suggested by Görçün et al. [36], the weight value of each criterion was reduced by 10% in each scenario, and the resulting difference value was distributed equally to the other criteria, providing the condition that the criterion weights were equal to one. Then, the application of the proposed model was repeated as many times as the number of scenarios, and the new ranking results obtained were compared with the original ranking results obtained at the beginning. Figure 2 shows the ranking performance of the alternatives according to the modified criterion weight coefficients. In addition to the sensitivity analysis on criterion weights, the threshold parameter τ = 0.2 used in the CODAS method was also kept constant to preserve the comparability and consistency of the results. This fixed value was chosen based on its proven robustness in prior studies, and it provided stable rankings across all scenarios tested in the validity analysis.

When the results were considered, the ranking results of the best first and second alternatives remained the same in all 69 scenarios and only in a scenario where the weight value of the C4 criterion was replaced. While the A10, A1, and A2 alternatives retained their ranking positions for all scenarios, minor changes were observed in the ranking performance of the others to the extent that they did not change the overall results. In addition, the mean similarity rate of the results obtained in all scenarios with the original ranking results was calculated as 0.7602. This value proves that the proposed model is highly consistent, robust, and valid.

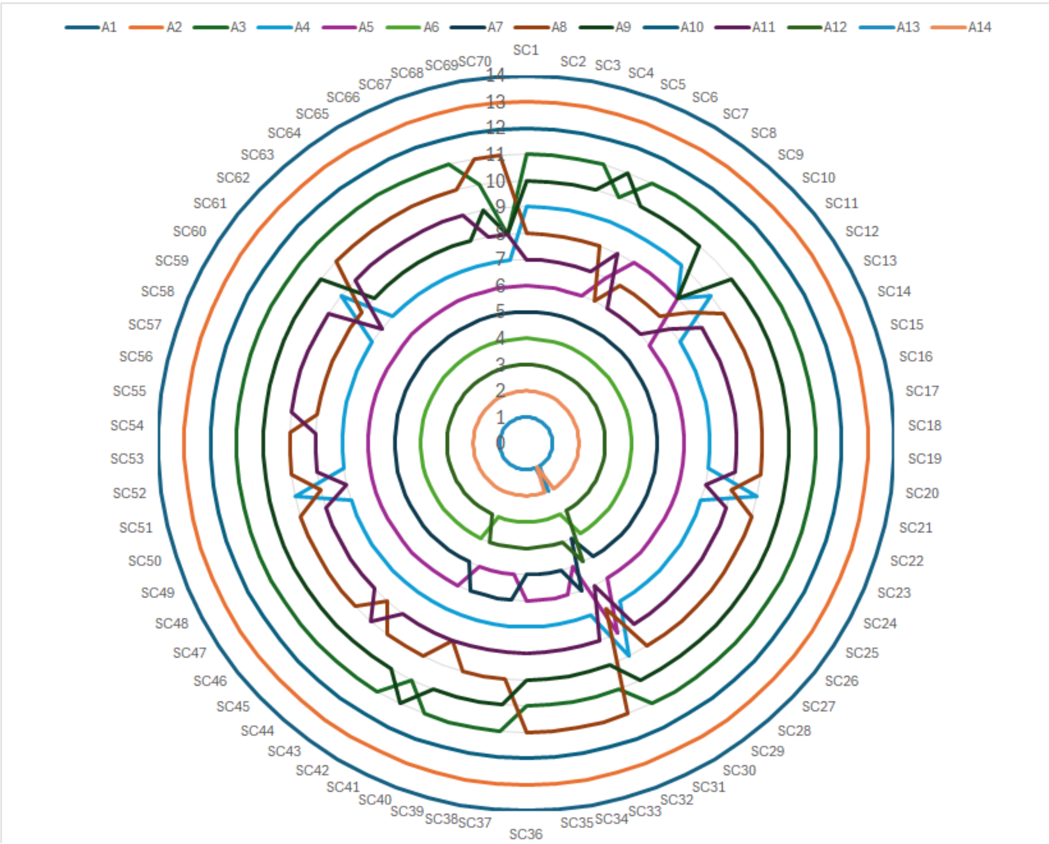

Fig. 2. The raking performances of the alternatives for seventy scenarios

In the second stage of the robustness test, the sequencing results obtained from applying the model proposed in this study were compared using extended versions of some popular T2NFN-based decision-making tools. In this context, CoCoSo [37], MAIRCA [38], MARCOS [39], and WASPAS [40] methods were used. Figure 3 shows the results obtained by performing a comparison analysis.

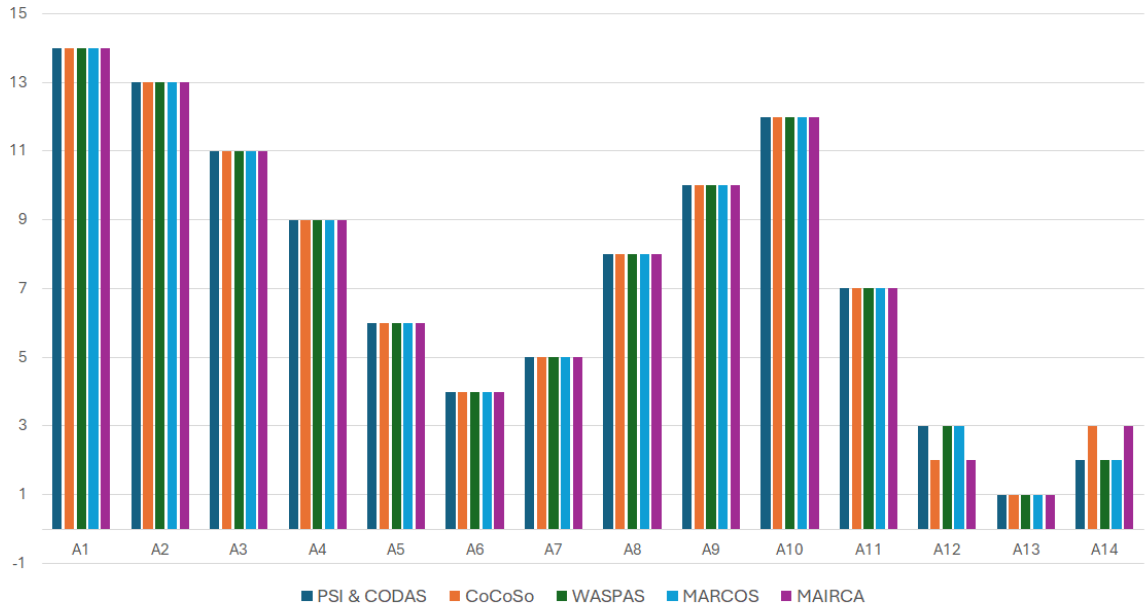

Fig. 3. Ranking performance of the alternatives Regarding implemented procedures

As shown in Figure 3, only the places of A12 and A14 alternatives in the ranking changed when the T2NFN-based MAIRCA method was applied, and all other alternatives maintained their places in the ranking. This comparison analysis shows that the applied model provides consistent, stable and compatible results with real-life conditions.

4. Conclusions

This investigation presents an integrated decision-making model consisting of a combination of Type-2 Neutrosophic Fuzzy numbers-based Preference Selection Index (PSI) and the Combinative Distance-based Assessment (CODAS) approaches to evaluate the financial performance of banks in Balkan countries. The proposed model has yielded highly reliable and robust results in assessing the financial performance of banks. According to these results, Türkiye İş Bankası (A13) performed the best compared to other banks in the region, followed by Türkiye Vakıflar Bankası (A14) and Türkiye Halk Bank (A12).

Türkiye İş Bankası (A13) showed a superior performance by ranking first in the ranking. The basis of this success is its high scores, especially in the total deposit and equity criteria. The study determined the total deposit criterion as the most important criterion because it expresses the funds banks provide to customers. Its strong performance in this criterion proves its customer confidence and success in liquidity management. At the same time, its high score in the total equity criterion reveals that the bank's financial structure and its effectiveness in risk management are sound.

Türkiye Vakıflar Bankası (A14) ranked second in the ranking. Behind this success is the superior performance in income-oriented criteria such as net interest income, fees, and commissions from operations. Net interest income is an important criterion reflecting the bank's lending capacity and efficiency. Its success shows that costs are managed effectively and revenue sources are optimized. In addition, high commissions from operating income demonstrate the bank's effectiveness in customer relations and its ability to use different revenue channels.

Türkiye Halk Bank ranked third, highlighting its success in operational cost management. Its employee and depreciation expenses criteria performance show that the bank uses its resources effectively and successfully increases its operational efficiency. Halk Bank's success in these criteria proves that controlling costs is essential in improving profitability. It helps the bank maintain its competitive advantage and support sustainable growth.

This ranking reflects the performance of banks in a realistic, logical, and compatible way with real-life conditions. Achievements in criteria focused on total deposits, equity, and income reveal banks' financial resilience, income diversification capacities, and operational effectiveness. These findings provide managers with essential insights into their strategic decision-making processes. Banks can sustain long-term success by increasing customer confidence, optimizing resource management, and diversifying revenue sources. In addition, this performance of the banks at the top of the ranking has the potential to encourage international capital flows by creating an attractive profile for investors. It can also significantly contribute to the development of the regional banking sector.

The ranking of the criteria used in the study and the relative weight values played a critical role in evaluating the banks' performance. It provided important insights regarding the managerial implications of the findings. The total deposit criterion (C1), which has the highest weighting value, was evaluated as an indicator of the liquidity level and customer confidence in the financial structures of banks. The fact that this criterion is determined as the top priority factor with a weighting value of 0.1603 reveals that banks should focus on increasing their deposits to ensure their sustainability and financial stability. This finding highlights the importance of banks developing effective marketing and customer service strategies to expand their customer base.

Total equity (C2) and labor & related expenses (C3) were both assigned equal weights of 0.1598, indicating their shared importance in the overall evaluation. While C2 reflects the financial resilience and growth capacity of banks, C3 highlights their operational efficiency and cost structure, both of which are critical for sustainable performance. Substantial equity ensures banks are resilient to economic fluctuations and increases their lending capacity. Regarding managerial inference, this criterion suggests that banks need to optimize their equity management and consolidate their financial strength through capital raising. Accordingly, managers can focus on investment projects to effectively use equity and develop strategies to diversify external financing sources.

Employee expenses (C3) and depreciation expenses (C4) criteria stood out as important factors in terms of cost management with weight values of 0.1598 and 0.1560, respectively. These criteria are critical indicators for assessing banks' operational efficiencies. Effective management of employee expenses helps to increase staff productivity and support profitability while controlling depreciation expenses, which contributes to the long-term performance of the bank's assets. These findings reveal the importance of banks turning to technological investments such as digitalization and automation to optimize their operational costs.

Net interest income (C6) and fees and commissions from operations (C7) represent the diversity of banks' income sources with weighted values of 0.1286 and 0.1346, respectively. The importance of these criteria emphasizes the necessity for banks to use different income channels effectively by increasing the quality of service without being dependent solely on traditional interest income. This finding indicates that banks must develop customer-centric innovation strategies and create new revenue streams by expanding their digital services.

As a result, the ranking of the criteria and the relative weight values revealed the strengths and weaknesses of the banks. Managerial implications include improving banks' liquidity management, equity optimization, operational cost control, and revenue diversification strategies. These insights can help banks increase their competitive advantage, become more attractive to investors, and support long-term sustainable growth.

The study's findings provide strategic guidance for investors, providing valuable information for low-risk and high-yield investments. In addition, regulatory agencies can use the results to improve banking standards and enhance financial stability. In this context, identifying high-performing banks has the potential to attract international capital to the region and contribute to the economic growth of Balkan countries.

Although the study makes significant contributions, it has some limitations. First, the analysis focused only on the Balkan region and was limited to generalizing to the other areas with different economic and regulatory dynamics. Second, although the criteria used in the study comprehensively address the financial performance of banks, it may be helpful to consider non-financial factors such as customer satisfaction and technological innovation. Finally, the publicly available financial data in the analysis does not contain additional information that more qualitative insights can supplement.

Future research may address these limitations and expand the geographic coverage of the model, use advanced fuzzy set theories such as range-valued or heuristic fuzzy sets to address uncertainties better and focus on predictive analytics by investigating the integration of the existing model with machine learning algorithms. In conclusion, the proposed method has significantly contributed to MCDM theoretical frameworks and has provided a powerful tool for financial sector stakeholders seeking to make more informed decisions under uncertain circumstances.

Author Contributions

"Conceptualization, O.F. Gorcun and M. Çanakçıoğlu; methodology, O.F. Gorcun; software, X.X.; validation O.F. Gorcun; formal analysis, X.X.; investigation, C.N. Durmuş and M.S. Topak; resources, Durmuş and M.S. Topak; data curation, M. Çanakçıoğlu, C.N. Durmuş and M.S. Topak; writing—original draft preparation, O.F. Gorcun, M. Çanakçıoğlu, and M.S. Topak; writing—review and editing, O.F.Gorcun, M. Çanakçıoğlu, and M.S. Topak; supervision, M. Çanakçıoğlu; project administration, O.F. Gorcun and C.N Durmuş. All authors have read and agreed to the published version of the manuscript."

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Data Availability Statement

The data used in this study were obtained from publicly available financial reports and balance sheets of banks operating in the Balkan countries. Based on these data, decision-makers conducted linguistic evaluations using predefined linguistic scales to assess the performance of the banks across specified criteria. The linguistic evaluation process and the associated data can be made available by contacting the authors upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

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Appendix A. Linguistics assessments of the experts for the fourteen Balkan banks

Options	DMs	C1	C2	C3	C4	C5	C6	C7
A1	DM1	VG	VG	VG	VG	VB	VB	VB
A1	DM2	VG	VG	VG	VG	B	B	B
A1	DM3	VG	VG	VG	VG	MB	MB	MB
A1	DM4	VG	VG	VG	VG	MB	MB	MB
A2	DM1	VB	B	B	B	VB	VB	VB
A2	DM2	B	MB	MB	MB	B	B	B
A2	DM3	MB	MB	MB	MB	M	M	MB

A2	DM4	M	M	M	M	M	M	MB
A3	DM1	VB	VB	VB	VB	B	B	VB
A3	DM2	B	B	B	B	MB	MB	B
A3	DM3	MB	MB	MB	MB	M	M	M
A3	DM4	M	M	M	M	M	M	M
A4	DM1	VB	VB	VB	VB	B	B	B
A4	DM2	B	B	B	B	MB	MB	MB
A4	DM3	MB	MB	MB	MB	G	M	M
A4	DM4	M	M	M	M	G	M	M
A5	DM1	VB	VB	VB	VB	VG	B	B
A5	DM2	B	B	B	B	VG	MB	MB
A5	DM3	MB	MB	MB	MB	G	M	M
A5	DM4	M	M	M	M	G	M	M
A6	DM1	VB	VB	VB	VB	G	M	M
A6	DM2	B	B	B	B	VG	MG	MG
A6	DM3	MB	MB	MB	MB	VG	G	G
A6	DM4	M	M	M	M	VG	G	G
A7	DM1	VB	VB	VB	VB	MG	MB	M
A7	DM2	B	B	B	B	G	M	MG
A7	DM3	MB	MB	MB	MB	VG	MG	G
A7	DM4	M	M	M	M	VG	MG	G
A8	DM1	VB	VB	VB	VB	B	B	MB
A8	DM2	B	B	B	B	MB	MB	M
A8	DM3	MB	MB	MB	MB	M	M	MG
A8	DM4	M	M	MB	M	M	M	MG
A9	DM1	VB	VB	VB	VB	B	B	B
A9	DM2	B	B	B	B	MB	MB	MB
A9	DM3	MB	MB	MB	MB	M	M	M
A9	DM4	M	M	M	M	M	M	M
A10	DM1	VB	VB	VB	VB	VB	VB	VB
A10	DM2	B	B	B	B	B	B	B
A10	DM3	MB	MB	MB	MB	MB	MB	MB
A10	DM4	M	MB	M	M	MB	MB	MB
A11	DM1	VB	VB	VB	VB	B	B	MB
A11	DM2	B	B	B	B	MB	MB	M
A11	DM3	MB	MB	MB	MB	M	M	MG
A11	DM4	M	M	M	M	M	M	MG
A12	DM1	VB	VB	VB	VB	VG	G	MG
A12	DM2	B	B	B	B	VG	VG	G
A12	DM3	MB	MB	MB	MB	G	VG	VG
A12	DM4	MB	MB	MB	MB	G	VG	VG
A13	DM1	VB	VB	VB	VB	VG	VG	VG
A13	DM2	B	B	B	B	VG	VG	VG
A13	DM3	MB	MB	MB	MB	VG	VG	VG
A13	DM4	MB	VB	MB	MB	VG	VG	VG
A14	DM1	VB	VB	VB	VB	VG	G	MG
A14	DM2	B	B	B	B	VG	VG	G
A14	DM3	MB	MB	MB	MB	VG	MG	M
A14	DM4	B	MB	VB	MB	VG	MG	M