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Interval PROMETHEE II, TOPSIS and EDAS Approaches for Multi-Criteria Ranking Problem of the Bank Branches in Iran

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ABSTRACT

Undoubtedly, rating bank branches is one of the essential tool managers use to promote branches. In this study, a multi-criteria problem applied in banking has been addressed. In this research, a framework for ranking 20 branches of Tose'e Ta'avon bank in Iran (Khuzestan province) using decision-making methods has been considered as a case study. Essential criteria are selected through experts and research literature. Then, according to the uncertainty in some indicators and the elimination of defects related to the investigation at a certain point, the data is determined in the form of interval values. The weighting of the criteria using experts' opinions, interval Shannon entropy, and the linear combination of the two, and considering the final matrix extracted from three 4-month intervals (geometric mean of 3 matrices) using three approaches, namely PROMETHEE II, EDAS, and TOPSIS with interval values, the ranking of bank branches has been used for a case study. Then, benchmark tests are used to validate the methods to provide a fairer ranking. Finally, the managers can see the actual position of the branches in identify throughout the year and use it to improve the bank's performance.

1. Introduction

The proper functioning of the banking system plays a decisive role in improving economic activities. The importance of banks in countries' economies is undeniable as they provide diverse duties and services to society, including opening accounts, issuing various types of guarantees, loan payments, financial supply, electronic banking, etc. Ranking bank branches in terms of performance is an appropriate measure that can qualitatively and quantitatively improve branches in the prevailing competitive environment and ultimately assist managers in their future decision-making. It can also increase branch efficiency and provide better services to society.

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Numerous criteria are used to examine the situation of bank branches, and factors such as the time and method of extracting data, the uncertainty of some data, the weights assigned to each criterion, and the ranking methodology can complicate the issue of evaluating bank branches. However, these issues can be addressed using multi-criteria decision-making methods.

The selection of criteria for ranking bank branches plays a decisive role mainly influenced by branches' income, costs, profits, and losses. A literature review in this field points to the studies by Kumbirai and Webb [19] and Bičo and Ganić [4], which considered criteria such as capital amounts, return on assets, liquidity, etc., for evaluating and ranking the banking sector (See [30]). The literature generally addresses the issue using the CAMEL framework criteria to evaluate banking sector performance [1,12, 23, 32, 35].

These criteria are categorized into several main groups: capital-based, asset quality, management, profit-based, and liquidity-based. The CAMEL criteria are widely used for ranking banks. However, for ranking bank branches (banks' subsidiaries), some criteria impact the CAMEL index and are realized in each branch. According to this research, these consist of multiple criteria that are considered the most important based on expert opinions and literature in the subject field.

Generally, our work seeks to address the following research question. What are the rating indicators of Tose’e Ta'avon bank branches in Iran (Khuzestan province) and how can they is ranked?

Another essential consideration in ranking bank branches is choosing an appropriate methodology. Various multi-criteria decision-making approaches can be selected, as outlined in the literature. Commonly used approaches include AHP, TOPSIS, ELECTRE, PROMETHEE, SAW, MULTIMOORA, EDAS, etc.

Niroomand et al. [26] proposed a SAW-based approach for ranking countries by financial credibility. Kosmidou and Zopounidis [18] presented the PROMETHEE approach to measure banking sector performance. Brauers et al. [8] considered CAMEL-based criteria and a MULTIMOORA-based approach for evaluating Lithuanian banks. Ginevičius and Podviezko [13] also focused on banking sector evaluation using TOPSIS. Bilbao-Terol and Colleagues [5] also used the TOPSIS approach to evaluate government bonds in terms of sustainability. A decision support system was developed by Doumpos and Zopounidis [10]. Hemmati et al. integrated DEA and TOPSIS in their research [15]. Wątróbski [35] utilized PROMETHEE II method for multi-criteria sustainability assessment.

Moreover, to analyze the financial performance of banks in Serbia, Mandic and colleagues [23] used the integrated AHP and TOPSIS methods to evaluate the performance of the banking sector. Classical MCDM can be combined for better outcomes. Combined MCDM approaches have also been applied to banking issues. For example, Wu et al. [36] introduced an MCDM framework combining AHP, SAW, TOPSIS, and VIKOR for evaluating banking performance in fuzzy environments. Shavardi et al. [31] proposed a fuzzy MCDM and BSC framework for private Iranian banking. Beheshtinia and Amidi [2] used the AHP approach and VIKOR and TOPSIS methods to evaluate and rank issues in the banking sector. They also divided the study's main criteria into two parts: internal and external.

Due to computational similarities, Ozkalipci et al. [33], considered an integrated MCDM model to evaluate publicly traded Turkish banks using EDAS, MOORA, OCRA, and TOPSIS. In summary, various individual and combined MCDM approaches have been employed in the literature for banking sector analysis and branch ranking issues.

This study utilizes a multi-criteria decision-making (MCDM) framework employing range-based PROMETHEE, EDAS, and TOPSIS approaches to evaluate and rank bank branches in Khuzestan province, Iran. The internal criteria include financial, customer, administrative, and learning and growth areas, and external criteria include social and environmental. Essential aspects of this research include:

- The problem focuses on the multi-criteria ranking of Tose'e Ta'avon bank branches in Khuzestan province.
- Banking experts' opinions were consulted to select critical evaluation criteria based on the CAMEL methodology and other performance factors relevant to ranking branches.
- Historical branch data from previous years is used for ranking to facilitate more robust decision-making. As a result, three decision matrices with range values related to three 4-month periods will be considered in this analysis.
- Shannon entropy distance, experts' opinions, and a linear combination of the two are employed to determine the weights of the evaluation criteria.

- Classic PROMETHEE II, EDAS, and TOPSIS approaches are extended in a range-based form for branch ranking.

This paper is structured as follows: Section 2 describes the characteristics of the multi-criteria ranking problem for Tose'e Ta'avon bank branches in Khuzestan. Section 3 outlines the proposed solution methodology, including criteria weighting and the MCDM approaches applied. Section 4 presents computational results from the case study and validation. Section 5 provides concluding remarks.

2. The Multi-Criteria Ranking Problem of Bank Branches in Iran (Khuzestan Province)

As mentioned, this research examines the multi-criteria ranking problem of Tose'e Ta'avon bank branches in Khuzestan province, Iran. This problem was formed in three stages, as shown in Figure 1.

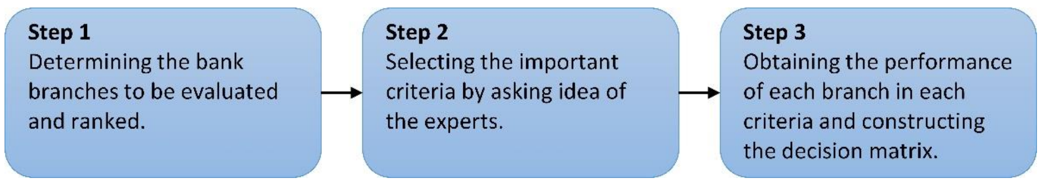

Figure 1. Stages of defining the multi-criteria ranking problem of bank branches in Khuzestan province, Iran

The steps in Figure 1 are explained in more detail below:

2.1. The branches of Tose'e Ta'avon Bank in Khuzestan province, Iran.

The Tose’e Ta’avon bank branches have been established in different cities of Khuzestan Province of Iran. Table 1 shows the location along with the code of these branches in Khuzestan province.

Table 1. The branches of the Tose’e Ta’avon bank in Khuzestan province of Iran

Branch code	Detailed name
Br-1	Ahvaz (Central)
Br-2	Dezfool
Br-3	Abadan
Br-4	Behbahan
Br-5	Masjed-Soleiman
Br-6	Ramhormoz
Br-7	Bandar-Mahshahr
Br-8	Izeh
Br-9	Shooshtar
Br-10	Andimeshk
Br-11	Khorramshahr
Br-12	Soosangerd
Br-13	Shadegan
Br-14	Shoosh
Br-15	Bagh-malek
Br-16	Ahvaz (Kiyanpars)
Br-17	Omidiyeh
Br-18	Hendijan
Br-19	Lali
Br-20	Ahvaz (Taleghani)

2.2. Important Evaluation Criteria

The most important and influential criteria for ranking bank branches based on the literature discussed in section one, as well as criteria based on the CAMEL methodology and other determining factors identified by a panel of experts from Tose'e Ta'avon bank, were selected. As a result, 15 criteria for evaluating and ranking bank branches, shown in Table 2, were chosen based on feedback from the literature and expert opinions. These criteria are divided into two categories: positive criteria, where higher values are preferable, and negative criteria, where lower values are desirable.

Table 2. The criteria selected for the proposed multi-criteria ranking problem

Criterion code	Description	Type
C-1	NPL, which is obtained from total loans paid divided by all charges of a branch	Negative
C-2	Common income per employee	Positive
C-3	Non-common income per employee	Positive
C-4	Non-performing loans per employee	Negative
C-5	Low-cost resources	Positive
C-6	Deposited resources	Positive
C-7	Amount of bank guarantee	Positive
C-8	Benefit	Positive
C-9	Total cost price of the services	Negative
C-10	Total bank advances paid to customers per employee	Positive
C-11	Total bank account balance per employee	Positive
C-12	Income from POS machines	Positive
C-13	Average income from ATM machines	Positive
C-14	Number of customers per employee	Positive
C-15	Number of electronic customers per employee	Positive

2.3. Decision Matrices

This subsection determines the decision matrix for the proposed multi-criteria ranking model of the Tose'e Ta'avon bank branches in Khuzestan province, Iran. This is an m×n dimensional matrix where m represents the number of branches (m=20), and n represents the number of criteria (n=15). The final values in this matrix are the geometric means of the values from three separate matrices, including performance data for the Tose'e Ta'avon bank branches in Khuzestan over three or four months. The first matrix contains data on each branch's performance against the key indices during the first quarter of the year (Farvardin to Tir). The second matrix has data for the second quarter (Mordad to Aban).

Moreover, the third matrix covers the third quarter (Azar to Esfand). The overall decision matrix is obtained by calculating the geometric mean of these three periodic matrices. This decision matrix is presented below:

$$\tilde{A} = \begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \cdots & \tilde{a}_{mn} \end{bmatrix} \tag{1}$$

In this matrix $\tilde{a}_{ij} = \left[a_{ij}^{l}, a_{ij}^{u}\right]$ the performance range of branch i of the bank for the selected criterion j is presented.

Matrix $\tilde{A}$ contains interval numbers and shows each branch's annual performance range, where the range's lower and upper values indicate the minimum and maximum values extracted from the final matrix (geometric mean of values from the three 4-month matrices).

Considering the decision matrix in an interval form has the following benefits:

- Like other real-world problems, there is an element of uncertainty in this research issue. Representing the decision matrix as an interval form eliminates this uncertainty.
- Taking the performance ranges over the three 4-month periods and calculating their geometric mean can facilitate fairer and more robust decision-making.

The decision matrix presented is used to rank the bank branches shown in Table 1. The following section will discuss the methodology.

3. Solution Methodology

As mentioned earlier, the ranking problem in this study aims to evaluate and rank the branches of the Tose'e Ta'avon bank in Khuzestan province based on predefined criteria measured using interval values.

In this section, a two-phase solution methodology is proposed for conducting the ranking as follows:

Phase 1: The weights representing the importance of each criterion (internal, external, and combined weights) are determined.

Phase 2: The PROMETHEE II, EDAS, and TOPSIS interval-based ranking methods are extended to rank the bank branches.

The details of these phases will be explained in the following sections.

3.1. Phase 1 - Determining the Criteria Importance Weights

In this study, we propose an approach that considers both expert opinions and decision matrix data. The proposed methodology for determining the criteria importance weights is as follows:

We are determining the weights based on expert opinions, defined as external weights.

- Determining the weights using the interval-form Shannon entropy weighting method applied to the decision matrix data, defined as internal weights.
- Determining the weights as a combination of the internal and external weights, defined as combined weights.

This approach is illustrated in Figure 2.

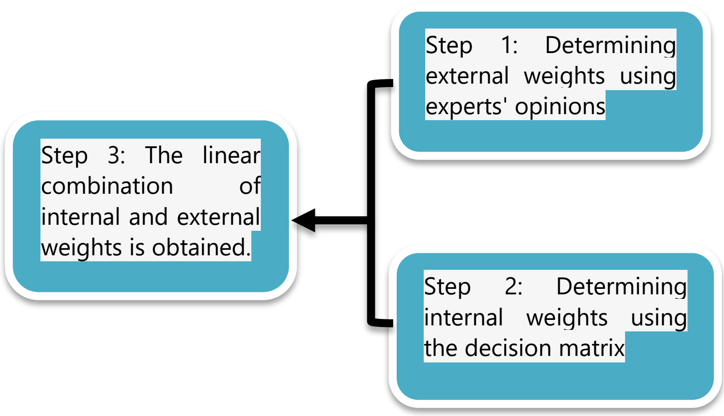

Figure 2. The proposed process for determining the final weights

3.1.1. Determining External Weights (Step 1)

The process of determining the external weights of criteria j (denoted by w_j^e) is explained below:

1. Select a number of expert bankers (denoted by s) who are knowledgeable about the banking sector.
2. Ask each expert to score each criterion denoted by $sc_{pj} \in \{1, 2, \dots, 10\}$, where sc_{pj} represents the score for criterion j given by expert banker p.
3. Calculate the external importance weight of each criterion as $w_j^e = \frac{\sum_{p=1}^{s} sc_{pj}}{\sum_{p=1}^{s}\sum_{j=1}^{n} sc_{pj}}$. This provides the normalized weighted averages of the expert scores.

The above steps yield definitive and normalized weight values.

3.1.2. Determining Internal Weights (Step 2):

Next, the interval Shannon entropy approach proposed by Latifi and Falahati Nejad [21] is employed to calculate the interval internal weight values. The steps are:

1. Normalizing matrix A using equation (2) and (3) as follows:

$$r_{ij}^l = \frac{a_{ij}^l}{\sum_{k=1}^{m} a_{kj}^l} \qquad \forall i, j \tag{2}$$

$$r_{ij}^u = \frac{a_{ij}^u}{\sum_{k=1}^{m} a_{kj}^u} \qquad \forall i, j \tag{3}$$

The entropy range for each criterion is calculated as below with lower and upper bounds (shown as h_j^l and h_j^u respectively).

$$h_j^l = \min\left\{-h_0 \sum_{i=1}^{m} r_{ij}^l \ln r_{ij}^l, -h_0 \sum_{i=1}^{m} r_{ij}^u \ln r_{ij}^u\right\} \qquad \forall j \tag{4}$$

$$h_j^u = \max\left\{-h_0 \sum_{i=1}^{m} r_{ij}^l \ln r_{ij}^l, -h_0 \sum_{i=1}^{m} r_{ij}^u \ln r_{ij}^u\right\} \qquad \forall j \tag{5}$$

where $h_0 = (\ln m)^{-1}$, $r_{ij}^l = 0 \Rightarrow r_{ij}^l \ln r_{ij}^l = 0$, and $r_{ij}^u = 0 \Rightarrow r_{ij}^u \ln r_{ij}^u = 0$.

Calculate the interval degree of diversification for criterion j (which is specified by $[d_j^l, d_j^u]$) as follows:

$$[d_j^l, d_j^u] = [1 - h_j^u, 1 - h_j^l] \qquad \forall j \tag{6}$$

Calculate the internal weight importance of each criterion in a range (in the form of $\widetilde{w}_j^{in} = [w_j^{in,l}, w_j^{in,u}]$) using the equation below.

$$[w_j^{in,l}, w_j^{in,u}] = \left[\frac{d_j^l}{\sum_{k=1}^{n} d_k^u}, \frac{d_j^u}{\sum_{k=1}^{n} d_k^l}\right] \qquad \forall j \tag{7}$$

Determining Combined Weights (Step 3): Based on the proposed approach for determining weights, the final interval weights (combined weights) of the criteria (represented by $\widetilde{w}_j = [w_j^l, w_j^u]$ for criterion j) are calculated by combining the internal and external weights as described below.

$$[w_j^l, w_j^u] = [(1-\lambda) w_j^{in,l} + \lambda w_j^e, (1-\lambda) w_j^{in,u} + \lambda w_j^e] \qquad \forall j \tag{8}$$

where $\lambda \in (0, 1)$ is importance of the external weight values determined by decision maker.

3.2. Interval Approach

The PROMETHEE method was first introduced by Brans [6] and is suitable for evaluating and ranking multi-criteria decision-making problems. Its summary is shown in the flowchart of Figure 3. It should be noted that Brans et al. [7] proposed six main types of preference functions: the usual criteria function, U-shaped criteria function, V-shaped criteria function, level criterion function, V-shaped criteria function with an indifference zone, and Gaussian criteria function. Any of these functions can be chosen for using the PROMETHEE II approach for solving multi-criteria decision-making problems.

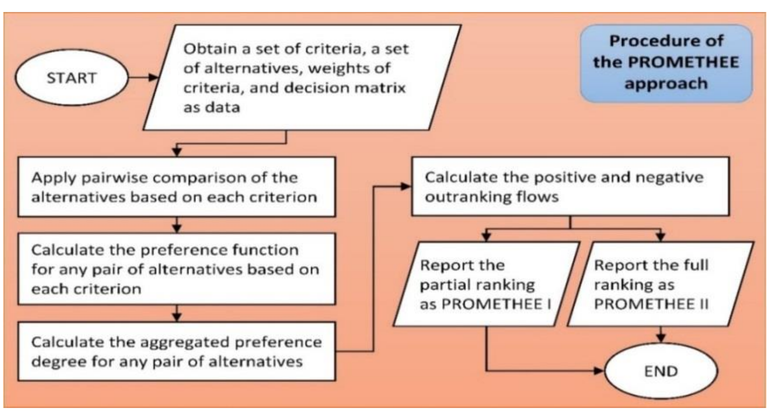

Figure 3. Summary of the PROMETHEE II approach

Furthermore, the classical PROMETHEE II approach shown in Figure 3 has been extended to handle interval data types. The following steps are proposed for this purpose:

Step 1. Determine a set of criteria (indexed by $j, k \in \{1,2, \dots, n\}$), a set of alternatives (bank branches, indexed by $i, l \in \{1,2, \dots, m\}$), and the weight of each criterion ($\widetilde{w}_j, j = 1,2, \dots, n$).as determined in Section 3.1. Define the interval decision matrix $\tilde{A} = \left[\tilde{a}_{ij} = [a_{ij}^l, a_{ij}^u]\right]_{m \times n}$ according to the procedure outlined in Section 3.2.

Step 2. Calculate the performance difference of the alternatives by the following formula,

$$d_j(\tilde{a}_{ij}, \tilde{a}_{lj}) = [a_{ij}^l, a_{ij}^u] - [a_{lj}^l, a_{lj}^u] = [a_{ij}^l - a_{lj}^u, a_{ij}^u - a_{lj}^l] \quad i, l = 1,2, \dots, m, \qquad j = 1,2, \dots, n \tag{9}$$

where, $d_j(\tilde{a}_{ij}, \tilde{a}_{lj})$ is the performance difference of alternatives i and l in criterion j. The performance difference is calculated for any pair of alternatives in any of the criteria.

Step 3. Calculate the preference function values by the below relationship (where $P_j(\tilde{a}_{ij}, \tilde{a}_{lj})$ is the preference function value of alternatives i and l in criterion j). In this study the V-shape criterion function with indifference area is applied for this aim. This function has been applied in the literature because of its accuracy.

$$P_j(\tilde{a}_{ij}, \tilde{a}_{lj}) = \begin{cases} 0 & a_{ij}^u - a_{lj}^l \le 0 \\ d_j(\tilde{a}_{ij}, \tilde{a}_{lj}) & \text{Otherwise} \end{cases} \qquad i, l = 1,2, \dots, m,\ j = 1,2, \dots, n \tag{10}$$

Step 4. Calculate the interval total preference index of the pairs of alternatives over all criteria by the following formula ($\widetilde{\Pi}_{il}$ is the interval total preference index of alternative i respecting to alternative l).

$$\widetilde{\Pi}_{il} = \sum_{j=1}^{n} \widetilde{w}_j d_j(\tilde{a}_{ij}, \tilde{a}_{lj}) = \sum_{j=1}^{n} [w_j^l, w_j^u] \times [a_{ij}^l - a_{lj}^u, a_{ij}^u - a_{lj}^l] \qquad i, l \in \{1,2, \dots, m\} \tag{11}$$

Note that in the matrix $\widetilde{\Pi} = [\widetilde{\Pi}_{\mathrm{il}}]_{\mathrm{m}\times\mathrm{m}}$ there is no value for the diagonal elements, but all other elements should be calculated by the above-mentioned formula.

Step 5. Obtain the interval positive outranking flow ($\tilde{\phi}_i^+$) and interval negative outranking flow ($\tilde{\phi}_i^-$) for each alternative by the following formulas.

$$\tilde{\phi}_i^+ = \frac{1}{m-1} \sum_{\substack{l=1 \\ l \ne i}}^{m} \widetilde{\Pi}_{il} \qquad i = 1,2, \dots, m \tag{12}$$

$$\tilde{\phi}_i^- = \frac{1}{m-1} \sum_{\substack{l=1 \\ l \ne i}}^{m} \widetilde{\Pi}_{il} \qquad i = 1,2, \dots, m \tag{13}$$

Actually, the value of $\widetilde{\Phi}_{\mathrm{i}}^+$ is average of the values of row i of matrix $\widetilde{\Pi}$, where, the value of $\widetilde{\Phi}_{\mathrm{i}}^-$ is average of the values of column i of matrix $\widetilde{\Pi}$.

Step 6. Calculate the interval net outranking flow ($\tilde{\phi}_i = [\phi_i^l, \phi_i^u]$) for each alternative by the following formula.

$$\tilde{\phi}_i = \tilde{\phi}_i^+ - \tilde{\phi}_i^- \qquad i = 1,2, \dots, m \tag{14}$$

Step 7. Rank the alternatives according to the descending order of the net outranking flow values. This step actually applies the concept of PROMETHEE II approach for complete ranking of the alternatives. According to this step, three different rankings of the bank branches are obtained as follow,

- Ranking according to the descending order of the lower bound of the values of $\tilde{\phi}_i$ (according to the descending order of the values of ϕ_i^l),
- Ranking according to the descending order of the upper bound of the values of $\tilde{\phi}_i$ (according to the descending order of the values of ϕ_i^u),
- Ranking according to the descending order of the average of the lower and upper bound values of $\tilde{\phi}_i$ (according to the descending order of the values of $\frac{\phi_i^l + \phi_i^u}{2}$).

The TOPSIS technique is used for ranking the options. The TOPSIS method ranks the options based on their similarity to the ideal option. The steps of the Interval TOPSIS method are listed below [37].

Step 1: Normalization of the decision matrix using the following equation for beneficial (positive aspect) indicators:

$$R_{ij} = \frac{[a_{ij} - min(a_{ij})]}{[max(a_{ij}) - min(a_{ij})]}, \qquad i = 1,2, \dots, m,\ j = 1,2, \dots, n, \tag{15}$$

where a_{ij} is the value of alternative i for the indicator j, and R_{ij} is the normalized value of a_{ij}. For lower and upper bounds of each alternative with a positive aspect, the same process is followed.

For non-beneficial (negative aspect) indicators:

$$R_{ij} = \frac{[\max(a_{ij}) - a_{ij}]}{[\max(a_{ij}) - \min(a_{ij})]} \tag{16}$$

For the lower and upper bounds of each alternative with a negative aspect, the same process is followed.

This normalization process is necessary to make the indicator values comparable. After normalization, all the values of the indicators should be between zero and one.

Step 2: Weighted decision matrix. In this step, the weights of the criteria are multiplied in the normalized matrix to obtain the weighted decision matrix.

$$\underline{x}'_i = w_j \underline{x}^*_{ij} \tag{17}$$

$$\overline{x}'_i = w_j \overline{x}^*_{ij} \tag{18}$$

Step 3: Determining the positive and negative ideal solutions. The positive and negative ideal solutions are determined from the following relationships.

$$\overline{A}^{+} = \{v_1^+, \dots, v_n^+\} = \left\{\left(\max_j \overline{x}'_i | i \in I\right), \left(\min_j \underline{x}'_i | i \in J\right)\right\} \tag{19}$$

$$\overline{A}^{-} = \{v_1^-, \dots, v_n^-\} = \left\{\left(\min_j \underline{x}'_i | i \in I\right), \left(\max_j \overline{x}'_i | i \in J\right)\right\} \tag{20}$$

In this relationship, *i* indicates criteria with a positive aspect and *j* indicates criteria with a negative aspect.

Step 4: Determining the distance of alternatives from the positive and negative ideal solutions. Using the following relationships, the distance of alternatives from the positive and negative ideal solutions are calculated.

$$d_j^+ = \left\{\sum_{i \in I} \left(\overline{x'_{ij}} - v_i^+\right)^2 + \sum_{i \in I} \left(\underline{x'_{ij}} - v_i^+\right)^2\right\}^{\frac{1}{2}} \quad j = 1,2, \dots, m \tag{21}$$

$$d_j^- = \left\{\sum_{i \in I} \left(\overline{x'_{ij}} - v_i^-\right)^2 + \sum_{i \in I} \left(\underline{x'_{ij}} - v_i^-\right)^2\right\}^{\frac{1}{2}} \quad j = 1,2, \dots, m \tag{22}$$

Step 5: Calculating the similarity index and ranking alternatives. Using the following relationship, the similarity index of alternatives is calculated and alternatives are ranked based on it.

$$CL = \frac{d_j^-}{(d_j^- + d_j^+)} \quad j = 1,2, \dots, m \tag{23}$$

In EDAS method, the basis of evaluation is the values proportional to the distance from the mean. This method was introduced by Keshavarz Ghorabaee in 2015 [17], and it can be considered similar to the TOPSIS and VIKOR methods, with the difference being that the distance from the mean is important in this method. In contrast, in TOPSIS and VIKOR methods, the distance from the positive and negative ideal solutions is considered in the calculations. The steps of the EDAS method are as follows:

Step 1: Production of the initial decision matrix in the time period of interest.

In this step, the decision matrix ($\tilde{A}$) is generated, where each element is an interval number with upper and lower bounds, as follows:

$$\tilde{A} = \begin{bmatrix} \check{z}_{11} & \cdots & \check{z}_{m1} \\ \vdots & \ddots & \vdots \\ \check{z}_{1n} & \cdots & \check{z}_{mn} \end{bmatrix},$$

$$\check{z}_{ij} = \left[z^l{}_{ij} \quad z^u{}_{ij}\right] \qquad i = 1.2. \dots .n, j = 1.2. \dots .m \tag{24}$$

Step 2: Determine the weight of each criterion.

The weight of each criterion is a grey number with upper and lower bounds.

$$\breve{W} = [\breve{w}_1 \quad \dots \quad \breve{w}_m], \quad \breve{w}_j = [w^l{}_j . w^u{}_j], \quad j = 1.2. \dots . m \tag{25}$$

Step 3: Normalize the decision matrix. If the criterion is a positive one (the higher the score the better):

$$[f^l{}_{ij}, f^u{}_{ij}] = \left[\frac{z^l{}_{ij} - \min_i(z^l{}_{ij})}{\max_i(z^u{}_{ij}) - \min_i(z^l{}_{ij})} \quad \frac{z^u{}_{ij} - \min_i(z^l{}_{ij})}{\max_i(z^u{}_{ij}) - \min_i(z^l{}_{ij})} \right] \qquad j = 1, \dots, m, i = 1, \dots, n \tag{26}$$

If the criterion is a negative one (the lower the score the better):

$$[f^l{}_{ij}, f^u{}_{ij}] = \left[\frac{\max_i(z^u{}_{ij}) - z^u{}_{ij}}{\max_i(z^u{}_{ij}) - \min_i(z^l{}_{ij})} \quad \frac{\max_i(z^u{}_{ij}) - z^l{}_{ij}}{\max_i(z^u{}_{ij}) - \min_i(z^l{}_{ij})} \right] \qquad j = 1, \dots, m, i = 1, \dots, n \tag{27}$$

Step 4: Calculate the average for the upper and lower bounds of each criterion:

$$AS^l{}_j = \frac{\sum_{i=1}^n f^l{}_{ij}}{n} \qquad j = 1.2. \dots . m \tag{28}$$

$$AS^u{}_j = \frac{\sum_{i=1}^n f^u{}_{ij}}{n} \qquad j = 1.2. \dots . m \tag{29}$$

Step 5: Calculate the distance in the positive direction $[PD_{ij}^- , PD_{ij}^+]$ and the distance in the negative direction $[ND_{ij}^- , ND_{ij}^+]$from the average obtained in the previous step:

$$PD_{ij}^- = \max\left(0. \min(\frac{f_{ij}^- - AS_j^-}{AS_j^-} . \frac{f_{ij}^+ - AS_j^+}{AS_j^+})\right) \tag{30}$$

$$PD_{ij}^+ = \max\left(0. \max(\frac{f_{ij}^- - AS_j^-}{AS_j^-} . \frac{f_{ij}^+ - AS_j^+}{AS_j^+})\right) \tag{31}$$

$$ND_{ij}^- = \max\left(0. \min(\frac{AS_j^- - f_{ij}^-}{AS_j^-} . \frac{AS_j^+ - f_{ij}^+}{AS_j^+})\right) \tag{32}$$

$$ND_{ij}^+ = \max\left(0. \max(\frac{AS_j^- - f_{ij}^-}{AS_j^-} . \frac{AS_j^+ - f_{ij}^+}{AS_j^+})\right) \tag{33}$$

$$[PD_{ij}^- , PD_{ij}^+] = \left[\max\left(0. \min\left(\frac{f_{ij}^- - AS_j^-}{AS_j^-} . \frac{f_{ij}^+ - AS_j^+}{AS_j^+}\right)\right), \max\left(0. \max\left(\frac{f_{ij}^- - AS_j^-}{AS_j^-} . \frac{f_{ij}^+ - AS_j^+}{AS_j^+}\right)\right)\right] \tag{34}$$

$$[ND_{ij}^- , ND_{ij}^+] = \left[\max\left(0. \min(\frac{AS_j^- - f_{ij}^-}{AS_j^-} . \frac{AS_j^+ - f_{ij}^+}{AS_j^+})\right), \max\left(0. \max(\frac{AS_j^- - f_{ij}^-}{AS_j^-} . \frac{AS_j^+ - f_{ij}^+}{AS_j^+})\right)\right] \tag{35}$$

Step 6: Calculate the weighted sum of the positive and negative distances obtained in the previous step:

$$[SWPD_i^- , SWPD_i^+] = \sum_{j=1}^m [PD_{ij}^- \quad PD_{ij}^+][w_j^- \quad w_j^+] \tag{36}$$

$$[SWND_i^- , SWND_i^+] = \sum_{j=1}^m [ND_{ij}^- \quad ND_{ij}^+][w_j^- \quad w_j^+] \tag{37}$$

Step 7: Normalize the values from the previous step:

$$[NSWPD_i^-, \quad NSWPD_i^+] = \frac{[SWPD_i^- \quad SWPD_i^+]}{\max_i(SWPD_i^+)} \tag{38}$$

$$[NSWND_i^- \quad , NSWND_i^+] = \left[1 - \frac{SWND_i^+}{\max_i(SWND_i^+)}, 1 - \frac{SWND_i^-}{\max_i(SWND_i^+)}\right] \tag{39}$$

Step 8: Calculate the average of the normalized values:

$$[NSWPD_i^-, NSWPD_i^+] = \frac{[SWPD_i^- \quad SWPD_i^+]}{\max_i(SWPD_i^+)} \tag{40}$$

$$[NSWND_i^-, NSWND_i^+] = \left[1 - \frac{SWND_i^+}{\max_i(SWND_i^+)}, 1 - \frac{SWND_i^-}{\max_i(SWND_i^+)}\right] \tag{41}$$

Step 9: Calculate the average of the normalized values:

$$[APS_i^-, \ APS_i^+] = \left[\frac{NSWPD_i^- + NSWND_i^-}{2}, \frac{NSWPD_i^+ + NSWND_i^+}{2}\right] \tag{42}$$

Step 10: Ranking of alternatives based on intervals:

$$P_{ij} = \mathrm{P}\left([ASP_i^- \quad ASP_i^+] \ \geq \ [ASP_j^- - ASP_j^+]\right) \tag{43}$$

$$P_{ij} = max\left\{1, \max\left(\frac{ASP_j^+ - ASP_i^-}{ASP_i^+ - ASP_i^- + ASP_j^+ - ASP_j^-}, 0\right)\right\} \tag{44}$$

$$IP_j = \sum_i P_{ij} \tag{45}$$

4. Case Study

In this section, the proposed decision-making framework in section 3 for ranking the branches of the Tose'e Ta'avon bank in Khuzestan province based on predefined criteria with interval type values is implemented. For this purpose, some of the parameters and indicators of the proposed solution approach are as follows:

Tose'e Ta'avon bank has 20 branches in Khuzestan province of Iran, so m=20. The number of criteria determined earlier is 15, so n=15.

Three experts were consulted to determine the external weights, so s=3.

Based on bankmanagers' view, the determination of final weight ranges, external and internal weights are equally scaled, so $\lambda = 0.5$.

After implementing phase 1 of the proposed solution approach, the external (objective) weights, internal (subjective) weights and final weights were obtained and are reported in Table 3.

Based on the results of Table 3, according to the experts' opinions (reflected as the external weight values), the criteria such as C-3, C-5, C-7, and C-8 are simultaneously the most important criteria. On the other hand, C-14 and C-15 are the least important criteria, with an external weight value of 0.04. According to the internal weight values and considering the center of each interval, the most crucial criterion is C-10, while the least important criterion is C-14. According to the final weight values and considering the center of each interval, the most crucial criterion is C-10, while the least important criterion is C-14.

In the next step, we use the weight values obtained from Table 3 to implement phase 2 of the proposed solution approach for ranking the branches. Since each criterion has three crucial weight values (external, internal, and final weight), each type of weight value can be used for the proposed PROMETHEE, EDAS, and TOPSIS distance-based approaches.

According to of Tables 4, 6 and 8 and and considering the ranking options obtained from step 9 of section 3.2.1, step 5 of section 3.2.2, and step 10 of section 3.2.3, 27 defined tests are defined in which each test leads to a ranking. Therefore, the rankings of Tables 5, 7, and 9 are defined using the proposed PROMETHEE II, TOPSIS, and EDAS approaches, in which the row and column of each ranking determine the characteristics of its test. Then, for each experiment of Table 4 a ranking of the bank branches is obtained which is represented by Table 5. The rankings represented by Table 5 are more or less different than each other. It is obvious that in all experiments, Br-19 is the worst branch, while according to 8 out of 9 experiments, Br-20 is the best branch.

Table 3. The weight values obtained for the criteria (for $\lambda = 0.5$).

Criteria	External weights (w_j^e)	Internal weights ($\tilde{w}_j^{in} = [w_j^{in,l}, w_j^{in,u}]$)	Final weight ($\tilde{w}_j = [w_j^l, w_j^u]$)
C-1	0.06	[0.011, 0.367]	[0.035, 0.213]
C-2	0.08	[0.004, 0.467]	[0.042, 0.283]
C-3	0.09	[0.004, 0.543]	[0.047, 0.316]
C-4	0.07	[0.022, 0.349]	[0.046, 0.209]
C-5	0.09	[0.005, 0.238]	[0.047, 0.164]
C-6	0.05	[0.003, 0.306]	[0.026, 0.178]
C-7	0.09	[0.045, 0.517]	[0.067, 0.303]
C-8	0.09	[0.032, 0.372]	[0.061, 0.231]
C-9	0.06	[0.001, 0.119]	[0.030, 0.089]
C-10	0.07	[0.028, 0.576]	[0.049, 0.323]
C-11	0.06	[0.004, 0.176]	[0.032, 0.118]
C-12	0.06	[0.000, 0.161]	[0.030, 0.110]
C-13	0.05	[0.005, 0.269]	[0.027, 0.159]
C-14	0.04	[0.001, 0.062]	[0.020, 0.051]
C-15	0.04	[0.003, 0.067]	[0.021, 0.053]

Table 4. The rankings by applying the interval PROMETHEE II approach for the case study

Outranking flow	Importance weight determination method		
	External weights	Internal weights	Final weights
Lower bound (ϕ_i^l)	Ranking 1	Ranking 4	Ranking 7
Upper bound (ϕ_i^u)	Ranking 2	Ranking 5	Ranking 8
Average ($(\phi_i^l + \phi_i^u)/2$)	Ranking 3	Ranking 6	Ranking 9

Table 5. The rankings obtained for the bank branches by different experiments of Table 4

Bank branch	Ranking 1	Ranking 2	Ranking 3	Ranking 4	Ranking 5	Ranking 6	Ranking 7	Ranking 8	Ranking 9
Br-1	2	2	2	3	2	2	3	2	2
Br-2	14	18	17	16	18	18	16	18	18
Br-3	10	9	9	11	14	12	10	12	11
Br-4	19	16	18	18	19	19	18	19	19
Br-5	6	7	7	7	10	8	7	10	8
Br-6	7	6	6	13	9	10	12	7	10
Br-7	5	3	3	6	3	5	6	3	4
Br-8	8	8	8	9	8	9	9	9	9
Br-9	4	4	5	4	5	4	5	5	5
Br-10	15	17	16	10	13	11	11	14	13
Br-11	11	10	10	15	11	13	14	11	12
Br-12	16	15	15	17	15	16	17	15	16
Br-13	17	12	14	19	12	17	19	13	17
Br-14	12	11	11	8	6	7	8	6	7
Br-15	18	19	19	12	17	14	13	17	15
Br-16	3	5	4	5	4	3	4	4	3
Br-17	13	13	13	14	16	15	15	16	14
Br-18	9	14	12	1	7	6	2	8	6
Br-19	20	20	20	20	20	20	20	20	20
Br-20	1	1	1	2	1	1	1	1	1

Table 6. Ranking using the interval TOPSIS approach for the case study

The basis of the ranking	Importance weight determination method		
	External weights	Internal weights	Final weights
The similarity index of alternatives	Ranking 10	Ranking 11	Ranking 12

Table 7. The ranks obtained for the bank branches with the different tests in Table 6 using the interval TOPSIS approach

Branch of Bank	Ranking 10	Ranking 11	Ranking 12
Br-1	2	2	3
Br-2	17	16	16
Br-3	16	19	18
Br-4	13	14	14
Br-5	10	13	12
Br-6	6	11	10
Br-7	3	6	6
Br-8	9	9	9
Br-9	5	5	4
Br-10	11	7	7
Br-11	8	10	11
Br-12	14	12	13
Br-13	12	8	8
Br-14	7	4	5
Br-15	18	17	17
Br-16	4	1	1
Br-17	15	15	15
Br-18	20	20	20
Br-19	19	18	19
Br-20	1	3	2

The rankings presented in Table 7 are more or less different from each other. Obviously, in all tests Br-18 is the worst branch while according to two tests out of three tests, Br-16 is the best branch.

Table 8. Ranking using the interval EDAS approach for the case study

The basis of the ranking	Importance weight determination method		
	External weights	Internal weights	Final weights
The output of step 9 of EDAS method	Ranking 13	Ranking 14	Ranking 15

Table 9. The ranks obtained for the bank branches with the different tests in Table 6 using the EDAS interval approach

Branch of bank	Ranking 13	Ranking 14	Ranking 15
Br-1	2	2	2
Br-2	17	18	18
Br-3	13	19	19
Br-4	14	15	14
Br-5	10	11	11
Br-6	7	10	9
Br-7	4	5	5
Br-8	8	8	8
Br-9	5	4	4
Br-10	11	9	10
Br-11	9	7	7
Br-12	16	16	16
Br-13	15	14	15
Br-14	6	6	6
Br-15	18	17	17
Br-16	3	3	3
Br-17	12	12	12
Br-18	19	13	13
Br-19	20	20	20
Br-20	1	1	1

The rankings presented in Table 9 are more or less different from each other. Obviously, in all tests Br-19 is the worst branch and in all tests Br-20 is the best branch.

4.1. Validation of results

Wu et.al [35] introduced three criterion tests for validating a method:

Criterion Test 1 - If the weight vector remains unchanged and a non-optimal option is replaced with a worse option, the rank of the better option should not change.

Criterion Test 2 - Transitivity property should be established in an effective MCDM decision-making method.

Criterion Test 3 - The solution of an MCDM problem should be the same in both the following cases:

a) Solving the problem in general without decomposing it into several MCDM sub-problems.

b) Decomposing the MCDM problem into two or more MCDM sub-problems, solving them, and aggregating the obtained ranks using transitivity property.

In the first step and to test the first criterion, the non-optimal option (branch) was replaced with the data below for branch B-11 in all three methods and directionality (using the Shannon entropy method), and the rank of the best branch remained unchanged. The results are shown in Table 10.

Table 10. The original and substituted data for applying the first criterion test

	Branch	Low-cost resources		Non-performing loans per employee		Non-common income per employee		Common income per employee		NPL	
Original Data	Br-11	0.2822	0.1272	0.9543	0.9163	0.2532	0.1003	0.3440	0.1705	0.9219	0.9020
Alternative Data	Br-11	0.2721	0.1570	0.8094	0.7560	0.5532	0.1113	0.2891	0.1280	0.7076	0.5055

	Branch	Total bank advances paid to customers per employee		Total cost price of the services		Benefit		Amount of bank guarantee		Deposited resources	
Original Data	Br-11	0.3270	0.0052	0.4292	0.3535	0.1624	0.0851	0.0736	0.0601	0.0804	0
Alternative Data	Br-11	0.3270	0.0123	0.4563	0.3332	0.2536	0.1265	0.0956	0.4231	0.2166	0

	Branch	Number of electronic customers per employee		Number of customers per employee		Average income from ATM machines		Income from POS machines		Total bank account balance per employee	
Original Data	Br-11	0.8089	0.8046	0.6369	0.5159	0.2699	0.1394	0.2583	0.0762	0.2812	0.2392
Alternative Data	Br-11	0.0621	0.0456	0.2018	0.1955	0.0465	0.1025	0.5119	0.3256	0.1526	0.1056

Table 11. The results of substituting the non-optimal data with the original data of branch Br-11 for applying the first criterion test - interval PROMETHEE II approach

Branch	Before the test	After the test
	The Rank of the branch by the internal weights	The Rank of the branch by the internal weights
Br-1	1	1
Br-2	17	17
Br-3	16	16
Br-4	13	13
Br-5	8	8
Br-6	7	7
Br-7	5	5
Br-8	10	10
Br-9	4	4
Br-10	6	6
Br-11	9	9
Br-12	15	15
Br-13	12	12
Br-14	11	11
Br-15	18	18
Br-16	3	3
Br-17	14	14
Br-18	19	19
Br-19	20	20
Br-20	2	2

Table 12. The results of substituting the non-optimal data with the original data of branch Br-11 for applying the first criterion test - interval TOPSIS approach

Branch	Before the test	After the test
	The Rank of the branch by the internal weights	The Rank of the branch by the internal weights
Br-1	2	2
Br-2	16	16
Br-3	19	19
Br-4	14	14
Br-5	13	13
Br-6	11	11
Br-7	6	6
Br-8	9	10
Br-9	5	5
Br-10	7	7
Br-11	10	9
Br-12	12	12
Br-13	8	8
Br-14	4	4
Br-15	17	17
Br-16	1	1
Br-17	15	15
Br-18	20	20
Br-19	18	18
Br-20	3	3

Table 13. The results of substituting the non-optimal data with the original data of branch Br-11 for applying the first criterion test - interval EDAS approach

Branch	Before the test	After the test
	The Rank of the branch by the internal weights	The Rank of the branch by the internal weights
Br-1	2	2
Br-2	18	18
Br-3	19	19
Br-4	15	15
Br-5	11	11
Br-6	10	9
Br-7	5	5
Br-8	8	8
Br-9	4	4
Br-10	9	10
Br-11	7	7
Br-12	16	16
Br-13	14	14
Br-14	6	6
Br-15	17	17
Br-16	3	3
Br-17	12	12
Br-18	13	13
Br-19	20	20
Br-20	1	1

With the changes made and the results obtained from Tables 11-13, it can be observed that the rankings do not change in more than 93% of cases. In particular, in the PROMETHEE method, applying the first criterion test did not result in any change in branch ranking.

In the second step and for the next criterion test, based on Tables 14-16, the problem has been decomposed into 7 sub-problems. Finally, the obtained ranks are examined.

Table 14. The results of decomposing the original problem into 7 sub-problems to apply the second criterion test - interval PROMETHEE II approach

Sub-problem 1		Sub-problem 2		Sub-problem 3		Sub-problem 4		Sub-problem5		Sub-problem 6		Sub-problem 7	
Rank	Branch	Rank	Branch	Rank	Branch	Rank	Branch	Rank	Branch	Rank	Branch	Rank	Branch
1	Br-1	1	Br-1	3	Br-14	3	Br-8	1	Br-10	7	Br-2	7	Br-3
7	Br-2	5	Br-7	5	Br-15	1	Br-9	2	Br-11	4	Br-4	4	Br-5
6	Br-3	6	Br-8	2	Br-16	2	Br-10	4	Br-12	1	Br-7	3	Br-6
5	Br-4	4	Br-9	4	Br-17	4	Br-11	3	Br-13	3	Br-11	5	Br-8
4	Br-5	3	Br-16	6	Br-18	6	Br-12	-	-	6	Br-12	1	Br-10
3	Br-6	7	Br-17	7	Br-19	5	Br-13	-	-	5	Br-13	2	Br-11
2	Br-7	2	Br-20	1	Br-20	-	-	-	-	2	Br-14	6	Br-17
-	-	-	-	-	-	-	-	-	-	8	Br-15	8	Br-19
-	-	-	-	-	-	-	-	-	-	9	Br-18	-	-

In more than 87% of the results, there was no change in the rankings of branches compared to the original problem.

Table 15. The results of decomposing the original problem into 7 sub-problems to apply the second criterion test - interval TOPSIS approach

Sub-problem 1		Sub-problem 2		Sub-problem 3		Sub-problem 4		Sub-problem5		Sub-problem 6		Sub-problem 7	
Rank	Branch	Rank	Branch	Rank	Branch	Rank	Branch	1	Br-10	7	Br-5	3	Br-2
1	Br-1	2	Br-1	3	Br-14	5	Br-8	3	Br-11	5	Br-6	6	Br-3
6	Br-2	5	Br-7	5	Br-15	1	Br-9	4	Br-12	2	Br-7	1	Br-4
7	Br-3	6	Br-8	1	Br-16	2	Br-10	2	Br-13	6	Br-8	4	Br-15
5	Br-4	4	Br-9	4	Br-17	4	Br-11	-	-	3	Br-10	2	Br-17
4	Br-5	1	Br-16	7	Br-18	6	Br-12	-	-	4	Br-11	7	Br-18
3	Br-6	7	Br-17	6	Br-19	3	Br-13	-	-	8	Br-12	5	Br-19
2	Br-7	3	Br-20	2	Br-20	-	-	-	-	1	Br-14	-	-
-	-	-	-	-	-	-	-	-	-	9	Br-15	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-

In over 92% of the results, the positions of the branches remained unchanged relative to the original problem.

Table 16. Results of decomposing the main problem into 7 sub-problems to apply the second criterion test - EDAS interval method

Sub-problem 1		Sub-problem 2		Sub-problem 3		Sub-problem 4		Sub-problem5		Sub-problem 6		Sub-problem 7	
Rank	Branch	Rank	Branch	Rank	Branch	Rank	Branch	Rank	Branch	Rank	Branch	Rank	Branch
1	Br-1	2	Br-1	3	Br-14	2	Br-8	2	Br-10	4	Br-2	7	Br-3
6	Br-2	5	Br-7	6	Br-15	1	Br-9	1	Br-11	9	Br-4	4	Br-5
7	Br-3	6	Br-8	2	Br-16	4	Br-10	3	Br-12	1	Br-7	5	Br-6
5	Br-4	3	Br-9	4	Br-17	3	Br-11	4	Br-13	3	Br-11	2	Br-8
3	Br-5	4	Br-16	5	Br-18	6	Br-12	-	-	6	Br-12	3	Br-10
4	Br-6	7	Br-17	7	Br-19	5	Br-13	-	-	5	Br-13	1	Br-11
2	Br-7	1	Br-20	1	Br-20	-	-	-	-	2	Br-14	6	Br-17
-	-	-	-	-	-	-	-	-	-	7	Br-15	8	Br-19
-	-	-	-	-	-	-	-	-	-	8	Br-18	-	-

In over 83 percent of the results, there was no change in the positions of the branches relative to the original problem.

5. Conclusion

In this study, an essential issue within the banking sector was investigated. A bank branch ranking problem was defined and solved as a case study of the Tose'e Ta'avon bank branches in Khuzestan province. Critical criteria for evaluating the banking sector were first selected from literature and experts in the field. To address the uncertain nature of real-world problems, branch data for the selected criteria over past years was obtained and displayed as interval values. A two-stage decision-making framework was proposed for ranking bank branches. In the first stage, criteria were weighted using expert opinions, interval Shannon entropy, and combined approaches. In the second stage, the classical PROMETHEE II, TOPSIS, and EDAS approaches were extended in an interval form and applied for bank branch ranking. Several rankings were obtained by applying the proposed solution method to the case study, and their similarities were compared. The validity of different methods was also tested. The decision maker can consider any of the rankings for subsequent management decisions.

Using the rankings developed in this research and even generalizing them to other bank branches and indicators can assist institution/bank managers in evaluating the performance of their subordinate units. The validations performed on the ranking results validate them, with criteria test results indicating that the presented rankings can be relied upon.

Considering all existing banking network resources in each county and comparing the share of that branch within the county could be a suitable performance metric. For example, compare the share of the Tose'e Ta'avon bank branch resources in a county out of the total available resources to the share of resources of other bank branches located in the relevant county, where a higher share indicates better branch performance. It is suggested that future research uses interval uncertain values based on degrees of belief and fuzzy interval values; other MCDM methods such as ELECTRE I, II, III, or VIKOR could be employed.

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