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A hybrid bi-objective mathematical model for multi-criteria ranking problem of the branches of Sepah bank: an integration of best-worst and SAW approaches

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Abstract. In this study we consider the multi-criteria ranking problem of the branches of Sepah bank in Fars province of Iran. Compared to the literature, a more complete set of criteria are considered to evaluate and rank the bank branches. The data for the last three years of the branches are considered to evaluate and rank them. A bi-objective mathematical model is proposed to evaluate the criteria and the bank branches simultaneously. For this aim, for the first time the best-worst method (BWM) and simple additive weighting approach (SAW) are integrated by the proposed mathematical model. By applying the proposed model, the criteria and branches are weighted and ranked simultaneously. In order to solve the proposed bi-objective model, a modification of the fuzzy programming approach called TH approach is applied. Based on the nature of the proposed model and the solution approach and their parameters, several experiments are designed and their results are used for sensitivity analysis purposes. The proposed model and solution approach are highly sensitive to their parameters' values.

Keywords: Best-worst method; simple additive weighting approach; multi-criteria decision-making; banking sector; hybridization.

1 Introduction

1.1 Conceptual background

In today's world, financial and credit institutions, as an important, vital, and critical sector of a economy of any country, play an important and significant role and stand in a special position. Banking efficiency

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in circulating money and capital, and channeling it towards productive activities, can directly impact the growth of economic sectors and pave the way for the development of capital markets and production. Evaluating the branches of a bank or financial institution is one of the effective components in creating a competitive environment among them, and it will undoubtedly set the units on a path towards performance enhancement. Identifying the current status and comparing the performance of each unit with others, along with ranking, can serve as a motivation for competitiveness and be the fundamental basis for progress.

Financial and credit institutions perform important financial and social roles in a country, including conducting financial transactions, providing a venue for investment, granting loans to customers, creating employment, and so on. A key objective and challenge for managers in this sector is to evaluate and rank different banks or bank branches in order to prioritize them for subsequent decision-making. For this purpose, the most important criteria are cost and revenue criteria. Since various criteria indicate a bank's cost and revenue efficiency, the problem of ranking the banking sector can be modeled as a multi-criteria decision-making (MCDM) problem. This issue is difficult and complex in certain aspects, such as selecting important criteria, gathering data from each bank branch, the uncertainty of some data, determining the importance weights of criteria, the evaluation method, etc.

1.2 Literature review

In this sub-section, some important and related studies of the literature in the field of evaluation problems of banking sector are presented.

Selection of the important and effective criteria for ranking of bank branches is an issue that has been focused on by the researchers of the field. In the studies performed [12] and [4], the criteria such as capital amount, return rate, cash amount, etc. are important criteria to evaluate and assess banking sector. The importance of these criteria also was mentioned in the [22].
In addition to the above-mentioned criteria, a set of criteria called CAMEL criteria are considered to evaluate, assess, and rank the banking sector units (see [27] and [9]). In the CAMEL criteria, there are several groups of criteria such as capital-based criteria, quality-based criteria, managerial criteria, benefit-based criteria, etc. These criteria provide a good structure to evaluate the banking sector units ([17]; [7]; [16]; [6]).

As the ranking problem of banking sector units is defined as a multiple criteria evaluation and ranking problem, application of MCDM approaches is important here. The approaches such as AHP, TOPSIS, ELECTRE, EDAS, SAW, etc. could be used for this aim. Most of the mentioned approaches have been employed by the researchers of the field in order to tackle assessment and ranking problems of the banking sector in different countries. Shahbandarzadeh designed an approach to evaluate the performance of bank branches [25]. He developed a Balanced Score Card (BSC) based approach for this aim. Rasoulinejad performed an study to rank the selected branches of Saderat bank in Tehran by integrating the approaches of DEAHP and ANP [20]. Secme et al. evaluated the performance of Turkish banking sector by introducing an approach based on AHP and TOPSIS approaches [23]. Motameni et al. integrated AHP and TOPSIS approaches for strategy performance evaluation problem of the banks [15]. Garcia et al. introduced a decision structure based on TOPSIS approach for ranking the Spanish savings banks [8]. Aghaei et al. performed a study to rank the Saman bank's branches in Tehran based on customer satisfaction factors [1]. They applied an integration of AHP and TOPSIS methods. Kazemi and Mousavi developed an entropy-based methodology to rank some Iranian private banks using several multi-criteria decision-making approaches [10]. Mahmudi and Bagherlou studied the problem of ranking the bank stock [14]. They applied an integration of AHP and TOPSIS approaches for this aim. Alidade and Ghasemi developed a methodology based on TOPSIS and BSC approaches for ranking the branches of Sepah bank of Sistan Baluchistan province of Iran [2]. Beheshtinia and Omidi developed a hybrid TOPSIS-VIKOR approach for performance evaluation in the banking industry [3]. Niroomand et al. introduced a simple mathematical programming model for countries' credit ranking problems [18]. Seyfi-Shishavan et al. applied an approach based on intuitionistic fuzzy best-worst method and fuzzy inference system for assessment of the banking industry performance [24].

1.3 Characteristics and novelties of this study

In this study, we consider the ranking problem of the branches of Sepah bank in Fars province of Iran. This study has the following research characteristics:

- We consider the most recent data (last three years) in order to perform a robust evaluation and ranking procedure for the bank branches.
- Compared to the literature, a more complete set of criteria are considered to evaluate and rank the bank branches.
- The three-year data are converted to a single using the geometric mean operator.
- A bi-objective mathematical model is proposed for simultaneously evaluation of the criteria and the bank branches. For this aim, for the first time the best-worst method (BWM) and simple additive weighting approach (SAW) are integrated by the proposed mathematical model.
- We apply a modification of the fuzzy programming approach called TH approach (Torabi and Hassini, 2008) in order to solve the proposed formulation and obtain a ranking for the bank branches.
- Several experiments based on the parameters and characteristics of the proposed bi-objective formulation and the solution approach are designed and their results are used for sensitivity analysis purposes.

1.4 Structure of the paper

The rest of this paper is organized as follows: Section 2 describes the ranking problem of the branches of Sepah bank in Fars province of Iran. Section 3 represents the proposed mathematical formulation and the solution methodology. Section 4 includes the obtained results. Discussion and managerial implications are given in Section 5 and finally Section 6 presents some concluding results.

2 Ranking problem of the branches of Sepah bank

As mentioned earlier, in this section the ranking problem of the branches of Sepah bank in Fars province of Iran is described. For this aim, based on the opinions of the managers, 20 branches from the same classification are considered to be evaluated and ranked. The branches of this bank are classified into three classifications e.g. Class 1, Class 2, and Class 3 where Class 1 contains top branches. According to the top managers of the bank, Class 1 branches from Shiraz city in Fars province are considered in this study. In order to respect the bank's rules and regulations, the exact titles of the branches are not published here. We just show them from B1 to B20 in the procedure of this paper.

In order to evaluate and rank the above-mentioned branches, a set of 14 criteria are considered. Based on the literature, these criteria are effective for performance of banking sector. So that, it is logical to evaluate overall performance of each bank branch and rank the branches by these criteria. We summarize these criteria in Table 1.

As there are 20 bank branches and 14 criteria detailed by Table 1, a decision matrix with 20 rows and 14 columns where each element includes the three-year data of the performance of its bank branch in its criterion. As a sample, the performance of the first branch in all criteria is represented by Table 2.

In order solve this problem and obtain a fair ranking of the branches, a mathematical model is introduced in next section.

3 Solution methodology

In this section a solution methodology is introduced to evaluate and rank the bank branches of the case study presented in Section 2. In order to evaluate alternatives under multiple evaluation criteria, there are generally two main steps e.g. (1) determining the importance weight of each criterion, and (2) determining the ranking of alternatives. In the first step, the importance weight values can be determined by methods such as the opinions obtained from experts of the field, the data of decision matrix, or combination of these methods. In the second step, the approaches such as TOPSIS (see Lai et al., [13]), ELECTRE (see Botti and Peypoch, [5]), SAW (see Niroomand et al., [19]), EDAS (see Keshavarz Ghorabaee et al., [11]), etc. can be used to obtain a suitable ranking of alternatives.

In this section we propose an integrated mathematical model to evaluate the criteria and the alternatives (bank branches) of the case study simultaneously. This model is applied instead of the two consecutive steps explained in the previous paragraph. In the proposed mathematical model, we hybridize the BWM (Rezaei, [21]) and SAW approach (Niroomand et al., [19]). The steps to introduce and implement the proposed mathematical model are described in continue.

Step 1. The last three years data for each bank branch in each criterion are considered. Here we use the notations y^1_{ij}, y^2_{ij}, and y^3_{ij} for the last three years data of bank branch i in criterion j where the number of bank branches and criteria are denoted by m and n respectively.

Step 2. The below geometric mean formula is applied to convert the three years data to single values data:

$$y_{ij} = \sqrt[3]{y^1_{ij} y^2_{ij} y^3_{ij}} \qquad i = 1,2,\ldots,m, \qquad j = 1,2,\ldots,n. \tag{1}$$

Here, y_{ij} is defined as the performance of bank branch i in criterion j.

Step 3. The decision matrix is normalized by the below formula:

$$y^n_{ij} = \frac{y_{ij} - min_i\{y_{ij}\}}{max_i\{y_{ij}\} - min_i\{y_{ij}\}} \qquad i = 1,2,\ldots,m, \qquad j = 1,2,\ldots,n, \tag{2}$$

$$y^n_{ij} = \frac{max_i\{y_{ij}\} - y_{ij}}{max_i\{y_{ij}\} - min_i\{y_{ij}\}} \qquad i = 1,2,\ldots,m, \qquad j = 1,2,\ldots,n. \tag{3}$$

Table 1: Details of the criteria considered for evaluating and ranking the bank branches

Criterion code	Criterion description	Type	References
C1	Total amount of deposits	Positive	[8]; [1]
C2	Total amount of loans	Positive	[8]; [1]
C3	Total amount of interest paid to the deposits	Negative	[15]; [9]
C4	Total amount of operational expenses	Negative	[15]; [9]
C5	Total amount of expenses	Negative	[4]; [27]
C6	Total amount of interest earned by the loans	Positive	[27]
C7	The amount of capital borrowed from the central branch of the bank	Negative	[22]; [4]
C8	Liquidity	Positive	[1]
C9	Total income from ATM machines	Positive	[22]; [4]
C10	Total income from POS machines	Positive	[22]; [9]
C11	Total number of electronic customers	Positive	[22]; [9]
C12	Total number of customers	Positive	[22]; [27]
C13	Total amount of bank guarantee	Positive	[4]; [27]
C14	Number of employees	Positive	[8]; [15]

In the above-mentioned equations, y_{ij}^n represents the normalized value of the performance of bank branch i in criterion j. Formula (2) is used for the positive criteria and formula (3) is used for the negative criteria.

Step 4. The below hybrid mathematical formulation is introduced which hybridizes the BWM and

Table 2: A part of the decision matrix for the first branch (B1)

Criteria	Last year	2 years ago	3 years ago	Criteria	Last year	2 years ago	3 years ago
C1	82934	74640.6	82934	C8	3.43	3.773	3.43
C2	27299	24569.1	27299	C9	50	55	60
C3	14496	15945.6	13046.4	C10	49	58.8	49
C4	9946	8951.4	11935.2	C11	1824	2189	2627
C5	24442	26886.2	21997.8	C12	8754	12256	17159
C6	2915	2623.5	2623.5	C13	154934	185920.8	170427.4
C7	333345	333345	400014	C14	35	35	36

SAW approaches:

$$\min \quad OF_1 = \xi^L \tag{4}$$

$$\max \quad OF_2 = \sum_{i=1}^{m} SC_i \tag{5}$$

s.t.

$$W_B - e_{Bj} W_j \leqslant \xi^L, \;\; j = 1,2,\ldots,n \tag{6}$$

$$W_B - e_{Bj} W_j \geqslant -\xi^L, \;\; j = 1,2,\ldots,n \tag{7}$$

$$W_j - e_{jw} W_W \leqslant \xi^L, \;\; j = 1,2,\ldots,n \tag{8}$$

$$W_j - e_{jw} W_W \geqslant -\xi^L, \;\; j = 1,2,\ldots,n \tag{9}$$

$$\sum_{j=1}^{n} W_j = 1, \tag{10}$$

$$SC_i = \sum_{j=1}^{n} y_{ij}^{n} W_j, \;\; i = 1,2,\ldots,m \tag{11}$$

$$\xi^L, W_j, SC_i \geqslant 0, \;\; i = 1,2,\ldots,m, \;\; j = 1,2,\ldots,n, \tag{12}$$

where

- B is the most important criterion and $W_B \in (0,1)$ is its weight value. Both parameters are determined by the experts in the field.
- W is the least important criterion and $W_W \in (0,1)$ is its weight value. Both parameters are determined by the experts in the field.
- e_{Bj} is the weight ratio of the most important criterion to criterion j. It is determined by the experts in the field.
- e_{jW} is the weight ratio of criterion j to the least important criterion. It is determined by the experts in the field.

- ξ^L is a continuous and non-negative variable in the procedure of the BWM approach.
- W_j is a continuous and non-negative variable which represents the importance weight value of criterion j.
- SC_i is a continuous and non-negative variable which calculates the overall score of bank branch i.
- Objective function (4) and constraints (6)-(9) and (12) perform the role of the BWM approach.
- Objective function (5) and constraints (10)-(12) perform the role of the SAW approach.

By solving this model, the importance weight of criteria and the scores of bank branches are determined simultaneously and are used to rank them.

Step 5. In this step an approach is introduced to obtain a Pareto-optimal solution of the bi-objective mathematical model of Step 4. For this aim the hybrid fuzzy programming approach proposed by Torabi and Hassini [26] is applied. This method is abbreviated as TH approach. For this aim we consider the index of $k \in \{1,2\}$ for the objective functions. For each objective function the positive ideal solution (POS_{OF_k}) and the negative ideal solution (NOS_{OF_k}) are obtained. For the minimization objective function POS_{OF_1} is obtained by solving the sub-model (4), (6)-(12). For the maximization objective function POS_{OF_2} is obtained by solving the sub-model (5), (6)-(12). Then, the following membership functions are obtained for the first and second objective functions:

$$\mu(OF_1) = \frac{NOS_{OF_1} - OF_1}{NOS_{OF_1} - POS_{OF_1}}, \tag{13}$$

$$\mu(OF_2) = \frac{OF_2 - NOS_{OF_2}}{POS_{OF_2} - NOS_{OF_2}}. \tag{14}$$

Based on the above-defined membership functions, the below single-objective model is solved to obtain a Pareto-optimal solution for the bi-objective model (4)-(12):

$$\max \quad \gamma\lambda_0 + (1-\gamma)\sum_{k=1}^{2} \theta_{OF_k}\, \mu(OF_k) \tag{15}$$

s.t.

$$\lambda_0 \leqslant \mu(OF_k),\ k = 1,2, \tag{16}$$

$$0 \leqslant \lambda_0 \leqslant 1 \tag{17}$$

$$W_B - e_{Bj}W_j \leqslant \xi^L,\ j = 1,2,\ldots,n \tag{18}$$

$$W_B - e_{Bj}W_j \geqslant -\xi^L,\ j = 1,2,\ldots,n \tag{19}$$

$$W_j - e_{jW}W_W \leqslant \xi^L,\ j = 1,2,\ldots,n \tag{20}$$

$$W_j - e_{jW}W_W \geqslant -\xi^L,\ j = 1,2,\ldots,n \tag{21}$$

$$\sum_{j=1}^{n} W_j = 1, \tag{22}$$

$$SC_i = \sum_{j=1}^{n} y_{ij}^n W_j,\ i = 1,2,\ldots,m \tag{23}$$

$$\xi^L, W_j, SC_i \geqslant 0,\ i = 1,2,...,m,\ j = 1,2,...,n \tag{24}$$

In the above model $\theta_{OF_k} \in (0,1)$ is the importance weight of objective function k, where $\sum_{k=1}^{2} \theta_{OF_k} = 1$. In addition, γ and λ_0 are the parameter and variable of the TH approach respectively (for more details see Torabi and Hassini [26]). Based on the literature, the value of γ is from the interval $(0,1)$ and is set to 0.4.

Step 6. As a result of Step 5, a score value for each bank branch is obtained (say SC_i is the score of bank branch$i$). Finally, the bank branches are ranked according to the decreasing order of the obtained SC_i values.

As the proposed solution methodology of this section is based on the bi-objective mathematical formulation (4)-(12), some characteristics and strengths of this mathematical model are described below:

• This bi-objective mathematical formulation hybridizes the BWM and SAW approaches.

• According to basic approaches used in the proposed objective mathematical formulation, the importance weight values of the criteria are determined by combination of experts' opinions and decision matrix data. This is an important advantage of this model that can provide a fair set of weight values for the criteria.

• In addition, when solving the model, an interactive approach is considered where the opinions of the decision makers also is considered to prioritize the objective functions.

4 Computational experiments and results

In this section, the case study of Section 2 is evaluated by the solution methodology proposed in Section 3. For this aim, the mathematical models of the proposed solution methodology are coded in GAMS and solved by its CPLEX solver. All required runs are executed on a PC with Core i7-1165G7 (2.80GHz) processor and 16 GB RAM.

In order to obtain the ranking results of the case study, according to Step 2 of the proposed solution methodology, the three years data of the decision matrix is converted to a single data decision matrix. By applying this step on the decision matrix, the results of Tables 3, 4 are obtained.

In the sequel, according to Step 3 of the proposed solution approach, the decision matrix of Tables 3, 4 is normalized. For this aim, the equations (2) and (3) are applied. Applying these equations for the data of Tables 3, 4 results in the normalized decision matrix of Tables 5, 6.

In order to rank the bank branches of the case study according to the normalized decision matrix of Table 4, the information of Table 5 is obtained from the experts of the case study. The method to obtain information of Table 7 is brainstorming method which is applied by a team of five experts from the top managers of the bank in Fars province. The data given in this table is related to the BWM part of the proposed formulation.

Now, in order to perform final experiments and obtain ranking of the bank branches, according to the coefficient parameters of the formulation (15)-(24), the experiments of Table 8 are defined. In these experiments the experts' opinions are considered, and the results of these experiments can be used for further sensitivity analysis of the parameters of the proposed solution methodology.

For each experiment of Table 8, Step 5 of the proposed solution methodology is performed by considering the normalized decision matrix of Tables 5, 6 and data of Table 7. For each experiment, the

Table 3: The single data decision matrix obtained for the case study1

Branch	C1	C2	C3	C4	C5	C6	C7
B1	80071.9	26356.9	14447.5	10204.5	24360.3	2717.3	354231.9
B2	76650.2	19304.5	12773.4	4708.2	15331.8	2037.1	312498.0
B3	427139.3	557894.3	36124.8	41058.2	109916.2	79212.8	510154.9
B4	104404.2	17766.4	7708.1	8091.2	15896.5	979.0	298203.5
B5	355312.1	1827209.9	97833.0	35590.4	323671.6	258182.0	850543.1
B6	138682.9	298107.0	13635.1	19658.6	69085.3	41037.3	497401.8
B7	59120.3	11147.6	4679.9	6387.0	10690.3	795.0	316521.0
B8	434470.2	573558.8	80201.9	29920.5	139384.0	76490.9	668212.5
B9	101318.0	16290.7	22977.0	6358.2	28298.7	1493.8	327241.0
B10	496524.7	856248.5	52693.2	29585.7	141734.0	103739.0	334916.1
B11	69047.6	24610.1	2631.9	6712.2	7717.9	3698.3	305868.0
B12	227833.4	111015.2	7686.2	18529.2	25689.3	16437.3	330840.2
B13	147098.1	142000.5	3538.9	12222.0	16593.9	12595.7	324540.6
B14	143778.5	61634.7	8459.8	10453.8	19040.2	6210.2	258868.3
B15	69005.3	15053.7	2043.0	6683.1	7467.8	1047.8	324455.9
B16	210501.2	204267.6	10627.3	12539.9	24945.9	20794.1	322562.6
B17	87038.7	39449.1	4131.0	5437.3	10550.2	2227.0	328138.4
B18	103637.9	149609.2	9287.0	5498.6	20418.3	17137.8	387790.5
B19	339273.1	306082.1	39164.8	15486.4	50563.6	41191.8	392072.1
B20	109209.1	69405.7	6223.6	8966.0	13472.9	5404.0	337174.5

obtained results could be presented in terms of optimal criteria weights, score of each bank branch, and ranking of each bank branch. The obtained results are summarized by Table 9, Table 10, and Tables 11, 12.

Table 9 reports the criteria weight values obtained by the experiments of Table 8. The values of this table also are schematically represented by Figure 1 and average of the weight values for the criteria are schematically represented by Figure 2. According to the values of this table, in general, the experiments affect the obtained weight values although in some cases, a pair of experiments result in the same set of important weight values. For example, experiments 2, 3, 5, 6, 8, and 9 obtain the same set of weight values, and experiments 1, 4, and 7 obtain similar set of weight values. For more comparison, the marginal mean values of the importance weight values of Table 8 are calculated and reported by Table

Table 4: The single data decision matrix obtained for the case study2

Branch	C8	C9	C10	C11	C12	C13	C14
B1	3.5	54.8	52.1	2189.0	12256.0	169956.6	35.3
B2	5.1	15.4	45.0	3296.4	9771.5	12189.4	40.7
B3	0.8	13.8	52.2	5054.7	15265.4	9433.3	34.0
B4	6.2	28.7	34.3	2188.0	8790.3	872.1	30.7
B5	0.2	57.5	37.4	2418.9	15276.0	6467.3	34.0
B6	0.5	65.1	31.0	2902.9	14700.0	756.9	31.3
B7	4.1	34.1	34.9	1097.1	8589.0	11675.8	34.0
B8	0.6	71.9	38.2	1863.3	11822.0	39629.8	31.7
B9	7.7	48.3	54.4	2577.9	9799.3	506.0	34.0
B10	0.7	36.9	40.3	1556.9	7505.4	4451.2	40.0
B11	2.1	39.0	28.0	3814.6	13709.3	10233.0	37.0
B12	1.7	63.2	27.8	2339.8	9407.6	1351.0	31.3
B13	1.0	97.7	27.8	2385.3	11244.9	6523.8	35.0
B14	1.9	29.8	39.9	1497.8	12606.6	8734.7	37.0
B15	2.8	58.5	23.2	2579.0	8817.8	2924.5	38.0
B16	1.0	11.7	49.3	1388.9	7530.1	193337.2	37.0
B17	2.2	46.4	36.4	2617.9	7969.1	11000.8	33.7
B18	0.7	55.7	36.2	1757.3	7020.5	1171.1	34.0
B19	1.0	34.3	26.9	1316.6	8347.1	32713.0	32.0
B20	1.4	46.0	49.1	2093.1	6768.0	285724.9	37.0

9. From this table, the sensitivity of obtained weight values to the changes in the parameter's values can be distinguished. According to the results of this table, the considered values for γ, have the same performance (changing the value of γ, does not affect the importance weight values), but changing the values of θ_{OF_1} and θ_{OF_2}, affect the obtained importance weight values. What can be said here is that the most important criterion in all experiments is C5 (total amount of expenses).

At the same time, for each experiment we obtain a set of score values for the bank branches which are used to rank the branches. These results for all experiments are shown by Tables 11, 12 . For each experiment, the score values of the branches and their associated rankings are represented. According to the values of this table, in general, the experiments affect the obtained score values although in some cases, a pair of experiments result in the same set of values. For example, experiments 2, 3, 5, 6, 8, and 9

Table 5: The normalized decision matrix obtained for the case study1

Branch	C1	C2	C3	C4	C5	C6	C7
B1	0.0479	0.0084	0.8705	0.8488	0.9466	0.0075	0.8388
B2	0.0401	0.0045	0.8880	1.0000	0.9751	0.0048	0.0906
B3	0.8414	0.3011	0.6442	0.0000	0.6760	0.3047	0.4247
B4	0.1035	0.0036	0.9409	0.9069	0.9733	0.0007	0.0665
B5	0.6772	1.0000	0.0000	0.1504	0.0000	1.0000	1.0000
B6	0.1819	0.1580	0.8790	0.5887	0.8051	0.1563	0.4031
B7	0.0000	0.0000	0.9725	0.9538	0.9898	0.0000	0.0974
B8	0.8581	0.3097	0.1841	0.3064	0.5828	0.2941	0.6918
B9	0.0965	0.0028	0.7815	0.9546	0.9341	0.0027	0.1156
B10	1.0000	0.4653	0.4712	0.3156	0.5754	0.4000	0.1285
B11	0.0227	0.0074	0.9939	0.9449	0.9992	0.0113	0.0794
B12	0.3857	0.0550	0.9411	0.6198	0.9424	0.0608	0.1216
B13	0.2011	0.0721	0.9844	0.7933	0.9711	0.0458	0.1110
B14	0.1935	0.0278	0.9330	0.8419	0.9634	0.0210	0.0000
B15	0.0226	0.0022	1.0000	0.9457	1.0000	0.0010	0.1109
B16	0.3461	0.1063	0.9104	0.7845	0.9447	0.0777	0.1077
B17	0.0638	0.0156	0.9782	0.9799	0.9903	0.0056	0.1171
B18	0.1018	0.0762	0.9244	0.9783	0.9590	0.0635	0.2179
B19	0.6405	0.1624	0.6125	0.7035	0.8637	0.1569	0.2251
B20	0.1145	0.0321	0.9564	0.8829	0.9810	0.0179	0.1323

obtain the same set of score values and rankings, and experiments 1, 4, and 7 obtain similar set of score values and rankings. According to the results of Tables 11, 12, B1 is the best branch where it obtains the first ranking in all experiments.

This should be noted that from the formulation (15)-(24) we can expect that changes in the value of γ could have minor changes in the obtained results. This could be because of constraint (16) where the value of λ_0 is determined as the minimum value among the membership function values of the objective functions. On the other hand, the objective function value with greater importance weight (θ_{OF_k}) may influence the integrated objective function (15) more. Therefore, as we see from the results, the changes in the value of γ has less effect on the obtained results compared to the changes in the values of θ_{OF_k}.

For further comparison of the obtained rankings of Tables 11, 12, we apply Jaccard Similarity Index

Table 6: The normalized decision matrix obtained for the case study2

Branch	C8	C9	C10	C11	C12	C13	C14
B1	0.4459	0.5020	0.9261	0.2759	0.6450	0.5941	0.4672
B2	0.6476	0.0441	0.6995	0.5557	0.3530	0.0410	1.0000
B3	0.0772	0.0251	0.9307	1.0000	0.9988	0.0313	0.3344
B4	0.8057	0.1985	0.3581	0.2756	0.2377	0.0013	0.0000
B5	0.0000	0.5323	0.4551	0.3340	1.0000	0.0209	0.3344
B6	0.0395	0.6213	0.2516	0.4563	0.9323	0.0009	0.0677
B7	0.5236	0.2604	0.3753	0.0000	0.2140	0.0392	0.3344
B8	0.0574	0.6999	0.4822	0.1936	0.5940	0.1372	0.1010
B9	1.0000	0.4264	1.0000	0.3742	0.3563	0.0000	0.3344
B10	0.0732	0.2932	0.5476	0.1162	0.0867	0.0138	0.9337
B11	0.2579	0.3177	0.1536	0.6867	0.8159	0.0341	0.6340
B12	0.2049	0.5996	0.1480	0.3140	0.3103	0.0030	0.0666
B13	0.1017	1.0000	0.1499	0.3255	0.5262	0.0211	0.4343
B14	0.2300	0.2104	0.5366	0.1013	0.6862	0.0289	0.6340
B15	0.3406	0.5443	0.0000	0.3745	0.2409	0.0085	0.7339
B16	0.1055	0.0000	0.8381	0.0737	0.0896	0.6761	0.6340
B17	0.2647	0.4034	0.4225	0.3843	0.1412	0.0368	0.3007
B18	0.0657	0.5124	0.4176	0.1668	0.0297	0.0023	0.3344
B19	0.1039	0.2638	0.1198	0.0555	0.1856	0.1129	0.1314
B20	0.1610	0.3992	0.8316	0.2517	0.0000	1.0000	0.6340

(JSI) (see Niroomand et al. [18]). This value takes a value between 0 and 1 for a pair of rankings. Its higher values for a pair or rankings show more similarity of them. The JSI values of the rankings of Tables 11, 12 are calculated and reported by Table 13. According to these values the least JSI value is 0.63 and the highest one is 1.

As a comparison study, the normalized decision matrix of the case study (Table 4) is used to implement the BWM and SAW approaches separately and consecutively. In order to apply BWM, we considered the same evaluations from Table 5. Therefore, the importance weight values of Table 14 are obtained. After that, applying the SAW approach, the scores and rankings of Table 15 are obtained.

According to the results of Tables 14 and 15, similar to the results obtained by the proposed approach, the most important criterion is C5 and the best performed branch is B1.

Table 7: Evaluation of the criteria according to the experts' opinions

Criterion (j)	W_B	W_W	e_{Bj}	e_{jW}
C1			1.0322	2.2682
C2			1.0434	2.2439
C3			1.0786	2.1707
C4			1.2307	1.9024
C5	0.0956		1	2.3414
C6			1.0001	2.3414
C7			1.2973	1.8048
C8			1.4328	1.6341
B9			1.7454	1.3414
B10			1.9200	1.2195
B11			1.7454	1.3414
B12			1.5000	1.5609
B13		0.0408	2.3414	1
B14			1.7777	1.3170

Table 8: Details of the experiments designed to rank the bank branches of the case study

Experiment	γ	θ_{OF_1}	θ_{OF_2}
Exp1	0.1	0.2	0.8
Exp2	0.1	0.5	0.5
Exp3	0.1	0.8	0.2
Exp4	0.4	0.2	0.8
Exp5	0.4	0.5	0.5
Exp6	0.4	0.8	0.2
Exp7	0.8	0.2	0.8
Exp8	0.8	0.5	0.5
Exp9	0.8	0.8	0.2

Table 9: The optimal importance weight values obtained by the experiments

	Marginal means of the weight values								
Criterion	Exp1	Exp2	Exp3	Exp4	Exp5	Exp6	Exp7	Exp8	Exp9
C1	0.078	0.093	0.093	0.078	0.093	0.093	0.078	0.093	0.093
C2	0.041	0.092	0.092	0.041	0.092	0.092	0.041	0.092	0.092
C3	0.096	0.089	0.089	0.096	0.089	0.089	0.096	0.089	0.089
C4	0.096	0.078	0.078	0.096	0.078	0.078	0.096	0.078	0.078
C5	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096
C6	0.041	0.096	0.096	0.041	0.096	0.096	0.041	0.096	0.096
C7	0.041	0.074	0.074	0.041	0.074	0.074	0.041	0.074	0.074
C8	0.041	0.067	0.067	0.041	0.067	0.067	0.041	0.067	0.067
C9	0.086	0.055	0.055	0.086	0.055	0.055	0.086	0.055	0.055
C10	0.078	0.050	0.050	0.078	0.050	0.050	0.078	0.050	0.050
C11	0.086	0.055	0.055	0.086	0.055	0.055	0.086	0.055	0.055
C12	0.096	0.064	0.064	0.096	0.064	0.064	0.096	0.064	0.064
C13	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
C14	0.085	0.054	0.054	0.085	0.054	0.054	0.085	0.054	0.054

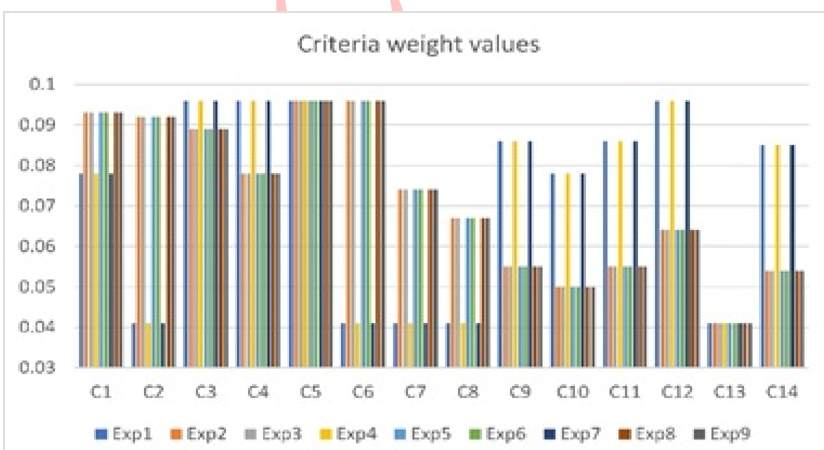

Figure 1: The optimal importance weight values obtained by the experiments

5 Discussion and managerial implications

Based on the integration of BWM and SAW in this study, the selection of C5 (which is total amount of expenses) as the most important criterion is logical and also managerially insightful. In today's com-

Table 10: The marginal means of the weight values for different values of the parameters

	μ			θ_{OF_1}			θ_{OF_2}		
Criterion	0.1	0.4	0.8	0.2	0.5	0.8	0.2	0.5	0.8
C1	0.088	0.088	0.088	0.078	0.093	0.093	0.093	0.093	0.078
C2	0.075	0.075	0.075	0.041	0.092	0.092	0.092	0.092	0.041
C3	0.091	0.091	0.091	0.096	0.089	0.089	0.089	0.089	0.096
C4	0.084	0.084	0.084	0.096	0.078	0.078	0.078	0.078	0.096
C5	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096
C6	0.078	0.078	0.078	0.041	0.096	0.096	0.096	0.096	0.041
C7	0.063	0.063	0.063	0.041	0.074	0.074	0.074	0.074	0.041
C8	0.058	0.058	0.058	0.041	0.067	0.067	0.067	0.067	0.041
C9	0.065	0.065	0.065	0.086	0.055	0.055	0.055	0.055	0.086
C10	0.059	0.059	0.059	0.078	0.050	0.050	0.050	0.050	0.078
C11	0.065	0.065	0.065	0.086	0.055	0.055	0.055	0.055	0.086
C12	0.075	0.075	0.075	0.096	0.064	0.064	0.064	0.064	0.096
C13	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
C14	0.064	0.064	0.064	0.085	0.054	0.054	0.054	0.054	0.085

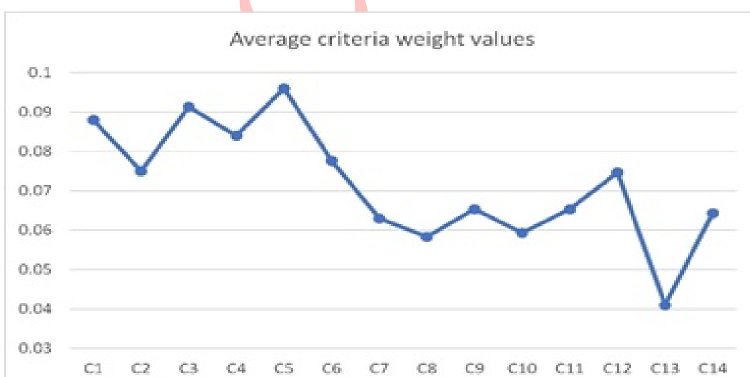

Figure 2: Average of the weight values for the criteria

petitive banking environment, operational efficiency and cost discipline are preferable determinants of sustainable profitability. This criterion directly determines a branch's operational reserve and its ability to manage resources in an effective way. By prioritizing C5, the proposed model aligns with a core financial essential such as minimizing operational waste to maximize net revenue and ensure long-term viability. Its domination over other potential criteria considered in this study says that, in the evaluated context,

Table 11: The optimal scores and rankings (RK) of the bank branches obtained by the experiments1

	*Exp*1		*Exp*2		*Exp*3		*Exp*4		*Exp*5	
Branch	SC_i	RK	SC_i	RK	SC_i	RK	SC_i	RK	SC_i	RK
B1	0.577	1	0.510	1	0.510	1	0.577	1	0.510	1
B2	0.534	2	0.450	5	0.450	5	0.534	2	0.450	5
B3	0.523	11	0.478	3	0.478	3	0.523	11	0.478	3
B4	0.405	3	0.375	9	0.375	9	0.405	3	0.375	9
B5	0.425	9	0.488	2	0.488	2	0.425	9	0.488	2
B6	0.470	20	0.414	20	0.414	20	0.470	20	0.414	20
B7	0.406	13	0.363	11	0.363	11	0.406	13	0.363	11
B8	0.411	14	0.409	13	0.409	13	0.411	14	0.409	13
B9	0.518	6	0.452	10	0.452	10	0.518	6	0.452	10
B10	0.418	15	0.415	6	0.415	6	0.418	15	0.415	6
B11	0.529	16	0.434	8	0.434	8	0.529	16	0.434	8
B12	0.413	17	0.372	16	0.372	16	0.413	17	0.372	16
B13	0.506	5	0.424	14	0.424	14	0.506	5	0.424	14
B14	0.478	18	0.401	15	0.401	15	0.478	18	0.401	15
B15	0.467	10	0.397	17	0.397	17	0.467	10	0.397	17
B16	0.457	12	0.409	4	0.409	4	0.457	12	0.409	4
B17	0.445	8	0.383	12	0.383	12	0.445	8	0.383	12
B18	0.421	7	0.371	18	0.371	18	0.421	7	0.371	18
B19	0.355	4	0.351	7	0.351	7	0.355	4	0.351	7
B20	0.508	19	0.435	19	0.435	19	0.508	19	0.435	19

cost evolvement is a more decisive factor for overall branch performance compared to revenue generation, emphasizing that financial health is basically driven by fiscal control. Furthermore, the top ranking obtained for branch B1 is a direct outcome of its performance on this crucial metric. This branch has demonstrably achieved the optimal balance by performing effective banking operations while incurring low relative expenses, therewith exhibiting good cost efficiency.

The managerial implications of this study are twofold. First, bank leadership should formally recognize and broadcast the best operational practices of the top branches. They can conduct a detailed process analysis to create benchmarks for other branches. Second, the bank should restructure its performance evaluation and incentive systems to place greater emphasis on expense management, while still

Table 12: The optimal scores and rankings (RK) of the bank branches obtained by the experiments2

	*Exp*6		*Exp*7		*Exp*8		*Exp*9	
Branch	SC_i	RK	SC_i	RK	SC_i	RK	SC_i	RK
B1	0.510	1	0.577	1	0.510	1	0.510	1
B2	0.450	5	0.534	2	0.450	5	0.450	5
B3	0.478	3	0.523	11	0.478	3	0.478	3
B4	0.375	9	0.405	3	0.375	9	0.375	9
B5	0.488	2	0.425	9	0.488	2	0.488	2
B6	0.414	20	0.470	20	0.414	20	0.414	20
B7	0.363	11	0.406	13	0.363	11	0.363	11
B8	0.409	13	0.411	14	0.409	13	0.409	13
B9	0.452	10	0.518	6	0.452	10	0.452	10
B10	0.415	6	0.418	15	0.415	6	0.415	6
B11	0.434	8	0.529	16	0.434	8	0.434	8
B12	0.372	16	0.413	17	0.372	16	0.372	16
B13	0.424	14	0.506	5	0.424	14	0.424	14
B14	0.401	15	0.478	18	0.401	15	0.401	15
B15	0.397	17	0.467	10	0.397	17	0.397	17
B16	0.409	4	0.457	12	0.409	4	0.409	4
B17	0.383	12	0.445	8	0.383	12	0.383	12
B18	0.371	18	0.421	7	0.371	18	0.371	18
B19	0.351	7	0.355	4	0.351	7	0.351	7
B20	0.435	19	0.508	19	0.435	19	0.435	19

maintaining a balanced focus on service quality and growth objectives. This shift can direct all branches to a more sustainable operational model, and transform the insight from the proposed hybrid model of this study into a strategic tool for enhanced organizational-wide financial performance in banking sector.

6 Concluding remarks

In this study a hybrid mathematical model was introduced to simultaneously evaluate the criteria and the alternatives for the multi-criteria ranking problem of the branches of Sepah bank in Fars province of Iran. According to the literature, a more complete set of criteria were considered to evaluate and rank

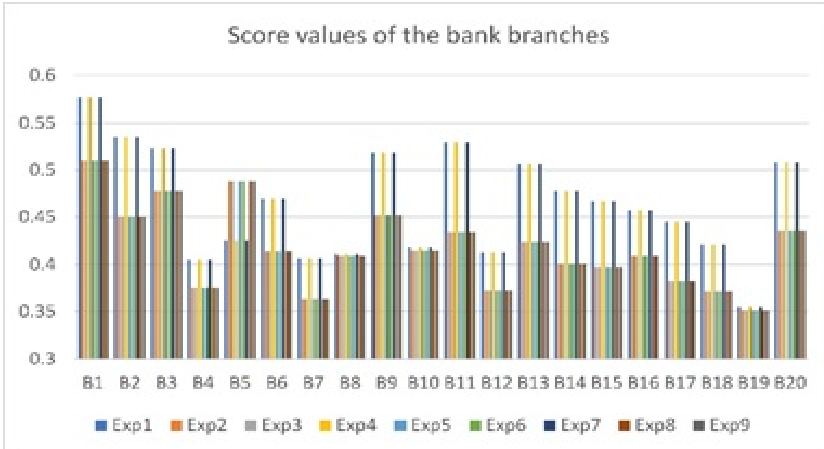

Figure 3: Score values of the bank branches

Table 13: The JSI values of the rankings obtained by the experiments

	*Exp*2	*Exp*3	*Exp*4	*Exp*5	*Exp*6	*Exp*7	*Exp*8	*Exp*9
*Exp*1	0.63	0.63	1	0.63	0.63	1	0.63	0.63
*Exp*2		1	0.63	1	1	0.63	1	1
*Exp*3			0.63	1	1	0.63	1	1
*Exp*4				0.63	0.63	1	0.63	0.63
*Exp*5					1	0.63	1	1
*Exp*6						0.63	1	1
*Exp*7							0.63	0.63
*Exp*8								1

the bank branches. The data for the last three years of the branches in the criteria were considered to evaluate and rank them. In order to solve the problem, a bi-objective mathematical model was developed for simultaneously evaluation of the criteria and the bank branches. In this model, for the first time BWM and SAW were integrated. In order to solve the proposed bi-objective model, a modification of the fuzzy programming approach called TH approach was applied. The problem and its mathematical formulation caused some important limitations such as dealing with multiple criteria and also dealing with multiple objective models. Based on the nature of the proposed model and the solution approach and their parameters, several experiments were designed and their results were used for sensitivity analysis purposes. As a result, the proposed model and solution approach were highly sensitive to the parameters of the solution approach. Also it is notable to mention that criterion "C5: total amount of expenses" obtained the highest importance weight in all experiments and the branch B1 was selected as the best branch.

Table 14: The importance weight values obtained by the classical BWM approach.

Criterion	**The importance weight values**
C1	0.093
C2	0.092
C3	0.089
C4	0.078
C5	0.096
C6	0.096
C7	0.074
C8	0.067
C9	0.055
C10	0.050
C11	0.055
C12	0.064
C13	0.041
C14	0.054

References

[1] M. Aghaei, A. Asadollahi, A. Pakari, *Ranking of Saman bank's branches in Tehran on the basis of customer satisfaction factors by F.M.C.D.M models*, Int. J. Sci. Manag. Dev. **1** (2013) 46–61.

[2] B. Alidade, M. Ghasemi, *Ranking the branches of bank Sepah of Sistan Baluchistan using balanced score card and fuzzy multi-attribute decision-making methods*, Res. J. Recent Sci. **4** (2015) 17–24.

[3] M.A. Beheshtinia, S. Omidi, *A hybrid MCDM approach for performance evaluation in the banking industry*, Kybernetes **46** (2017) 1386–1407.

[4] A. Bičo, M. Ganić, *The efficiency of banking sector in Bosnia and Herzegovina in comparison to Slovenia: comparative analysis*, J. Econ. Soc. Stud. **2** (2012) 125–149.

[5] L. Botti, N. Peypoch, *Multi-criteria ELECTRE method and destination competitiveness*, Tour. Manag. Perspect. **6** (2013) 108–113.

[6] S. Contreras, M.D. Delis, A. Ghosh, I. Hasan, *Bank failures, local business dynamics, and government policy*, Small Bus. Econ. **58** (2022) 1823–1851.

[7] K. Elitcha, *The moderating role of stock markets in the bank competition–entrepreneurship relationship*, Small Bus. Econ. **56** (2021) 1333–1360.

Table 15: The score values and rankings obtained by the classical SAW approach.

Branch	SC_i	**RK**
B1	0.512	1
B2	0.451	5
B3	0.480	3
B4	0.376	16
B5	0.490	2
B6	0.415	10
B7	0.364	19
B8	0.410	12
B9	0.453	4
B10	0.416	9
B11	0.435	7
B12	0.373	17
B13	0.425	8
B14	0.402	13
B15	0.398	14
B16	0.411	11
B17	0.384	15
B18	0.372	18
B19	0.352	20
B20	0.436	6

[8] F. Garcia, F. Guijarro, I. Moya, *Ranking Spanish savings banks: A multicriteria approach*, Math. Comput. Model. **52** (2010) 1058–1065.

[9] B. Gavurova, J. Belas, K. Kocisova, T. Kliestik, *Comparison of selected methods for performance evaluation of Czech and Slovak commercial banks*, J. Bus. Econ. Manag. **18** (2017) 852–876.

[10] A. Kazemi, J. Mousavi, *Ranking Iranian private banks using multi-criteria decision-making methods*, J. Quant. Res. Manag. **3** (2013) 121–140.

[11] M. Keshavarz Ghorabaee, E.K. Zavadskas, L. Olfat, Z. Turskis, *Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS)*, Informatica **26** (2015) 435–451.

[12] M. Kumbirai, R. Webb, *A financial ratio analysis of commercial bank performance in South Africa*, Afr. Rev. Econ. Financ. **2** (2010) 30–53.

[13] Y.J. Lai, T.Y. Liu, C.L. Hwang, *TOPSIS for MODM*, Eur. J. Oper. Res. **76** (1994) 486–500.

[14] A. Mahmudi, H. Bagherlou, *Ranking the bank stock with multi-criteria decision-making method*, 3rd Iran. Manag. Account. Conf., Tehran University, 2014.

[15] A.R. Motameni, M. Javadzadeh, M. Tizfahm, *The strategy performance evaluation of the banks*, J. Strateg. Manag. Stud. **1** (2010) 141–159.

[16] A. Miglo, *Crowdfunding and bank financing: substitutes or complements?*, Small Bus. Econ. **59** (2022) 1115–1142.

[17] S. Niroomand, A. Bazyar, M. Alborzi, H. Miami, A. Mahmoodirad, *A hybrid approach for multi-criteria emergency center location problem considering existing emergency centers with interval type data: a case study*, J. Ambient Intell. Humaniz. Comput. **9** (2018) 1999–2008.

[18] S. Niroomand, N. Mirzaei, A. Hadi–Vencheh, *A simple mathematical programming model for countries' credit ranking problem*, Int. J. Finance Econ. **24** (2019) 449–460.

[19] S. Niroomand, S. Mosallaeipour, A. Mahmoodirad, *A hybrid simple additive weighting approach for constrained multicriteria facilities location problem of glass production industries under uncertainty*, IEEE Trans. Eng. Manag. **67** (2019) 846–854.

[20] E. Rasoulinejad, *Ranking of selected branches of Bank Saderat in Tehran using the integrated model DEAHP and ANP*, M.A. Thesis in Industrial Management, University of Tehran, Tehran, Iran, 2009 (in Persian).

[21] J. Rezaei, *Best–worst multi-criteria decision-making method*, Omega **53** (2015) 49–57.

[22] R.M. Said, M.H. Tumin, *Performance and financial ratios of commercial banks in Malaysia and China*, Int. Rev. Bus. Res. Pap. **7** (2011) 157–169.

[23] N. Secme, A. Bayrakdaroglu, C. Kahraman, *Fuzzy performance evaluation in Turkish banking sector using Analytic Hierarchy Process and TOPSIS*, Expert Syst. Appl. **36** (2009) 11699–11709.

[24] S.A. Seyfi-Shishavan, F. Kutlu Gündoğdu, E. Farrokhizadeh, *An assessment of the banking industry performance based on intuitionistic fuzzy Best–Worst Method and fuzzy inference system*, Appl. Soft Comput. **113** (2021) 107990.

[25] H. Shahbandarzadeh, *Design the method evaluated the performance bank branches by using multi-criteria decision-making techniques*, Doctoral Dissertation, University of Tehran, Tehran, Iran, 2006.

[26] S.A. Torabi, E. Hassini, *An interactive possibilistic programming approach for multiple objective supply chain master planning*, Fuzzy Sets Syst. **159** (2008) 193–214.

[27] P. Wanke, M.A.K. Azad, C.P. Barros, *Efficiency factors in OECD banks: A ten-year analysis*, Expert Syst. Appl. **64** (2016) 208–227.