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Research Article

A Comparative Study on Performance Measurement of Decision-Making Units: A Case Study in Iranian Tejarat Banks

M. Hasannezhad[1] and S. E. Hosseini[2]

[1] *Industrial Engineering Department, Mazandaran University of Science & Technology, Babol, P.O. Box 734, Iran*
[2] *Lecturer of Management group, Tehran municipality, Tehran, Iran*

Correspondence should be addressed to M. Hasannezhad, hasannezhad.mo@gmail.com

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Nowadays, vicissitude in administrative systems through Performance Measurement (PM) is one of the necessary and inevitable subjects, on which the improvement of efficiency and effectiveness in banking systems depend greatly. In this paper, we focused on efficiency analysis of Tejarat bank branches in order to propose the corrective actions on utilizing resources. Hence, we compute the efficiencies of units based on input-oriented CCR model with three approaches which differ on combination method of inputs and outputs and then rank them by Anderson & Peterson (AP) model. The results represent that the CCR model based on confined fuzzy weights presents the high level of accuracy in identifying efficient units as well as giving useful information on improving the inefficient branches.

1. Introduction

Performance measurement is the process that allows organizations to prevent principal problems before occurrence. So, PM can predicate as a major control mechanism for organization strategies by providing information on coordination of units with plans. The present PM methods of banks consist of financial ratios, which lead to various results because of the heterogeneity of standards. Hence, recently the new techniques have recommended for PM of banks that one of the most frequently used methods is Data Envelopment Analysis (DEA). DEA is a nonparametric mathematical programming technique that was introduced based on Farrell's pioneering work, aiming at the measurement of Decision Making Units' (DMUs) relative efficiencies [1]. In DEA models, improvement way is to reach the efficiency frontier, which is composed of reference units and virtual one. The main purpose of DEA is to evaluate a number of similar units with different inputs and outputs, for instance, banks, schools, hospitals, refineries, power plants, and so forth. There are several features for DEA such as realistic and geminate evaluation for the set of ingredients, ability of auto-compensation that determine the benchmark unit and determine strategies to improve the performance. In recent years, the fuzzy sets theory has been proposed as a method of quantifying uncertain data in DEA models. The theory of fuzzy sets makes possible for linguistic data to apply directly in DEA models. Also, fuzzy DEA model is a form of fuzzy linear programming models.

In this paper, we utilize the input-oriented CCR model in order to evaluate the efficiency of Tejarat bank branches by three approaches, which differ on combination type of inputs and outputs according to expert opinions. So, we use the mixed fuzzy approach of Analytic Hierarchy Process (AHP) and CCR model consisting two stages; first, the paired comparisons matrix begets from performing the CCR multiplier model for each unit and then, the final ranking will be done by solving an AHP model. In other words, in this model the paired comparisons have been done by DEA and the final ranking by AHP model.

This paper is organized as follows: next section, Section 2, is related to overview of DEA literature, Section 3 describes the preliminary of basic subjects, Section 4 includes research methodology, in Section 5 the different approaches of CCR model have solved to get the efficiency of units, analysis of results have presented in Section 6, and paper concluded in Section 7.

2. Literature Review on DEA

The first utilization of nonparametric methods for PM was presented in 1957 with the publication of an article by Farrell [2]. After that, Charnes et al. introduced the basic model of DEA called CCR as a radial model through their original paper [3] and proposed that the efficiency of a DMU can be obtained as the maximum ratio of weighted outputs to weighted inputs, subject to the condition that the same ratio for all DMUs must be less than or equal to one. An important feature of this radial model is that Technical Efficiency (TE) is measured by an efficiency score in objective function of the linear programming formulation in basic DEA model. Technical efficiency of a production unit indicates the maximum potential of output based on given inputs, considering physical production relationship [4, 5]. DEA developments can be related to its successful applications in several areas such as economic efficiency [6], environmental factors [7], mathematical model for measuring efficiency [8], performance management [9], performance and productivity assessment of health centers [10], and productive efficiency in manufacturing [11]. Furthermore, in last two decades DEA has been used greatly for measuring the performance of banks. For example, Sherman and Landiino used DEA technique for efficient management of a bank by studying 80 branches in a year [12]. Also, Parkan utilized DEA on measuring the performance of service operation in a bank with 35 branches in Calgary [13]. Other researches in this area include the study of Golany and Storbeck in six 3-month period in America [14] and sensitivity analysis of bank efficiency in Hong Kong's banking system by Drake et al. [15]. Due to the complexity computation of DEA, several special software products have been developed [16].

3. Preliminary

3.1. Modified Input-Oriented CCR Model

In initial DEA model, according the optimum condition model can allot zero weight to some inputs or outputs. It means the useless of related parameter in evaluation and thus meaningful skew exists in results. This problem is highlighted specially by assigning zero weight to more important factors in model. Avoiding this defect, Charnes et al. assigned the positive lower bound like $\varepsilon(\varepsilon > 0)$ for all important weights [17]. These lower bounds of inputs or outputs prevent from assigning zero weight to factors and so consider all data in evaluation, but it should be mentioned that existence of this lower bound lead to the feasible solutions for various DEA models and ensures the feasibility of linear programming problem [18]. Both of technical and scale efficiencies are considered through CCR model by means of optimal value. If we use DEA model with independent inputs and outputs in order to achieve the efficiency frontier, we call it input-oriented method. The modified input-oriented CCR model follows as below [19]:

$$\begin{aligned}
&\text{Max}\sum_{r=1}^{s} u_r y_{ro} - \sum_{i=1}^{m} v_i x_{io},\\
&\text{s.t.}\sum_{i=1}^{m} v_i x_{io} = 1,\\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0,\\
&u_r \ge \varepsilon, \quad v_i \ge \varepsilon, \quad v_i \ge 0,
\end{aligned} \tag{3.1}$$

u_r and v_i are, respectively, weight vector of input and output; y_{ro} and x_{io} are amounts of output r and input i value for unit o; y_{rj} and x_{ij} are amounts of output r and input i value for unit j; ε is small positive scalar; s is total output; m is number of inputs; n is number of units.

3.2. *Fuzzy CCR Model*

As DEA is a boundary method which is sensitive to outliers, it is very difficult to evaluate the efficiency of DMUs with varied input and output by conventional DEA models. Most of previous researches utilized simulation techniques faced with imprecise data [20]. In recent years, fuzzy sets theory has been proposed as a method for quantifying imprecise data in DEA models. We can find several fuzzy approaches to assess the efficiency of DEA models in the literature. Cooper et al. [21] proposed a model to deal with imprecise data such as bounded data, ordinal data, and ratio bounded data in DEA. Kao and Liu [22] utilized DEA for efficiency measurement of fuzzy functions, whereas some observations were fuzzy numbers. Another approach was introduced by Guo and Tanaka in planning techniques that measured the efficiency of possible interest with fuzzy inputs and outputs [23] in which we utilized their proposed model in this paper. The previous researches on DEA can be classified into four distinct approaches, namely, tolerance approach, defuzzification approach, α-level-based approach, and fuzzy ranking approach. As fuzzy DEA model is a form of fuzzy linear programming models, it can present applied problems in common DEA models. The general fuzzy CCR model regarding fuzzy inputs and outputs follows as below

$$\begin{aligned}
&\operatorname{Max} U^T Y_o,\\
&\text{s.t.:}\, V^T x_o \approx \tilde{1},\\
&\quad U^T Y_j \lesssim V^T X_j, \quad (j = 1, \ldots, n),\\
&\quad U \geq 0, \quad V \geq 0,
\end{aligned} \tag{3.2}$$

where $X_j = (x_j, c_j)$, $Y_j = (y_j, d_j)$, respectively, are m-dimension input and s-dimension output fuzzy vectors of unit j. Due to positive assumption for inputs and outputs, we can illustrate them as $x_j - c_j > 0$, $y_j - d_j > 0$. Constraints of model (3.2) are approximately equal and larger as well as objective function is type of maximum. Also, we consider number one in first constraint as approximate $(e < 1)e$ that is indicator of the skew from number one and the variable e is the fuzzy number which is predetermined by decision makers.

In this paper, fuzzy variables are explicitly defined and interpreted as a result of expert opinion in which no variable is completely ignored, as mentioned before in Section 3.1. In order to integrate the alternate optima for the weights, the two-step procedure of Cooper et al. [24] can be considered.

Definition 3.1. For two symmetric triangular fuzzy variables of $Z_1 = (z_1, w_1)$ and $Z_2 = (z_2, w_2)$, relationship $Z_1 \lesssim Z_2$ is shown by the following inequalities

$$\begin{aligned}
&z_1 - (1-h)w_1 \leq z_2 - (1-h)w_2,\\
&z_1 + (1-h)w_1 \leq z_2 + (1-h)w_2,
\end{aligned} \tag{3.3}$$

where the variable $h(0 \leq h \leq 1)$ is the probability level and already predetermined by decision makers. For large amount of h, the small domain of inputs and outputs is considered. In other words, all data have a great degree of probability and otherwise is true. For instance, amount of $h = 1$ illustrates only the mean of data, whereas $h = 0$ means that all parts of the data have been considered.

It is clear that the fuzzy unequal $\lesssim$ in (3.2) is calculated by comparing frontier points of z_1 and z_2 in level h as $(h \leq k \leq 1)$. In other word, if the inequalities of (3.3) were justifiable in level h, they certainly would be justifiable in level k. Maximizing symmetric triangular fuzzy variable $Z = (z, w)$ depended on maximizing the phrases $z - (1-h)w$ and $z + (1-h)w$. So it is needed to maximize the phrase $\lambda_1(z - (1-h)w) + \lambda_2(z + (1-h)w)$ in which λ_1 and λ_2 are, respectively, the weights of frontier points of variable z in level h, whereas $\lambda_1 + \lambda_2 = 1$, $\lambda_1, \lambda_2 \geq 0$. Also, λ_1 is related to the worst condition for variable z unlike λ_2 that indicates the optimistic viewpoint in maximizing z. As this paper utilized the pessimistic viewpoint, so the objective function is shown as below:

$$\operatorname{Max} \theta = z - (1-h)w. \tag{3.4}$$

In first constraint of (3.2), $v^T X_\circ \approx \tilde{1}$, the objective is finding vector v^T as established fuzzy constraint. So the value of $v^T X_\circ$ can be considered as upper limit of constraint that means frontier left points of $v^T X_\circ$ in level h can increase up to the frontier right points of fuzzy number one in level h. Therefore, we should solve the optimizing problem as below in order to get the value of vector v^T (model inputs weights) as the result

$$\begin{aligned} &\text{Max}\, v^T c_o, \\ &\text{s.t.:}\, v^T x_\circ - (1-h) v^T c_o = 1 - (1-h)e, \\ &\quad v^T x_\circ + (1-h) v^T c_o \le 1 + (1-h)e, \\ &\quad v \ge 0. \end{aligned} \tag{3.5}$$

The optimal value of the model above is g_0. So, the linear programming model for efficiency measurement of DMUs proposed by Guo and Tanaka [23] can be written in fuzzy condition as below:

$$\begin{aligned} &\text{Max}\; U^T y_o - (1-h) U^T d_o, \\ &\text{s.t.:}\; v^T c_o \ge g_o, \\ &\quad v^T x_o - (1-h) v^T c_o = 1 - (1-h)e, \\ &\quad v^T x_o + (1-h) v^T c_o \le 1 + (1-h)e, \\ &\quad U^T y_j - (1-h) U^T d_j \le v^T x_j - (1-h) v^T c_j, \\ &\quad U^T y_j + (1-h) U^T d_j \le v^T x_j + (1-h) v^T c_j, \quad (j = 1, \ldots, n), \\ &\quad U \ge 0, \quad v \ge 0. \end{aligned} \tag{3.6}$$

This model use symmetric triangular fuzzy inputs and outputs as $X_o = (x_o, c_o)$, $Y_o = (y_o, d_o)$, but the efficiency obtained from this model for corresponding unit is an asymmetric triangular fuzzy number of $E = (w_l, \eta, w_r)$, in which η is fuzzy efficiency center, w_l and w_r are, respectively, left and right variation from η. These values calculate as follows:

$$\begin{aligned} \eta &= \frac{U^{*T} y_o}{V^{*T} x_o}, \\ w_1 &= \eta - \frac{U^{*T}(y_o - d_o(1-h))}{V^{*T}(x_o - c_o(1-h))}, \\ w_r &= \frac{U^{*T}(y_o - d_o(1-h))}{V^{*T}(x_o - c_o(1-h))} - \eta, \end{aligned} \tag{3.7}$$

where V^* and U^* are the vector coefficients obtained from this model. As a result, if $\eta + w_r \ge 1$ the corresponding unit is efficient at the α-level and otherwise is inefficient. Also, the fuzzy efficiency center for all units is less than one. Fuzzy efficiency measurement of units through model (3.6) is similar to efficiency measurement by CCR model.

3.3. AP Model on Ranking of Efficient Units

In order to rank the efficient units, Sexton and Colleagues presented firstly cross-evaluation matrix for full ranking of DMUs [25]. After that, the effort of Anderson and Peterson which was called AP model was the first acceptable result in ranking efficient units [26]. In AP method, corresponding limitation on corresponding unit deletes from evaluation process and leads to sign number one for objective function. Therefore, the efficiency of corresponding unit can exceed one. Considering the no impact of inefficient units on forming efficiency frontier, technical efficiency of them would be constant by deleting in AP method, inverse of efficient units. There are many researches which have been done to improve AP model. Hashimoto presented a model based on certain areas in order to ensure full ranking of units [27]. Mehrabian et al. improved AP model through their MAJ model [28], which was reviewed by Zarafatangiz et al. [29]. They improved the MAJ model by a new model, which can evaluate the efficiency of DMUs jointly with two aspects of being input oriented and output oriented [29]. The mathematical AP model for full ranking of DMUs by using modified CCR model is shown as below:

$$
\begin{aligned}
\text{Max } x &= \sum_{r=1}^{s} u_r y_{ro}, \\
\text{s.t.: } &\sum_{i=1}^{m} v_i x_{io} = 1, \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \quad j = 1, \ldots, n, \ j \neq 0, \\
&u_r \ge \varepsilon, \quad v_i \ge \varepsilon.
\end{aligned}
\tag{3.8}
$$

3.4. Fuzzy AHP

This method is a kind of compensation models for decision-making problems which was firstly proposed by Saaty based on analysis of human brain for complex fuzzy problems [30]. Performance of AHP is related to hierarchy structure and paired comparisons of decision components. It can be pointed on several procedures governed on AHP such as bilateral condition rule, homogeneity rule, independence rule, and expectations rule. In last two decades, extension of DEA in efficiency evaluation of DMUs has leaded to its general application on other techniques such as MCDM in order to eliminate the infirmities [31]. Hence, Theodor utilized MCDM for solving weights constraint problem in DEA models [32]. Also, Sinuang et al. integrated DEA and AHP as a synthetic model in order to rank the DMUs [33]. Since 1983, fuzzy AHP has been developed by researches and so several approaches have been proposed. In this paper, we use Buckley approach in fuzzy AHP as the algorithm below.

Step 1. First, all of paired comparisons should be converted to trapezoidal fuzzy number. So, triangular fuzzy number of (a, b, c) indicates (a, b, b, c) and definitive number of (a) shows (a, a, a, a). Therefore, we can compute these fuzzy weights as $\overline{a}_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij})$, which belong to both of paired comparisons matrix for criteria and components.

Step 2. Compute the geometric mean of W_i for any matrix obtained from Step 1 as below:

$$a_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}, \quad b_i = \left(\prod_{j=1}^{n} b_{ij}\right)^{1/n}, \quad C_i = \left(\prod_{j=1}^{n} c_{ij}\right)^{1/n}, \quad d_i = \left(\prod_{j=1}^{n} d_{ij}\right)^{1/n},$$
$$a = \left(\sum_{i=1}^{n} a_i\right)^{1/n}, \quad b = \left(\sum_{i=1}^{n} b_i\right)^{1/n}, \quad c = \left(\sum_{i=1}^{n} c_i\right)^{1/n}, \quad d = \left(\sum_{i=1}^{n} d_i\right)^{1/n}, \tag{3.9}$$

where a_{ij} and b_{ij} are, respectively, the left and right foots of trapezoidal fuzzy number of row i in column j. So, we compute the value of a by sum of n numbers as well as b, c, and d similarly. The values of W_i for $i = 1, \ldots, n$, can be obtained as below and include all of fuzzy weights of paired comparisons matrix for criteria and components

$$W_i = \left(\frac{a_i}{d}, \frac{b_i}{c}, \frac{c_i}{b}, \frac{d_i}{a}\right), \quad \forall_i. \tag{3.10}$$

Step 3. According Step 2, we can assign k_i for fuzzy weights of paired comparisons matrix for criteria as well as n_{ij} for components. In other words, the values of k_i and n_{ij} have been integrated as W_i in model, as $(k_i,\ n_{ij} \in W_i)$. So, the final weight of each component computes as below

$$u_i = \sum_{j=1}^{n} k_i . n_{ij}, \quad \forall_i. \tag{3.11}$$

Synthetic AHP/DEA model combines the two separate models of AHP and DEA, which consist of two stages: first, DEA model runs for both DMUs separately and then, considering the result of first stage, the paired comparisons matrix has existed for alternatives and then the ranking caused by solving AHP model. In other words, in this model the paired comparisons have been obtained through DEA model and the final ranking results by AHP model.

4. Methodology

Considering applied aspect of research, the objectives can be summarized to as follows: (1) model design, (2) efficiency measurement of bank with fuzzy approach and (3) determining the efficiency by deleting each input or output. In this research, the method of collecting information is based on study of bank documents. Also, we used the literature and expert opinion regarding the importance of inputs and outputs variables jointly, which was done through paired comparisons questionnaires. So, we have selected the inputs and outputs by two stages: first, the components have been gathered through library studies and expert opinions and then, the number of components has been modified by experts in order to prevent the skew in efficiency. The inputs and outputs are considered as shown in Table 1.

In order to utilize data as inputs or outputs, the following should be considered: each of inputs and outputs is consists of several separate subfactors. In this research, we considered

Table 1: List of model inputs and outputs.

Inputs			
Costs (X_1)	Personnel (X_2)	Capital (X_3)	Equipment (X_4)
Doubtful accounts (X_{11})	No. of personnel (X_{21})	Branch account change (X_{31})	No. of computers (X_{41})
Interest charges (X_{12})			No. of ATMs (X_{42})
Non-interest charges (X_{13})			
Outputs			
Incomes (Y_1)	Deposits (Y_2)	Facilities (Y_3)	Bank services (Y_4)
Revenue of loan (Y_{11})	Investment deposit (Y_{21})	Current a note facility (Y_{31})	No. of payment bote (Y_{41})
Penalties of delay (Y_{12})	Saving deposit (Y_{22})	Current a note facility (Y_{32})	No. of guarantees (Y_{42})
Bank charges (Y_{13})	Current deposit (Y_{23})	Current non-note facility (Y_{33})	No. of payment loans (Y_{43})
		Current non-note facility (Y_{34})	

the number of personnel and equipments to find these input weights in usual CCR model, but in fuzzy CCR model we dedicated different weights to different equipments and sum of them are introduced as input weight. Also, bank personnel are scored by education level and also their experience year in order to get the total score of personnel by summation of two factors.

Statistical population of research includes 25 branches of Tejarat Bank in Rey city. Due to the single level of Fuzzy-AHP table in this study, each table was computed until stage two and then, the weights were calculated by paired comparisons matrix. However the obtained weights are all trapezoidal fuzzy numbers, we can use Minkowsky method in order to convert the fuzzy numbers to definite number and then, change it to numerical scale of 10. We can summarize the process of research implementation as below.

(1) Determine the efficient parameters on performance measurement of bank branches.

(2) Determine the final parameters.

(3) Implement DEA model with different approaches.

(4) Analyze obtained information.

In this paper, we utilize DEA-solver software to solve the DEA model, SPSS software for statistical analysis, and Expert Choice software to compute the inconsistency of components weights.

5. Implementing DEA Models

As mentioned before, efficiency measurement of bank branches has computed through input-oriented CCR model with three different approaches, which differ on combination type of input and output parameters. If we use the similar value criteria for combining the homogenous data, then the problem can be solved by usual CCR model, elsewhere we have to modify the fuzzy weights obtained from expert opinion. These approaches are considered, respectively, as below

(a) usual CCR model with data combination based on similar value criteria (type *a*),

(b) usual CCR model with data combination based on group fuzzy weights (type *b*),

(c) unusual CCR model with data combinations based on confined fuzzy weights (type *c*).

5.1. Usual CCR Model Based on Similar Value Criteria

In order to combine the homogenous data based on similar value criteria, we sum the data together and then enter final data as input or output. So, the inputs and outputs of this model have been computed as below

$$
\begin{aligned}
X_1 &= X_{11} + X_{12} + X_{13}, \\
X_2 &= X_{21}, \\
X_3 &= X_{31}, \\
X_4 &= X_{41} + X_{42}, \\
Y_1 &= Y_{11} + Y_{12} + Y_{13}, \\
Y_2 &= Y_{21} + Y_{22} + Y_{23}, \\
Y_3 &= Y_{31} + Y_{32} + Y_{33} + Y_{34}, \\
Y_4 &= Y_{41} + Y_{42} + Y_{43}.
\end{aligned} \tag{5.1}
$$

In order to obtain the efficiency of bank branches, we can enter data as shown above in usual input-oriented CCR model and solve it. Also, according to AP model in ranking of DMUs, the efficiency of bank branches has computed by deleting a major factor of inputs or outputs from CCR model. The result is followed as shown in Table 2.

By using AP model for ranking the efficient units, the result indicates that 44% of bank branches identify as efficient units, which represents the unsuitable segregation of branches.

5.1.1. Sensitivity Analysis of Input and Output Factors

As Table 2 shows, after computing the efficiency value of bank branches through CCR model, it has been obtained again by deleting a factor of input or output for all branches. The signal * in such table box indicates that the efficiency of a unit has been constant by deleting related factor. This table prepares useful information related to inefficient units. For instance, the efficiency of branch 10 decreased by deleting the income factor (Y_1) and shows that branch 10 has been successful in income producing, whereas its efficiency increased by deleting the facility factor (Y_3) and indicate the infirmity of unit 10 in vesting facilities. Also, the results show the lower costs and inefficient utilization of human resource in this branch. So, the branch 10 can increase facilities and decrease the rest of personnel. Similarly, we can analyze the impact of each factor for other bank branches.

Table 2: Efficiency value of DMUs based on CCR model with similar value criteria.

Branch no.	Efficiency value	Efficiency value by AP model	Efficiency value of branch by deleting a factor of input or output							
			$X1$	$X2$	$X3$	$X4$	$Y1$	$Y2$	$Y3$	$Y4$
1	0.728	*	0.569	*	0.674	0.643	0.720	*	*	*
2	0.958	*	0.780	0.785	0.924	0.958	0.764	0.915	0.837	0.924
3	0.458	*	0.456	0.434	0.436	0.437	*	0.341	0.454	0.405
4	1	1.319	*	0.878	*	*	*	*	*	0.864
5	1	5.376	*	*	*	*	*	*	*	*
6	0.608	*	0.586	0.574	0.593	*	0.584	*	0.603	0.565
7	0.961	*	0.604	*	0.854	*	0.620	0.816	0.821	0.861
8	1	2.047	*	*	*	*	*	*	*	*
9	1	1.929	*	*	*	*	*	*	*	*
10	0.502	*	0.375	0.677	0.505	0.497	0.345	*	0.672	0.477
11	0.709	*	0.590	*	0.599	0.669	*	0.655	*	0.676
12	0.794	*	0.783	0.771	0.781	*	0.684	*	*	*
13	0.735	*	0.678	*	0.671	*	*	0.390	*	*
14	1	2.024	*	*	*	*	*	*	0.939	*
15	1	1.137	*	*	*	*	*	*	*	*
16	1	1.393	*	*	*	*	*	*	*	*
17	0.939	*	1	0.836	0.798	*	0.559	1	1	0.970
18	0.633	*	*	0.586	0.622	*	0.621	*	*	*
19	1	1.622	*	*	*	0.875	*	*	*	*
20	1	1.354	*	*	*	*	*	*	*	*
21	0.915	*	0.718	*	0.799	0.762	0.468	0.762	*	0.761
22	1	3.587	*	*	*	*	*	*	*	*
23	1	1.278	*	*	0.785	*	*	0.820	*	*
24	0.674	*	0.566	*	0.672	0.669	0.560	0.671	0.648	*
25	0.678	*	0.575	1	0.937	*	0.608	0.668	0.543	*

As a result, by deleting the inputs, cost, personnel, capital, and equipment, the efficiency value of, respectively, 13, 9, 15 and 8 branches has been changed. So, two factors of cost and capital have more importance between inputs, and among outputs by deleting; income, deposit, facility, and services, the efficiency value of, respectively, 11, 10, 9, and 9 branches has been changed which justify the importance of income between outputs. Also, the equipment of banks has the least effect on efficiency of branches.

5.2. Usual CCR Model Based on Group Fuzzy Weight

This model utilizes the usual input-oriented CCR model and unlike type a, the inputs and outputs of model have been computed by fuzzy combination of components.

5.2.1. How to Compute the Fuzzy Weights

The fuzzy weights of inputs and outputs have been obtained through paired comparison tables of which a sample exists in the appendix. So, these tables have been distributed among 10 experts in order to get the final fuzzy weight of each factor. Thus, the similar process should be done that income fuzzy weights are described for instance as below.

(a) Convert the linguistic variables such as old equipment into trapezoid fuzzy numbers.

(b) Determine the incompatible matrix before analysis of data on paired comparisons matrix. So, first, all of matrix data should be defuzzificated and entered in matrix as definite data. Then, by computing the incompatibility of each matrix it is observed that only four matrixes had information incompatibility. After sending the incompatible questionaries and remustering of them it has found that finally 50% of paired comparisons matrixes have information compatible and so rest of them are deleted.

(c) Determine the weight of each component by fuzzy AHP method. This process has been done for five decision maker units as below.

  (1) All components of comparisons matrix should be written as trapezoid fuzzy number, nee $(a_{ijk}, b_{ijk}, c_{ijk}, d_{ijk})$, where indexes of i represent row number, j is the column number, and k is the decision maker number. For example, all components of first matrix can be shown as $(a_{ij1}, b_{ij1}, c_{ij1}, d_{ij1})$, where number one represents the first decision maker. For income comparisons matrix $i = 1, 2, 3$; $j = 1, 2, 3$; $k = 1, 2, 3, 4, 5$.

  (2) Constitute a new matrix with components based on trapezoid fuzzy number as $(a'_{ij}, b'_{ij}, c'_{ij}, d'_{ij})$ which has been obtained as below:

$$
\begin{aligned}
a'_{ij} &= \left(a_{ij1} \times a_{ij2} \times a_{ij3} \times a_{ij4} \times a_{ij5}\right)^{1/5}, \\
b'_{ij} &= \left(b_{ij1} \times b_{ij2} \times b_{ij3} \times b_{ij4} \times b_{ij5}\right)^{1/5}, \\
c'_{ij} &= \left(c_{ij1} \times c_{ij2} \times c_{ij3} \times c_{ij4} \times c_{ij5}\right)^{1/5}, \\
d'_{ij} &= \left(d_{ij1} \times d_{ij2} \times d_{ij3} \times d_{ij4} \times d_{ij5}\right)^{1/5}.
\end{aligned}
\tag{5.2}
$$

  (3) Solve the matrix above by fuzzy AHP method. Considering the single level of matrix, it can run until stage two in fuzzy AHP method.

After running the mentioned process, fuzzy weights of income components are obtained as

$$
W_{Y11} = 0.456, \qquad W_{Y12} = 0.205, \qquad W_{Y13} = 0.339. \tag{5.3}
$$

5.2.2. The Final Weights of Inputs and Outputs

If we implement the process above for all inputs and outputs according to expert opinions, then the final fuzzy weights of factors can be obtained as shown in Table 3.

Due to the constant weights of capital and bank services among major factors, these components will be computed based on countable units and entered rightly for measuring the efficiency. Meanwhile, as mentioned before, in fuzzy CCR model the bank's personnel are scored by education level and also their experience year in order to get the total score of

Table 3: Final fuzzy weights of inputs and outputs.

	Inputs weights	
Costs (X_1)	Personnel (X_2)	Equipment (X_4)
$W_{X11} = 0.541$		$W_{X41} = 7.906$
$W_{X12} = 0.243$		$W_{X42} = 8.395$
$W_{X13} = 0.216$		
	Outputs weights	
Incomes (Y_1)	Deposits (Y_2)	Facilities (Y_3)
$W_{Y11} = 0.456$	$W_{Y21} = 0.279$	$W_{Y31} = 0.225$
$W_{Y12} = 0.205$	$W_{Y22} = 0.292$	$W_{Y32} = 0.223$
$W_{Y13} = 0.339$	$W_{Y23} = 0.280$	$W_{Y33} = 0.287$
		$W_{Y34} = 0.265$

personnel by summation of two factors. Table 4 indicates the final fuzzy weights of personnel. Also, we can utilize the following phrases in personnel equations:

i = personnel level, ($i = 1, 2, \ldots, 5$),

a_i = number of personnel for each education level,

b_i = sum of experience years of personnel for each education level.

5.2.3. The Efficiency Computation of Bank Branches

In order to compute the quantity of inputs and outputs, we have combined the components of factors by multiplying of each component to its related fuzzy weight. These accounts have been obtained as below

$$
\begin{aligned}
X_1 &= 0.541X_{11} + 0.243X_{12} + 0.216X_{13},\\
X_2 &= 2.436a_1 + 0.223b_1 + 4.518a_2 + 0.457b_2 + 5.805a_3 + 0.549b_3\\
&\quad + 7.845a_4 + 0.815b_4 + 10a_5 + 1b_5,\\
X_3 &= X_{31},\\
X_4 &= 7.906X_{41} + 8.395X_{42},\\
Y_1 &= 0.456Y_{11} + 0.205Y_{12} + 0.339Y_{13},\\
Y_2 &= 0.279Y_{21} + 0.292Y_{22} + 0.280Y_{23},\\
Y_3 &= 0.225Y_{31} + 0.223Y_{32} + 0.287Y_{33} + 0.265Y_{34},\\
Y_4 &= Y_{41} + Y_{42} + Y_{43}.
\end{aligned}
\tag{5.4}
$$

The final quantity of inputs and outputs have entered the usual CCR model based on group fuzzy weights and so we can obtain the efficiency of bank branches and classify them through AP model. The results have been indicated in Table 5.

According to the result, the number of efficient units in this usual model is relatively high as well as obtained in type a, and it reaches up to 48% of total units which is indicator of unsuitable segregation of branches.

Table 4: Final fuzzy weights of personnel.

Final personal weights (W_{X2})					
Personal level	Secondary sch.	Diploma	college cr.	bachelor	Ms.c
Education level weight	2.436	4.518	5.805	7.845	10
Experience year score	0.223	0.457	0.549	0.815	1

Table 5: Efficiency value of DMUs based on group fuzzy weights.

Branch no.	Efficiency value based on group fuzzy weights	Efficiency value based on AP model	Branch ranking based on group fuzzy weights
1	0.850	*	16
2	1	1.032	12
3	0.782	*	18
4	1	1.790	5
5	1	5.170	1
6	0.749	*	19
7	0.893	*	15
8	1	2.44	3
9	1	1.408	9
10	0.550	*	25
11	0.714	*	20
12	0.909	*	14
13	0.646	*	22
14	1	1.889	4
15	1	1.157	10
16	1	1.476	7
17	0.923	*	13
18	0.627	*	23
19	1	1.640	6
20	1	1.424	8
21	0.680	*	21
22	1	3.240	2
23	1	1.090	11
24	0.826	*	17
25	0.596	*	24

5.3. Unusual CCR Model Based on Confined Fuzzy Weights

In usual CCR model based on group fuzzy weights, we used expert opinion for combination of homogenous parameters. One of the major problems of this model is disability of fuzzy model to control the final weights of inputs and outputs after solving the model. So, CCR model based on confined fuzzy weights is extended in order to control the weights of parameters. Meanwhile, we add some constraints to original fuzzy model for weights control by using the below process: first, we determine the final weights of inputs and outputs by paired comparisons matrix which is made of expert opinions. This process is similar to one

Table 6: The final weights of factors based on confined fuzzy weights.

	Inputs weights		
Costs ($X1$)	Personnel ($X2$)	Capital ($X3$)	Equipment ($X4$)
$W_{X1} = 0.212$	$W_{X2} = 0.319$	$W_{X3} = 0.091$	$W_{X4} = 0.310$
	Outputs Weights		
Incomes ($Y1$)	Deposits ($Y2$)	Facilities ($Y3$)	Bank services ($Y3$)
$W_{Y1} = 0.244$	$W_{Y2} = 0.162$	$W_{Y3} = 0.274$	$W_{Y4} = 0.167$

as presented in Section 5.2.1. The final weights of inputs and outputs are followed as shown in Table 6.

By utilizing the final weights in original fuzzy CCR model, the definite efficiency of each bank branch is obtained, but the solution area of problem may be changed to infeasible area. Therefore, it is necessary to determine the certain area for obtained weights. So, we assume the large domain as certain area and enter a new variable called α to the model. Whatever α is closer to one, the computed efficiency is more definite and otherwise by small account of α closer to zero, the efficiency has been fuzzier and expert opinion has more affect on weights. Also, we suppose that the minimum weight dedicated to each factor is zero and the maximum can reach multiple of factor's weight. For instance, income output in model can be written as $[0, 0.488]$ instead of 0.244, where α coefficient applied as below:

$$0.244 - 0.244(1 - \alpha) \leq W_{Y1} \leq 0.244 + 0.244(1 - \alpha). \tag{5.5}$$

This constraint is indicator of triangular fuzzy number as $(0, 0.244, 0.488)$ which can distribute into two unilateral constraints as below:

$$\begin{aligned} W_{Y1} &\geq 0.244\alpha, \\ W_{Y1} &\leq 0.488 - 0.244\alpha. \end{aligned} \tag{5.6}$$

According to α coefficient, we can enter the following constraints for other factors into fuzzy CCR model:

$$\begin{aligned} W_{X1} &\geq 0.212\alpha, \\ W_{X1} &\leq 0.424 - 0.212\alpha, \\ W_{X2} &\geq 0.319\alpha, \\ W_{X2} &\leq 0.638 - 0.319\alpha, \\ W_{X3} &\geq 0.091\alpha, \\ W_{X3} &\leq 0.182 - 0.091\alpha, \\ W_{X4} &\geq 0.310\alpha, \\ W_{X4} &\leq 0.620 - 0.310\alpha, \end{aligned}$$

$$
\begin{aligned}
&W_{Y2} \geq 0.162\alpha,\\
&W_{Y2} \leq 0.324 - 0.162\alpha,\\
&W_{Y3} \geq 0.274\alpha,\\
&W_{Y3} \leq 0.548 - 0.274\alpha,\\
&W_{Y4} \geq 0.167\alpha,\\
&W_{Y4} \leq 0.334 - 0.167\alpha.
\end{aligned}
\tag{5.7}
$$

Considering these constraints, the fuzzy CCR model converts to unusual model based on confined fuzzy weights which can be solved in order to compute the efficiency of bank branches. Table 7 indicates the comparative results of efficiency value which has been computed through three types of CCR model in this research.

In order to prevent the infeasible solution for some of branches, we have to utilize property coefficient of α that is obtained through effort and error method. So, we solved the fuzzy model first with coefficient of $\alpha = 1$ which result in infeasible area for efficiency of branch. Then, we resolved it by coefficient of $\alpha = 0.9$. This process has been continued until receiving the feasible solution for all bank branches. In this research, coefficient of $\alpha = 0.6$ has been found to solve the fuzzy CCR model type c. As the results shows in Table 7, number of efficient units has meaningful reduction down to 4 units which indicate the power of model in segregation of branches.

It should be mentioned that in this research we solved totally 375 CCR models, with 9*25 models related to approach a, 25 models related to approach b, and 5*25 models according α coefficient ($\alpha = 1, 0.9, 0.8, 0.7, 0.6$) related to approach c.

6. Analysis of Results

6.1. Analysis of Correlation for Efficiency and Rank of DMUs

In this section, we survey the correlation of efficiency for branches which has been obtained by three approaches and also their ranking through AP model. Therefore, we utilized the coefficient of the correlation in order to survey the efficiency computed for three approaches as below:

$$
r = \frac{n\sum x_i y_i - \left(\sum x_i\right)\left(\sum y_i\right)}{\sqrt{\left[n\sum x_i^2 - \left(\sum x_i\right)^2\right].\left[n\sum y_i^2 - \left(\sum y_i\right)^2\right]}}. \tag{6.1}
$$

Also, we utilized the Spearman rank correlation coefficient to survey the correlation of ranking of units together which have been obtained through three approaches and can be computed as below, where d_i is the difference of the rank for special unit in three approaches

$$
r_s = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)}. \tag{6.2}
$$

The results are shown in Table 8.

Table 7: Comparative result of efficiency value through three types of CCR model.

Branch no.	Similar value criteria (a)			Group fuzzy weights (b)			Confined fuzzy weights (c)		
	Efficiency value	AP efficiency value	Full ranking	Efficiency value	AP efficiency value	Full ranking	Efficiency value	AP efficiency value	Full ranking
1	0.728	*	**18**	0.850	*	**16**	0.613	*	**11**
2	0.958	*	**13**	1	1.032	**12**	0.445	*	**20**
3	0.458	*	**25**	0.782	*	**18**	0.492	*	**18**
4	1	1.319	**9**	1	1.79	**5**	0.529	*	**16**
5	1	5.376	**1**	1	5.17	**1**	1	2.356	**1**
6	0.608	*	**23**	0.749	*	**19**	0.552	*	**15**
7	0.961	*	**12**	0.893	*	**15**	0.628	*	**9**
8	1	2.047	**3**	1	2.44	**3**	1	1.829	**2**
9	1	1.929	**5**	1	1.408	**9**	0.303	*	**25**
10	0.502	*	**24**	0.550	*	**25**	0.407	*	**22**
11	0.710	*	**19**	0.714	*	**20**	0.672	*	**7**
12	0.794	*	**16**	0.909	*	**14**	0.578	*	**13**
13	0.735	*	**17**	0.646	*	**22**	0.399	*	**23**
14	1	2.024	**4**	1	1.889	**4**	1	1.033	**4**
15	1	1.137	**11**	1	1.157	**10**	0.386	*	**24**
16	1	1.393	**7**	1	1.476	**7**	0.627	*	**10**
17	0.939	*	**14**	0.923	*	**13**	0.695	*	**6**
18	0.633	*	**22**	0.627	*	**23**	0.504	*	**17**
19	1	1.622	**6**	1	1.64	**6**	0.852	*	**5**
20	1	1.354	**8**	1	1.424	**8**	0.669	*	**8**
21	0.915	*	**15**	0.680	*	**21**	0.439	*	**21**
22	1	3.587	**2**	1	3.24	**2**	1	1.063	**3**
23	1	1.278	**10**	1	1.09	**11**	0.589	*	**12**
24	0.674	*	**21**	0.826	*	**17**	0.552	*	**14**
25	0.678	*	**20**	0.596	*	**24**	0.454	*	19
Mean of efficiency value	0.864	—	—	0.870	—	—	0.615	—	—

As Table 8 shows, the efficiency of bank branches in two approaches of types a and b have relatively high correlation as well as their ranking and indicates that the weights dedicated based on expert opinions is not affective on ranking and the efficiency of DMUs. This correlation is much less for other types of relations and means that the fuzzy weights of experts are affective on efficiency and ranking of units. In other words, dedication of confined fuzzy weights to factors leads to the visible movement on ranking of bank branches.

6.2. Analysis of Bank Branches Based on CCR Models

Considering different CCR models which are solved in this research, it results that the branch number five is the best branch totally with the rank and efficiency number of one in all approaches. After that, respectively, branches numbers 8, 14, and 22 can be predicated as

Table 8: Analysis of correlation for efficiency and rank of DMUs.

Correlation of coefficient (r)	
Between similar value criteria and group fuzzy weights approaches	$r = 0.827$
Between similar value criteria and confined fuzzy weights approaches	$r = 0.419$
Between group fuzzy weights and confined fuzzy weights approaches	$r = 0.475$
Spearman rank correlation coefficient (r_s)	
Between similar value criteria and group fuzzy weights approaches	$r_s = 0.918$
Between similar value criteria and confined fuzzy weights approaches	$r_s = 0.530$
Between group fuzzy weights and confined fuzzy weights approaches	$r_s = 0.605$

Table 9: Comparative display of efficiency for bank branches.

	Different approaches of CCR model		
	Similar value criteria	Group fuzzy weights	Confined fuzzy weights
Number of efficient units	11	12	4
Percent of efficient units	44%	48%	16%
Minimum of efficiency	0.458	0.550	0.303
Maximum of efficiency	1	1	1
Mean of efficiency	0.864	0.868	0.615

good branches at all with efficiency of one. Also, it has been observed that the efficiency and ranking of branches have been strongly affected by exerting the confined fuzzy weights for inputs and outputs. For instance, branch number 9 with the rank of 5 and 9 in two types of *a* and *b*, gained the rank 25 in type *c* based on confined fuzzy weights.

In order to provide the comparative condition for different types of CCR model, we summarize the results of problems based on different aspect of efficiency as shown in Table 9.

This comparative study displays that the fuzzy approach based on confined fuzzy weights have stronger segregation than other approaches by two reasons; first is the minimum number of efficient branches in this approach and second is that there is meaningful difference between efficiency of this approach and the others. Furthermore, in this approach in order to compute the efficiency of DMUs the expert opinions have been considered as much as possible.

7. Conclusion

In this study, the performance measurement of bank branches has been considered by applying the different approaches of basic input-oriented CCR model, which differ together in combination type of inputs and outputs. Also, we have improved the major problems of DEA models from two aspects of infirmity of segregation and illusive distribution of weights by configuring the fuzzy approach based on confined weights. The results represent the high correlation of efficiency and ranking for two approaches of CCR model based on similar value criteria and group fuzzy weights, whereas it has descended for confined fuzzy weights approach. As a result, the obtained efficiency for branches can indicate the performance power of branches in using inputs and producing outputs. Also, the CCR model based on confined fuzzy weights presented the high level of accuracy in identifying the efficient units in order to offer the corrective actions on applying resources.

Table 10

	Costs (Doubtful Accounts, Interest charges, etc.)	*Personnel* (No. of personnels)	*Capital* (Branch acoount change)	Equipment (Computers, ATMs)
Costs (Doubtful Accounts, Interest charges, etc.)				
Personnel (No. of personnels)				
Capital (Branch acoount change)				
Equipment (No. of computers, NO. of ATMs)				

Table 11

	Incomes (Revenue ofl oan, bank charges, etc.)	*Deposits* (Investment deposit, Saving deposit, etc.)	*Facilities* (Current a note facility, Capital a note facility, etc.)	Bank services (payment bote, garantees, etc.)
Incomes (Revenue ofl oan, bank charges, etc.)				
Deposits (Investment deposit, Saving deposit, etc.)				
Facilities (Current a note facility, Capital a note facility, etc.)				
Bank services (payment bote, garantees, etc.)				

Appendix

See Tables 10 and 11.

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