



## Designing A Mixed System of Network DEA for Evaluating the Efficiency of Branches of Commercial Banks in Iran

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### ABSTRACT

One of the most important applications of data envelopment analysis technique is measuring the efficiency of bank branches. Performance measurement in the banking industry is important for several groups, including bank managers, customers, investors, and shareholders. The purpose of this study is to examine and design a mixed structure to measure the efficiency of branches of Iranian banks according to their policies. In order to obtain the efficiency of the structure divisions proposed in this study, a slack-based NDEA model was selected to solve its mathematical model. The study sample consists of 31 branches of a large commercial bank in Iran. The advantage of this research to previous studies is that the result will be more realistic considering the inputs and outputs consistent with Iran's banking conditions.

## 1 Introduction

The banking industry is one of the most sophisticated industries in the world [1]. In other words, the banking industry has the most important role in developing financial systems. So, it can be said that the economic growth of countries is dependent on this industry. On the other hand, the services provided by banks affect not only the economic growth of the country but also affect the daily lives of the people [2]. Due to the role of banks in all economic activities and the policy of economic liberalization, the banking industry has moved towards internationalization in recent years. Therefore, banks face fierce competition, they need to have enough information from their performance status and other competitors to compete in the industry, and if necessary, take corrective action. To confront this competitive environment, many academic researchers and bank managers have invested in finding ways to enhance the performance of commercial banks [3]. So far, several studies have been carried out on the performance evaluation of banks and various methods have been used to evaluate the performance of banks. One of these methods is the Data Envelopment Analysis (DEA) method. Data Envelopment Analysis is a non-parametric, mathematical programming approach that enables performance evaluation of similar decision-making units that have multiple data and outputs. The main advantage of this method over other methods is the ability to simultaneously examine multiple inputs and outputs with-

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out the need to determine the relationship between inputs and outputs. DEA was developed to measure the efficiency of the decision maker, regardless of its internal structure. In other words, the system is considered as a black box in which inputs are used to generate outputs [4,5]. There are structures in which the entire operation is divided into more than two processes. These structures may be series, parallel, or a combination of these. These structures are generally called network structures [4,5]. Unlike classical DEA models, NDEA can model an organization and measure the performance of its components [6]. The conventional DEA models used to evaluate banks performance (assuming inputs are consumed to produce outputs) act as a black box. The major disadvantage of using DEA classic models to evaluate the performance of banks is that they only look at the inputs and outputs of the model, and no reviews are made within decision-making units. As a result, bank managers cannot identify the source of inefficiencies within their branches. Therefore, if the performance of the bank branches is not measured in the performance of the sub-processes, then there is actually an apparent estimate of the performance of the bank. Thus, using the NDEA approach, the weakness of the traditional DEA models can be resolved and measured the efficiency of all components of a bank branch. In recent years, the banking industry in Iran has been pushing for reform and elimination of constraints. In other words, reforms have begun since the arrival of private banks and the withdrawal of the monopoly of this industry from government banks. As a result, the banks entered the competition to gain their maximum share of the monetary and financial market. Therefore, they should regularly performance evaluation of their organization. Therefore, the purpose of this study is to present a structure and model compatible with the work processes of Iranian banks in order to evaluate their exact performance.

The remainder of the paper is organized as follows: Section 2 presents a review of the literature. Section 3 presents the Methodology. Presents The Numerical illustration in Section 4. Conclusions follow in Section 5.

## 2 Review of Literature

DEA technique was developed in 1978 by Charnes et al.[7]. This technique is a nonparametric efficiency analysis method for comparing units to the efficiency boundary. DEA a well-known managerial tool for measuring relative Efficiency. In literature, there are several parametric and nonparametric methods for calculating the performance of bank branches, But the DEA approach has given more studies. In recent years, many studies have focused on assessing the performance of the banking industry by developing DEA models. The first studies on performance evaluation in the banking industry are Benston[8] and Greenbaum[9]. In 2009, Avkiran measured the performance of 15 United Arab Emirates banks using a slacks-based model[10], He divided the system into three profit centers Division: loans, advances, and overdrafts (Division 1), mortgaged real estate loans (Division 2), and discounted commercial bills (Division 3). In 2013, Lin and Chiu[11] applied a slacks-based model to measure the performance of thirty Taiwanese banks by separating their operations into three stages: production, service, and profitability. In both of these studies, writers used the model developed by Tone and Tsutsui[12], since it can evaluate intermediate measures directly in a single procedure.

Goyal and Aggarwal [13] investigated the performance of 66 banks in India for the period 2015–2016. Wanke et al.[14] reviewed the strategic fit assessment of mergers and acquisitions (M&A) in South African banks. Abreu et al.[15] reviewed 87 articles published in the banking sector between

January 2011 and July 2017. Fernandes et al.[16] measured the efficiency of peripheral European domestic banks and the effects of bank-risk determinants on Their Performance over 2007-2014. Zhou et al.[17] evaluated the performance of 16 commercial banks in Chinese for the period 2015–2016. Keramati et al.[18] examined the impact of IT investment on the performance of 102 branches of the largest private bank in Iran. Ebrahimnejad et al.[19] investigated the performance of the 49 an Iranian bank with used a division parameters distance function model. Jahanshahloo et al. [20] measured the performance of 39 branches of An Iranian bank, in which the functions were classified as services, deposits, and sales. Amirteimoori and Nashtaei [21] classified the functions of a bank into deposits, services, and sales, to evaluate the efficiency of 28 branches of a commercial bank in Iran. Izadikhah [22] evaluated the financial performance of 15 privet bank branches in Markazi province of Iran. Izadikhah et al.[23] reviewed the performance of 15 branches of the Philadelphia National Bank using a two-stage model. Tavana et al.[24] evaluated the performance of 29 branches of the Detroit National Bank by proposing a two-stage dynamic model. Esfandiar et al.[25] assessed the performance of banks admitted to the Tehran Stock Exchange. But the difference between all previous researches, with this study, is the design of a new structure commensurate with the policies of Iranian commercial banks.

### 3 Methodology

#### 3.1 Network Slacks-Based Measure

Tone and Tsutsui [12] developed the NSBM model, this model can directly evaluate the intermediate products. Their model and its related reviews are briefly mentioned below.

$$\rho_0^* = \min \frac{\sum_{k=1}^K w^k \left[ 1 - \frac{1}{m_k} \left( \sum_{i=1}^{m_k} \frac{S_i^{k-}}{x_{io}^k} \right) \right]}{\sum_{k=1}^K w^k \left[ 1 + \frac{1}{r_k} \left( \sum_{r=1}^{r_k} \frac{S_r^{k+}}{y_{ro}^k} \right) \right]} \quad (1)$$

subject to:

$$x_0^k = X^k \lambda^k + s^{k-} \quad (k = 1, \dots, K).$$

$$y_0^k = Y^k \lambda^k + s^{k+} \quad (k = 1, \dots, K).$$

$$e \lambda^k = 1 \quad (k = 1, \dots, K).$$

$$Z^{(k,h)} \lambda^h = Z^{(k,h)} \lambda^k \quad (\forall (k, h))$$

$$\lambda^k \geq 0, s^{k-} \geq 0, s^{k+} \geq 0 \quad (\forall k)$$

Where  $\sum_{k=1}^K w^k$ ,  $w^k \geq 0 (\forall k)$ , and  $w^k$  is the relative weight of division k which is determined corresponding to its importance.

**Definition 1** (Non-oriented overall efficiency). We call  $\rho_0^*$  the non-oriented overall efficiency of

DMUo. If we have  $\rho_0^* = 1$  the DMUo is called overall efficient.

**Definition 2** (Non-oriented divisional efficiency). We define the non-oriented divisional efficiency score by

$$\rho_k = \min \frac{1 - \frac{1}{m_k} (\sum_{i=1}^{m_k} \frac{s_i^{k-*}}{x_{io}^k})}{1 + \frac{1}{r_k} (\sum_{r=1}^{r_k} \frac{s_r^{k+*}}{y_{ro}^k})} \quad (k = 1, \dots, K). \tag{2}$$

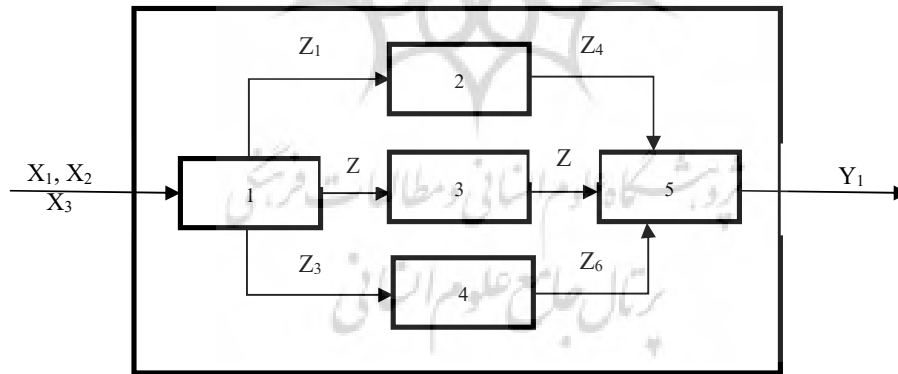
Where  $s^{k-*}$  and  $s^{k+*}$  are the optimal input- and output-slacks for Eq. (1) [12].

### 3.2 Relational Model

Equation (2) is nonlinear and it is not able to measure the efficiency of the system, Therefore, it is better to use a linear model to obtain a relationship between system efficiency and division. Applying the relational model proposed by Kao [26], We can calculate system and division efficiency (see [5,26]). For the sake of calculating the system and division efficiency simultaneously, a relational model is presented in the appendix.

### 4 Numerical Illustration

In this section, we illustrate an example in the banking industry. Operations within banks are considered as a series of sequential processes that convert human and physical resources to financial resources. For this purpose, based on the research carried out in this area and the interview and survey of experts, the conceptual model of this research was extracted as shown in Fig. 1.



**Fig. 1:** Structure of the Banking example in Iran

The inputs and outputs of this system are shown in Table 1.

**Table 1:** The selected variables

Input	Fixed assets (X1)	A long-term, tangible asset held for banks use and not expected to be converted to cash in the current or upcoming fiscal year.
	Employees (X2)	a person employed for wages or salary.
	Operating costs (X3)	They are the cost of resources used by an organization just to maintain its existence.
Intermediate	Deposits (Z1)	It is recorded as a liability for the bank, representing the amount owed by the bank to the customer for a specific year.
	loans (Z2)	Loans are recorded by the amount of outstanding principal, with unearned income excluded.
	obligations (Z3)	The bank guarantees the real and legal persons in relation to the execution of their duties and obligations.
	Non-operating costs (Z4)	A non-operating expense is an expense incurred by a business that is unrelated to the business' core operations. Like paying profits to deposits.
	Income (Z5)	The money received from the loans.
	fees (Z6)	It is mainly derived from service and penalty charges. Examples are deposit and transaction fees.
Output	Profit (Y)	The residual income of a firm after adding total revenue and gains and subtracting all expenses and losses for the reporting period.

The data set consists of observations on 31 branches of an Iranian bank in the years 2016–2017 is presented in Table 2<sup>1</sup>. By implementing the proposed model for assessing the performance of bank branches, the results of evaluating the efficiency of bank branches are presented in Table 3. The values of the variables 'u', 'v' and 'w' are given in the appendix. As shown in Table 3, the second columns show the overall system efficiency. In this example, branches 4, 8, 18, 20, 27, 29, and 30 have a 100 percent efficiency, while the least efficiency was shown by branch 15. The Third to seventh columns shows the efficiency of the subsystems. In Division 1, branches 4, 8, 18, 20, 26, 27, 29 and 30 and 31 have earned 100 percent efficiency, while the least efficiency was shown by branch 15, 21 and 10. In Divisions 2, 3 and 4, all branches have 100 percent efficiency. But in Division 5, branches 4, 8, 18, 20, 27, 29, and 30 have the efficiency of a 100 percent, while the least efficiency was shown by branch 15, 22 and 25.

<sup>1</sup> The unit of all data except Employees is Billion Rials.

**Table 2:** The dataset

Unit	X1	X2	X3	Z1	Z2	Z3	Z4	Z5	Z6	Y
1	0,3042	0.0240	15	0.9216	0.6255	0.0369	0.0089	0.0237	0.0026	0.0065
2	0,0859	0.0069	6	0.3147	0.1036	0.0147	0.0031	0.0050	0.0008	0.0042
3	0,0823	0.0068	8	0.3508	0.1884	0.0033	0.0048	0.0075	0.0009	0.0034
4	0,0000	0.0070	6	0.3574	0.0679	0.0050	0.0035	0.0039	0.0006	0.0186
5	0,1320	0.0195	16	0.6882	0.2612	0.0088	0.0096	0.0187	0.0013	0.0091
6	0,1234	0.0101	6	0.4305	0.1337	0.0616	0.0035	0.0070	0.0015	0.0051
7	0,1017	0.0167	8	0.6228	0.4454	0.0123	0.0038	0.0304	0.0012	0.0111
8	0,0452	0.0281	6	1.1178	0.3943	0.0376	0.0042	0.0148	0.0011	0.0363
9	0,0886	0.0060	6	0.3049	0.0638	0.0171	0.0034	0.0054	0.0007	0.0034
10	0,0816	0.0071	6	0.2893	0.0613	0.0040	0.0032	0.0040	0.0006	0.0058
11	0,0398	0.0068	6	0.3337	0.0427	0.0085	0.0034	0.0024	0.0006	0.0073
12	0,0207	0.0048	8	0.2272	0.0560	0.0012	0.0031	0.0030	0.0005	0.0044
13	0,0040	0.0044	5	0.2237	0.0388	0.0024	0.0027	0.0025	0.0003	0.0043
14	0,0311	0.0046	4	0.1746	0.0770	0.0027	0.0024	0.0040	0.0003	0.0027
15	0,0000	0.0018	6	0.2707	0.0648	0.0064	0.0039	0.0049	0.0008	0.0000
16	0,0306	0.0055	7	0.2232	0.0996	0.0008	0.0037	0.0043	0.0009	0.0040
17	0,0072	0.0052	5	0.2531	0.0809	0.0023	0.0027	0.0034	0.0005	0.0040
18	0,0000	0.0018	4	0.1749	0.0506	0.0012	0.0022	0.0033	0.0004	0.0133
19	0,0355	0.0145	8	0.3670	0.1968	0.0336	0.0045	0.0137	0.0012	0.0041
20	0,0050	0.0090	2	0.4211	0.0773	0.0890	0.0030	0.0043	0.0004	0.0175
21	0,0219	0.0064	6	0.2656	0.0468	0.0013	0.0034	0.0035	0.0007	0.0056
22	0,0278	0.0029	5	0.1489	0.0697	0.0110	0.0031	0.0045	0.0007	0.0008
23	0,0825	0.0058	7	0.3476	0.0474	0.0082	0.0032	0.0038	0.0006	0.0046
24	0,0396	0.0039	5	0.1971	0.0344	0.0040	0.0029	0.0019	0.0005	0.0044
25	0,0607	0.0092	6	0.5525	0.1296	0.0849	0.0035	0.0096	0.0017	0.0014
26	0,0000	0.0055	6	0.3558	0.0649	0.0172	0.0041	0.0046	0.0006	0.0043
27	0,0069	0.0056	6	0.9171	0.5361	0.1968	0.0035	0.0174	0.0027	0.0310
28	0,5350	0.0083	8	0.4893	0.1777	0.0136	0.0344	0.0156	0.0066	0.0205
29	0,0000	0.0086	4	0.2451	0.0523	0.0001	0.0023	0.0017	0.0003	0.0091
30	0,0000	0.0078	5	0.2758	0.0686	0.0023	0.0027	0.0021	0.0009	0.0111
31	0,0000	0.0027	5	0.1199	0.0826	0.0017	0.0026	0.0030	0.0008	0.0015

**Table 3:** Efficiency measures

DMU	$E_0$	$E_0^{(1)}$	$E_0^{(2)}$	$E_0^{(3)}$	$E_0^{(4)}$	$E_0^{(5)}$
DMU01	0.04	0.43	1.00	1.00	1.00	0.10
DMU02	0.06	0.27	1.00	1.00	1.00	0.22
DMU03	0.04	0.30	1.00	1.00	1.00	0.12
DMU04	1.00	1.00	1.00	1.00	1.00	1.00
DMU05	0.03	0.23	1.00	1.00	1.00	0.14
DMU06	0.08	0.37	1.00	1.00	1.00	0.21
DMU07	0.15	0.48	1.00	1.00	1.00	0.31
DMU08	1.00	1.00	1.00	1.00	1.00	1.00
DMU09	0.04	0.31	1.00	1.00	1.00	0.12
DMU10	0.07	0.21	1.00	1.00	1.00	0.32
DMU11	0.09	0.22	1.00	1.00	1.00	0.43
DMU12	0.06	0.22	1.00	1.00	1.00	0.26
DMU13	0.07	0.25	1.00	1.00	1.00	0.30
DMU14	0.05	0.26	1.00	1.00	1.00	0.18
DMU15	0.00	0.00	1.00	1.00	1.00	0.00
DMU16	0.04	0.23	1.00	1.00	1.00	0.19
DMU17	0.07	0.27	1.00	1.00	1.00	0.26
DMU18	1.00	1.00	1.00	1.00	1.00	1.00
DMU19	0.03	0.29	1.00	1.00	1.00	0.11
DMU20	1.00	1.00	1.00	1.00	1.00	1.00
DMU21	0.06	0.19	1.00	1.00	1.00	0.30
DMU22	0.01	0.29	1.00	1.00	1.00	0.04
DMU23	0.06	0.36	1.00	1.00	1.00	0.16
DMU24	0.07	0.22	1.00	1.00	1.00	0.31
DMU25	0.03	0.56	1.00	1.00	1.00	0.05
DMU26	0.20	1.00	1.00	1.00	1.00	0.20
DMU27	1.00	1.00	1.00	1.00	1.00	1.00
DMU28	0.06	0.25	1.00	1.00	1.00	0.24
DMU29	1.00	1.00	1.00	1.00	1.00	1.00
DMU30	1.00	1.00	1.00	1.00	1.00	1.00
DMU31	0.10	1.00	1.00	1.00	1.00	0.10

## 5 Conclusions

In recent decade, with the arrival of private banks, the banking industry has changed in Iran. Therefore, the monopoly of this industry has come out of the hands of the state-owned banks and fierce competition has been formed between all banks. Therefore, banks need to assess their performance in order to survive in a highly competitive interbank market. In general, performance evaluation can be interesting for banking industry experts and academics researchers to identify the strengths and weaknesses of the system. So far, several studies have been published using various models of DEA to evaluate the efficiency of the Iranian banking system. Here we developed the structure and models Avkiran [10] and Lin and Chiu [11] according to the conditions and policies of Iranian banks. In other words, we opened the black box to evaluate the efficiency of the branches of Iranian banks and carefully identified and designed all divisions and their relationship. This study differs from previous studies in terms of structure, inputs, intermediate products, outputs and solving models. To solve the model linearly, the proposed relational model by Kao [26] is used. Using the information and data from 31 branches of a large commercial bank in Iran, we showed the application of the proposed method and structure in the banking industry. One of the most important strategies for banks is to reduce costs and maximize profits. The proposed structure of this study can have important managerial points for senior bank executives. Additional future research may include a more complex structure in which inputs, outputs, and stages change with respect to new policies.

## Appendix

In the section, we show the proposed relational model in Section 3.2 and the values of the variables 'u', 'v' and 'w' and the code of the GAMS program for this model.

The relational model for this structure under constant returns to scale is:

$$E_0 = \max. \frac{\sum_{r=1}^s u_r Y_{r0}}{\sum_{i=1}^s v_i X_{i0}} \quad (a)$$

$$s.t. \quad \sum_{g=1}^h w_g Z_{gj} - \sum_{i=1}^m v_i X_{ij} \leq 0, \quad j=1, \dots, 31$$

$$w_4 Z_{4j} - w_1 Z_{1j} \leq 0, \quad j=1, \dots, 31$$

$$w_5 Z_{5j} - w_2 Z_{2j} \leq 0, \quad j=1, \dots, 31$$

$$w_6 Z_{6j} - w_3 Z_{3j} \leq 0, \quad j=1, \dots, 31$$

$$\sum_{r=1}^s u_r Y_{rj} - \sum_{g=1}^h w_g Z_{gj} \leq 0, \quad j=1, \dots, 31$$

$$u_r, v_i, w_g \geq \varepsilon, \quad r=1 \quad i=1, 2, 3 \quad g=1, \dots, 6$$

At optimality, we have the following system and division efficiencies:

$$E_0 = \sum_{r=1}^s u_r^* Y_{r0} / \sum_{i=1}^m v_i^* X_{i0} \quad (b)$$

$$E_0^{(l)} = \sum_{g=1}^h w_g^* Z_{g0} / \sum_{i=1}^m v_i^* X_{i0}$$



$$E_0^{(2)} = w_4^* Z_{40} / w_1^* Z_{10}$$

$$E_0^{(3)} = w_5^* Z_{50} / w_2^* Z_{20}$$

$$E_0^{(4)} = w_6^* Z_{60} / w_3^* Z_{30}$$

$$E_0^{(5)} = \sum_{r=1}^s u_r^* Y_{r0} / \sum_{g=1}^h w_g^* Z_{g0}$$

In this study, in order to prevent the vanishing of the weight of the variables, the lower limit of 0.005 was used for  $v_i$ ,  $w_d$ , and  $u_r$  variables. Table A1 shows the values of the variables 'u', 'v' and 'w'.

**Table A1:** Values of Variables

DMU	V(i1)	V(i2)	V(i3)	U(o1)	W(d1)	W(d2)	W(d3)	n(g1)	n(g2)	n(g3)
DMU01	0.01	0.07	0.26	6.35	0.25	0.31	0.01	26.17	8.15	0.07
DMU02	0.01	0.17	0.01	14.18	0.58	0.88	0.01	58.42	18.20	0.09
DMU03	0.01	0.01	141.12	10.36	0.58	0.53	0.01	42.68	13.29	0.02
DMU04	535.12	0.15	15.50	53.60	1.68	5.84	0.01	171.61	101.60	0.04
DMU05	0.01	0.06	0.01	3.67	0.21	0.34	0.01	15.10	4.70	0.03
DMU06	0.01	0.17	0.01	15.05	0.60	0.84	0.01	73.58	16.02	0.21
DMU07	0.01	0.11	8.93	13.51	0.67	0.14	0.01	109.78	1.98	0.05
DMU08	0.01	0.17	0.01	27.55	0.68	0.62	0.01	180.31	16.39	0.17
DMU09	0.01	0.15	14.33	11.07	1.00	0.14	0.01	90.01	1.60	0.12
DMU10	0.01	0.17	0.01	11.52	0.52	0.96	0.01	47.46	14.78	0.03
DMU11	0.01	0.17	0.01	12.95	0.54	0.93	0.01	53.33	16.61	0.07
DMU12	0.01	0.01	199.98	12.99	0.73	0.89	0.01	53.54	16.68	0.01
DMU13	167.69	0.05	19.86	17.32	0.86	1.43	0.01	71.35	22.23	0.04
DMU14	0.01	0.25	1.41	17.07	0.97	1.14	0.01	71.35	21.91	0.05
DMU15	0.01	0.17	0.01	0.01	0.01	0.01	0.01	0.35	0.07	0.04
DMU16	0.01	0.01	175.43	10.95	0.75	0.61	0.01	45.12	14.06	0.01
DMU17	0.01	0.20	0.86	17.31	0.76	0.93	0.01	71.33	22.22	0.02
DMU18	845.83	0.22	75.00	75.19	3.25	8.53	0.01	258.39	130.77	0.01
DMU19	0.01	0.12	0.01	7.95	0.40	0.71	0.01	32.75	10.20	0.14
DMU20	99.20	0.25	0.01	57.14	1.19	0.01	5.61	166.91	0.09	1247.22
DMU21	0.01	0.17	0.01	10.01	0.53	0.96	0.01	41.23	12.84	0.01
DMU22	0.01	0.01	336.16	15.53	1.33	1.29	0.01	63.99	19.93	0.08
DMU23	0.01	0.01	166.31	12.85	1.04	0.01	0.01	113.43	0.06	0.07
DMU24	0.01	0.01	249.95	15.27	0.93	1.08	0.01	62.89	19.59	0.04
DMU25	0.01	0.14	16.44	18.34	0.99	0.01	0.15	156.33	0.07	7.52
DMU26	1030.51	0.17	0.01	47.67	0.47	9.01	14.49	40.46	127.15	415.35
DMU27	86.99	0.07	0.01	32.26	1.09	0.01	0.01	284.67	0.15	0.36
DMU28	0.01	0.12	0.01	2.97	0.01	1.38	0.01	0.07	15.78	0.01
DMU29	956.34	0.25	0.01	109.46	1.35	12.79	0.01	143.94	393.50	0.01
DMU30	786.19	0.20	0.01	90.09	0.96	10.71	0.01	98.26	349.86	0.01
DMU31	824.50	0.19	27.38	69.53	1.75	9.54	1.19	80.62	262.79	2.52

The GAMS program code is as follows.

```

$title phd Thesis SAJAD AKBARI
$title A Mixed Systems (Five-Division) Bnking Structur(1) NEW DATA
$onsymxref

```

\$onsymlist  
\$onuellist  
\$onuelxref

Sets

i "Iputs" /i1 ,i2 ,i3/  
r "Outputs" /o1/  
j "Units" /DMU01\*DMU31/  
d /d1,d2,d3/  
g /g1,g2,g3/;

Alias (1,j);

Parameters

xo(i) "Inputs of under evaluation DMU"  
yo(r) "Outputs of under evaluation DMU"  
zo(d)  
Bo(g)  
e0 "Efficiency of system"  
e1 "Efficiency of sub process1"  
e2 "Efficiency of sub process2"  
e3 "Efficiency of sub process3"  
e4 "Efficiency of sub process4"  
e5 "Efficiency of sub process5";

Scalar Epsilon /0.005/;

Variables

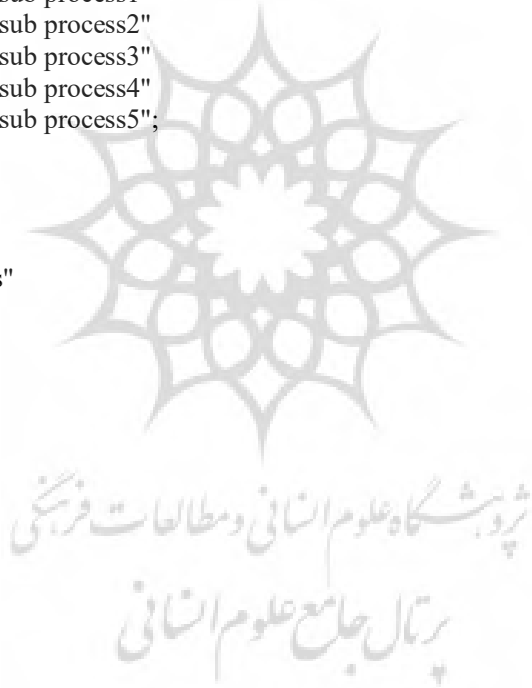
v(i) "Output weights"  
u(r) "Input weights"  
w(d)  
n(g)  
e "Efficiency";

Positive Variables

v  
u  
w  
n;

Equations

Objective1  
Const1  
Const2(j)  
Const3(j)  
Const4(j)  
Const5(j)  
Const6(j)  
Const7(d)  
Const8(i)



```

Const9(r)
Const10(g);
Objective1.. e=e=Sum(r,yo(r)*u(r));
Const1.. Sum(i,xo(i)*v(i))=e=1 ;
Const2(j).. Sum(d,z(d,j)*w(d))-Sum(i,x(i,j)*v(i))=l=0;
Const3(j).. (n('g1')*Bo('g1'))-(w('d1')*zo('d1'))=l=0;
Const4(j).. (n('g2')*Bo('g2'))-(w('d2')*zo('d2'))=l=0;
Const5(j).. (n('g3')*Bo('g3'))-(w('d3')*zo('d3'))=l=0;
Const6(j).. Sum(r,y(r,j)*u(r))-Sum(g,B(g,j)*n(g))=l=0;
Const7(d).. w(d)=g=Epsilon;
Const8(i).. v(i)=g=Epsilon;
Const9(r).. u(r)=g=Epsilon;
Const10(g).. n(g)=g=Epsilon;

Model Network_DEA_Model /All/;

File Network /Results.txt/;

Puttl Network 'Title ' System.title, @60 'Page' System.page//;

Put Network ;

Put @12'e', @19'v(i1)',@27'v(i2)',@35'v(i3)', @43'u(o1)',@51'w(d1)', @59'w(d2)', @67'w(d3)',
@75'n(g1)', @83'n(g2)', @91'n(g3)@100'e0', @108'e1', @116'e2', @125'e3', @132'e4', @140'e5'/;

Loop(l,
Loop(i,xo(i)=x(i,l));
Loop(r,yo(r)=y(r,l));
Loop(d,zo(d)=z(d,l));
Loop(g,Bo(g)=B(g,l));
Solve Network_DEA_Model Using LP Maximizing e;

Put l.tl:6;
Put e.l:8;
Loop(i,Put v.l(i):8);
Loop(r,Put u.l(r):8);
Loop(d,Put w.l(d):8);
Loop(g,Put n.l(g):8);

e0=(u.l('o1')*yo('o1'))/((v.l('i1')*xo('i1'))+(v.l('i2')*xo('i2'))+(v.l('i3')*xo('i3')));
Put e0:8;

e1=((w.l('d1')*zo('d1'))+(w.l('d2')*zo('d2'))+(w.l('d3')*zo('d3')))/((v.l('i1')*xo('i1'))+(v.l('i2')*xo('i2'))+
(v.l('i3')*xo('i3')));
Put e1:8;

e2=(n.l('g1')*Bo('g1'))/(w.l('d1')*zo('d1'));
Put e2:8;

e3=(n.l('g2')*Bo('g2'))/(w.l('d2')*zo('d2'));

```

Put e3:8;

$e4=(n.l('g3')*Bo('g3'))/(w.l('d3')*zo('d3'));$

Put e4:8;

$e5=(u.l('o1')*yo('o1'))/((w.l('d1')*zo('d1'))+(w.l('d2')*zo('d2'))+(w.l('d3')*zo('d3')));$

Put e5:8;

Put /;

Option decimals=4;

Display e.l,e.m;

Display v.l,u.l;

Display v.m,u.m);

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