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Data envelopment analysis modeling in a two-level network for performance measurement and prediction under uncertainty conditions using the game theory and data mining approach

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Abstract

Calculating and analyzing performance in organizations is of great importance. In this research, we aim to present a new approach in studies related to two-tier networks for evaluating and predicting cost efficiency under fuzzy uncertainty conditions in various provinces of Iran. Classic models have been combined with game theory, fuzzy theory, and data mining methods for this purpose. This combined model was used to evaluate the efficiency of provincial insurance and medical centers of the Social Security Organization of the country. As a result, the ranking of provincial units of the Social Security Organization of the country was determined based on their insurance and medical status, and smaller provinces such as Zanjan, Hamedan, and Qazvin had a higher level of efficiency than larger provinces such as East Azerbaijan, Kerman, and Mazandaran. The final innovation of this research can be considered the use of a more comprehensive combined model based on a fuzzy data envelopment analysis model with slack-based measure and neural network data mining model to evaluate the efficiency of provincial insurance and medical centers of the Social Security Organization of the country.

Keywords: Relation Efficiency; Cost Efficiency; Data Envelopment Analysis; Game Theory; Network Process; Data mining; Perceptron Neural Network; Time series.

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1. Introduction

In comparison to all models, data envelopment analysis is a better method for organizing and analyzing data because it allows for performance to change over time and does not require any assumptions about performance boundaries. Additionally, it can consider multiple inputs and outputs for each decision-making unit [1]. Data envelopment analysis is one of the most important non-parametric techniques in measuring efficiency, which measures the relative efficiency of evaluated units using mathematical modeling. The weakness of traditional models in evaluating the performance of network-structured processes led researchers to develop models to overcome this problem. In general, network data envelopment analysis refers to a category of models that have some common characteristics. These models do not have a specific formula and are formulated based on the structure of the network and the unit under study [2].

Various approaches have been proposed for modeling network structures, each with its own strengths and weaknesses. Game theory is one of the approaches that has attracted researchers' attention in recent years due to its significant advantages. On the other hand, most developed models in this field are only applicable to situations where the problem data is certain and deterministic, whereas these conditions are not always met in real-world problems. Therefore, there is a need for models that can be used in different uncertain conditions.

2. Research background

The possibility of such structures was first discussed by Charnes et al. [19]. Since then, extensive research has been carried out on identifying and modeling such structures. Some researchers have developed models for evaluating performance under specific conditions, while others have examined the properties and characteristics of models. Others have used existing models to solve real-world problems. Farr and Grosskopf [20] and Farr et al. [21] proposed several network data envelopment analysis models that can be used to extend traditional data envelopment analysis models for various scenarios. The first category of these models is static models, which, like traditional data envelopment analysis models, do not consider time but can model internal system processes. In this type of model, some outputs of certain processes are used as inputs for other processes (see [22], [23], [24] for examples). Two-stage data envelopment analysis models are a special type of these models. The second category is dynamic models in which some outputs of a process in one period are used as inputs for the same process in the next period, and they can be considered as intermediate criteria at each time unit (see [25], [26], [27], [28], [29]). The third category is technology acceptance or Shared flow models, which are used to allocate resources properly among different stages of production technologies. Kao [35] classified these models into nine categories, including independent models, system distance-based models, process distance-based models, agent-based distance-based models, variable deficiency and surplus-based models, Ratio-form system efficiency models, Ratio-form process efficiency models, game theory-based models, and value-based models. Farr and Grosskopf [20], based on the research by Shepherd [36] and Shepherd and Farr [37], proposed a set of models to address structures that traditional data envelopment analysis cannot handle. Kao and Huang [135] developed another model for calculating system efficiency by considering the serial relationship between two processes. The advantage of their model is that the overall efficiency of the system is the product of the efficiencies of its components. This advantage can be extended to serial systems with more than two processes [136]. Dantzig [183] formulated the general linear programming problem with uncertain data, and Dantzig and Madansky [184] proposed a probabilistic method for solving two-stage linear programming problems. Charnes and Cooper [185] introduced a special case of stochastic programming with chance constraints. Bell [186] presented a second-order programming approach for solving a series of problems that use stochastic programming.

3. Research Methodology

All scientific research is classified based on two criteria: a) purpose, and b) nature and method of data collection. Research is classified based on its purpose into three categories: fundamental, applied, and practical research. Fundamental research focuses on discovering scientific laws and principles. Applied research uses the knowledge and information gained from fundamental research to meet human needs and optimize tools, methods, objects, and patterns towards developing well-being, comfort, and improving the quality of life.

According to the mentioned classifications, since the results of this research can be used for ranking decision-making centers such as production units, hospitals, schools, libraries, projects, etc., it is applied research based on its purpose. Also, considering that operational research tools are used to model the input-output relationships of decision-making centers in order to calculate their efficiency, this research is classified as quasi-experimental in terms of research methodology.

The statistical population of this research is the insurance and medical data of the provinces of the country for the year 1399 in order to investigate the efficiency according to the determined model. Data collection methods are generally divided into two categories: library and field methods. In this study, a library method was used to gather information. A library method was also used to complete the literature review and theoretical foundations of the research. The data collection tool is the website of the Social Security Organization.

The general research model is presented in Figure (3-1). Based on the presented model, information analysis methods include two-level network coverage data analysis, fuzzy transformation method for input data due to the uncertain nature of the data, game theory methods due to the competitive nature of the units in coverage analysis data such as two-stage centralized method, Nash bargaining and Stakelberg for calculating network efficiency based on the performance of components and how they interact with each other. Finally, time series and neural network methods are used to predict overall efficiency.

4. Research Findings:

In this section, we compare the results obtained from three methods: centralized method, Nash bargaining method, and Stakelberg method.

- 4.1. Comparison of overall efficiency using the three methods of centralized, Nash bargaining, and Stakelberg for alpha equal to 0.5.

The results obtained from the three methods are compared and presented in the table below.

Table (1): Results with three focused methods, Nash Bargaining, Shapley Value, and Concentration for alpha equal to 0.5.

MU Unit	Province Name	Total Efficiency of Centralized Method	Total Efficiency of Non-Centralized Method	Total Efficiency of Stochastic Frontier Analysis Method
1	East Azerbaijan	0.001	0.109	0.003
2	West Azerbaijan	0.431	0.431	0.431

MU Unit	Province Name	Total Efficiency of Centralized Method	Total Efficiency of Non-Centralized Method	Total Efficiency of Stochastic Frontier Analysis Method
3	Ardabil	0.420	0.419	0.420
4	Isfahan	0.001	0.290	0.003
5	Alborz	0.201	0.201	0.201
6	Ilam	0.242	0.241	0.242
7	Bushehr	0.576	0.576	0.576
8	Tehran	0.000001	0.784	0.000001
9	Chaharmahal and Bakhtiari	0.525	0.525	0.525
10	South Khorasan	0.513	0.513	0.513
11	Razavi Khorasan	0.001	0.370	0.004
12	North Khorasan	0.694	0.681	0.694
13	Khuzestan	0.001	0.251	0.003
14	Zanjan	0.832	0.832	0.832
15	Semnan	0.785	0.783	0.785
16	Sistan and Baluchestan	0.303	0.303	0.305
17	Fars	0.0003	0.111	0.001

MU Unit	Province Name	Total Efficiency of Centralized Method	Total Efficiency of Non-Centralized Method	Total Efficiency of Stochastic Frontier Analysis Method
18	Qazvin	0.810	0.792	0.811
19	Qom	0.301	0.301	0.301
20	Kurdistan	0.432	0.418	0.432
21	Kerman	0.0001	0.081	0.002
22	Kermanshah	0.315	0.315	0.315
23	Kohgiluyeh and Boyer-Ahmad	0.515	0.515	0.515
24	Golestan	0.533	0.527	0.563
25	Gilan	0.196	0.196	0.196
26	Lorestan	0.485	0.485	0.485
27	Mazandaran	0.0003	0.075	0.002
28	Markazi	0.552	0.552	0.620
29	Hormozgan	0.228	0.228	0.228
30	Hamadan	0.800	0.800	0.800
31	Yazd	0.600	0.600	0.600

According to the above table, it can be concluded that the results obtained from the Nash bargaining method are more reasonable compared to the concentrated and Stackelberg methods.

- 4.2. Comparison of overall performance using three methods, Nash bargaining and Stackelberg method for alpha equals zero.

Comparison of the results obtained from three focused methods, Nash bargaining method, and Stackelberg method for alpha equals zero are presented in the table below.

Table (2): Results obtained from three pure methods, no-till, and Stolberg methods for alpha equal to zero.

Unit DMU	Province Name	Total Efficiency of Centralized Method	Total Efficiency of Non-Radial Slacks-Based Measure Method	Total Efficiency of Stochastic Frontier Analysis Method
1	East Azerbaijan	0.0005	0.177	0.417
2	West Azerbaijan	0.439	0.433	0.439
3	Ardabil	0.419	0.419	0.419
4	Isfahan	0.0006	0.290	0.359
5	Alborz	0.201	0.201	0.201
6	Ilam	0.240	0.240	0.240
7	Bushehr	0.576	0.576	0.576
8	Tehran	0.001	0.784	0.090
9	Chaharmahal and Bakhtiari	0.525	0.525	0.525
10	South Khorasan	0.513	0.513	0.513
11	Razavi Khorasan	0.0008	0.412	0.427

Unit DMU	Province Name	Total Efficiency of Centralized Method	Total Efficiency of Non-Radial Slacks-Based Measure Method	Total Efficiency of Stochastic Frontier Analysis Method
12	North Khorasan	0.698	0.698	0.698
13	Khuzestan	0.0001	0.274	0.032
14	Zanjan	0.603	0.843	0.603
15	Semnan	0.692	0.780	0.692
16	Sistan and Baluchestan	0.243	0.285	0.245
17	Fars	0.0003	0.093	0.124
18	Qazvin	0.732	0.809	0.733
19	Qom	0.301	0.301	0.301
20	Kurdistan	0.369	0.419	0.369
21	Kerman	0.0001	0.151	0.340
22	Kermanshah	0.315	0.315	0.315
23	Kohgiluyeh and Boyer-Ahmad	0.460	0.516	0.194
24	Golestan	0.461	0.531	0.470
25	Gilan	0.196	0.196	0.196
26	Lorestan	0.468	0.485	0.468

Unit DMU	Province Name	Total Efficiency of Centralized Method	Total Efficiency of Non-Radial Slacks-Based Measure Method	Total Efficiency of Stochastic Frontier Analysis Method
27	Mazandaran	0.0003	0.075	0.232
28	Markazi	0.553	0.553	0.621
29	Hormozgan	0.223	0.228	0.223
30	Hamadan	0.583	0.809	0.583
31	Yazd	0.601	0.601	0.601

Based on the above table, it can be concluded that the results obtained from the Nash bargaining method are more reasonable compared to the concentrated and Stackelberg methods.

- 4. 3. Comparison of the Nash bargaining method for alpha values of 0.5 and 0

Considering the more desirable results obtained from the Nash bargaining method for alpha values of 0.5 and 0 in the above tables, the comparison of these values for the Nash bargaining method is presented in the table below.

Table (3): Results obtained from Nash bargaining method for alpha values of 0.5 and 0.

DMU unit	Province name	Alpha = 0	Alpha = 0.5
1	East Azerbaijan	0.177	0.109
2	West Azerbaijan	0.433	0.431
3	Ardabil	0.419	0.419
4	Isfahan	0.290	0.290

DMU unit	Province name	Alpha = 0	Alpha = 0.5
5	Alborz	0.201	0.201
6	Ilam	0.240	0.241
7	Bushehr	0.576	0.576
8	Tehran	0.784	0.784
9	Chaharmahal and Bakhtiari	0.525	0.525
10	South Khorasan	0.513	0.513
11	Razavi Khorasan	0.412	0.370
12	North Khorasan	0.698	0.681
13	Khuzestan	0.274	0.251
14	Zanjan	0.843	0.832
15	Semnan	0.780	0.783
16	Sistan and Baluchestan	0.285	0.303
17	Fars	0.093	0.111
18	Qazvin	0.809	0.792
19	Qom	0.301	0.301
20	Kurdistan	0.419	0.418
21	Kerman	0.151	0.081
22	Kermanshah	0.315	0.315
23	Kohgiluyeh and Boyer-Ahmad	0.516	0.515

DMU unit	Province name	Alpha = 0	Alpha = 0.5
24	Golestan	0.531	0.527
25	Gilan	0.196	0.196
26	Lorestan	0.485	0.485
27	Mazandaran	0.075	0.075
28	Markazi	0.553	0.552
29	Hormozgan	0.228	0.228
30	Hamedan	0.809	0.800
31	Yazd	0.601	0.600

- 4. 4. Final ranking of the insurance and medical efficiency of social security centers in the provinces of the country using the Nash bargaining method.

The ranking of the insurance and medical efficiency of social security centers in the provinces of the country using the Nash bargaining method for alpha values of 0.5 and 0 based on the degree of high efficiency is presented in the table below.

Table (4): Results of the ranking of insurance and medical efficiency of social security centers in the provinces of the country using the Nash bargaining method for alpha values of 0.5 and 0.

One DMU	Province Name	Nash bargaining method	Nash bargaining method
		Alpha = 0	Alpha = 0.5
14	Zanjan	0.832	0.843
30	Hamedan	0.8	0.809
18	Qazvin	0.792	0.809
8	Tehran	0.784	0.784

One DMU	Province Name	Nash bargaining method	Nash bargaining method
15	Semnan	0.783	0.78
12	North Khorasan	0.681	0.698
31	Yazd	0.6	0.601
7	Bushehr	0.576	0.576
28	Mehrjerd (Markazi)	0.552	0.553
24	Golestan	0.527	0.531
9	Chaharmahal and Bakhtiari	0.525	0.525
23	Kohgiluyeh and Boyer-Ahmad	0.515	0.516
10	South Khorasan	0.513	0.513
26	Lorestan	0.485	0.485
2	West Azerbaijan	0.431	0.433
3	Ardabil	0.419	0.419
20	Kurdistan	0.418	0.419
11	Razavi Khorasan	0.37	0.412
22	Kermanshah	0.315	0.315
16	Sistan and Baluchestan	0.303	0.285
19	Qom	0.301	0.301

One DMU	Province Name	Nash bargaining method	Nash bargaining method
4	Esfahan	0.29	0.29
13	Khuzestan	0.251	0.274
6	Ilam	0.241	0.24
29	Hormozgan	0.228	0.228
5	Alborz	0.201	0.201
25	Gilan	0.196	0.196
17	Fars	0.111	0.093
1	East Azerbaijan	0.109	0.177
21	Kerman	0.081	0.151
27	Mazandaran	0.075	0.075

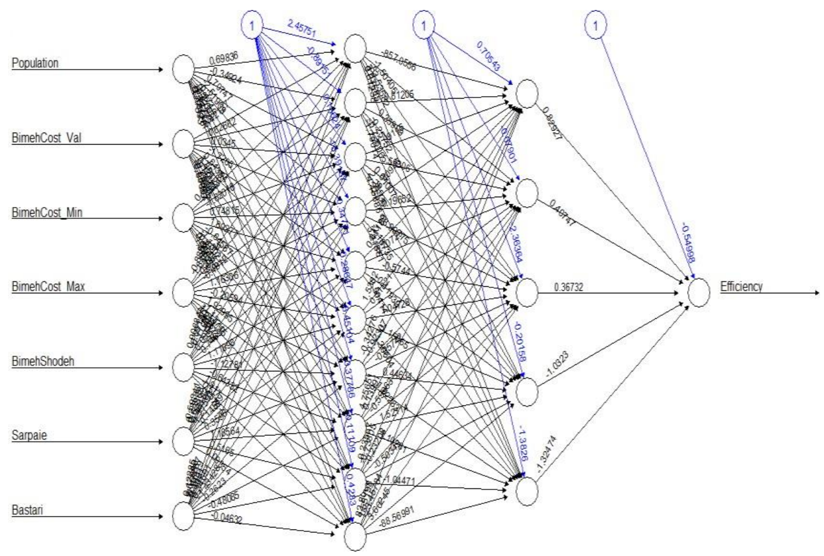
According to the above table, smaller provinces such as Zanjan, Hamedan, and Qazvin had a higher level of efficiency compared to larger provinces such as East Azerbaijan, Kerman, and Mazandaran in terms of insurance and medical efficiency of social security centers using the Nash bargaining method.

4-5 Simulation with Neural Networks

Neural networks are powerful tools for prediction that, unlike traditional statistical methods, can approximate systems with nonlinear structures. One of the most commonly used techniques in neural networks for prediction is multi-layer perceptron networks. Therefore, in this study, a multi-layer perceptron neural network was used to predict the future efficiency value of units. The results obtained from this prediction indicate the appropriate estimation of this technique. The number of layers in a neural network is another important criterion in its design. The common number of layers for a three-layer network architecture is used. The first layer is dedicated to inputs, while the middle layer is composed of neurons that perform calculations on the inputs. It should be noted that a three-layer neural network is capable of simulating any type of nonlinear equations. However, depending on the problem, there may be a need for more layers. The number of layers in a neural network is determined by trial and error method in a problem. In this study, a three-layer neural network was used. Usually, sigmoid, hyperbolic tangent, or sigmoid tangent functions are used for the hidden layer in neural networks. In this study, 'purelin' and 'tansig' functions were used for the first, second, and third layers, respectively. The backpropagation training process in the network is performed by determining how the learning records are placed in the network and with what distribution. The initial weights of the connections between neurons are randomly determined by the network. Then, using the existing weights, the output of the network is calculated and compared with the actual output. In this way, the level of network error is calculated, and if the amount of error differs from the desired value in the network, the network continues its work again, and by changing the initial coefficients and repeating the previous steps, it continues until it reaches an acceptable level of error.

To obtain the appropriate structure for a neural network, trial and error method is usually employed. In this way, a four-layer perceptron neural network including input layer, hidden layers 1 and 2, and output layer has been used. The number of neurons in the input and output layers of neural networks depends on the nature of the problem. However, it is not possible to obtain an exact number of neurons in the hidden layer and this is another issue that must be estimated through trial and error. In this study, a four-layer neural network including input, output, and two hidden layers has been used with 10 and 5 neurons in the first and second hidden layers, respectively. The neural network model is as follows in Fig. 1.

Fig. 1. of the designed neural network.



To achieve this, first the performance values of provincial units of the Social Security Centers along with other data values of that organization are entered into Excel. Then, they are used in a neural network simulation using R software. In this section, the training, testing, and validation data are introduced, and their corresponding results are discussed.

4.6. Training Data Simulation

Training data refers to a set of data that includes known answers used during the neural network training process. In other words, this dataset is used to train the neural network model. The best results obtained from a neural network that was not based on Nash bargaining method were used to design the neural network for training. This neural network is listed in the table 5 below.

Table (5): Input Data Table for the Neural Network Model

Row	Province	Population	Total Healthcare Cost (million Rials)	Lower Bound of Healthcare Costs	Upper Bound of Healthcare Costs	Total Number of Insured Persons (Primary and Subsidiary)	Total Number of Outpatient Visits to Paraclinical Centers in the Province	Total Number of Inpatient Beds	Efficiency Rate
1	East Azerbaijan	4,110,780	2,386,035	1,966,513	2,622,017	1,798,772	3,878,337	22,206	0.109
2	West Azerbaijan	3,433,195	1,411,060	1,162,962	1,550,615	1,087,989	2,966,591	12,373	0.431
3	Ardabil	1,335,776	5,605,099	4,619,587	6,159,449	518,218	1,821,837	11,828	0.419
4	Isfahan	5,384,287	36,466,444	30,054,761	40,073,015	2,901,619	7,883,910	47,822	0.290
5	Alborz	2,851,937	10,380,133	8,555,055	11,406,740	1,168,376	2,754,568	5,133	0.201

6	Ilam	610,004	2,449,543	2,018,854	2,691,805	247,859	643,893	244	0.241
7	Bushehr	1,223,250	5,417,496	4,464,969	5,953,292	897,826	2,217,021	17,411	0.576
8	Tehran	13,950,178	67,503,033	55,634,367	74,179,157	7,845,889	12,502,381	78,547	0.784
9	Chaharmahal and Bakhtiari	996,520	3,748,374	3,089,319	4,119,092	408,912	1,883,890	9,156	0.525
10	South Khorasan	808,453	566,424	466,833	622,444	340,956	1,092,528	4,067	0.513
11	Razavi Khorasan	6,765,518	3,080,194	2,538,622	3,384,829	2,490,742	4,804,883	31,323	0.370
12	North Khorasan	907,493	544,355	448,644	598,192	295,797	1,196,438	7,769	0.681
13	Khuzestan	4,952,837	30,148,447	24,847,621	33,130,161	2,510,873	8,234,150	25,251	0.251
14	Zanjan	1,111,861	723,670	596,431	795,242	464,905	1,489,902	13,083	0.832
Row	Province	Population	Total Healthcare Cost (million Rials)	Lower Bound of Healthcare Costs	Upper Bound of Healthcare Costs	Total Number of Insured Persons (Primary and Subsidiary)	Total Number of Outpatient Visits to Paraclinical Centers in the Province	Total Number of Inpatient Beds	Efficiency Rate
15	Semnan	738,492	1,971,739	1,625,059	2,166,746	424,402	2,042,590	5,974	0.783

16	Sistan and Baluchestan	2,917,772	4,771,604	3,932,640	5,243,521	727,513	2,696,389	11,986	0.303
17	Fars	5,100,843	28,408,789	23,413,837	31,218,449	1,929,042	2,896,328	14,035	0.111
18	Qazvin	1,339,288	3,995,799	3,293,241	4,390,988	663,984	2,345,204	21,654	0.792
19	Qom	1,358,763	5,914,781	4,874,819	6,499,759	697,636	1,739,116	7,488	0.301
20	Kurdistan	1,685,476	4,351,687	3,586,555	4,782,074	560,408	1,638,967	12,699	0.418
21	Kerman	3,327,524	13,079,947	10,780,176	14,373,568	1,312,359	2,787,318	34,389	0.081
22	Kermanshah	2,052,875	9,022,872	7,436,433	9,915,244	643,372	2,149,821	14,049	0.315
23	Kohgiluyeh and Boyer-Ahmad	749,734	2,018,514	1,663,610	2,218,147	276,379	1,269,178	5,948	0.515
24	Golestan	1,964,959	4,746,502	3,911,952	5,215,936	710,973	2,275,202	19,408	0.527
25	Gilan	2,660,885	19,687,270	16,225,772	21,634,362	988,817	2,499,550	9,924	0.196
26	Lorestan	1,851,224	7,132,723	5,878,618	7,838,157	615,981	3,615,810	15,946	0.485
27	Mazandaran	3,452,503	15,760,261	12,989,226	17,318,968	1,636,428	2,550,904	20,849	0.075
28	Markazi	1,503,013	13,347,388	11,000,594	14,667,459	796,839	3,067,701	20,365	0.552
29	Hormozgan	1,867,801	7,508,033	6,187,939	8,250,586	889,996	1,021,991	11,106	0.228

30	Hamedan	1,827,656	1,051,590	866,695	1,155,593	653,999	2,172,692	20,328	0.80
31	Yazd	1,197,104	11,245,481	9,268,254	12,357,672	826,381	2,585,931	15,727	0.60

After providing the aforementioned input data table to the neural network model designed in R, the performance level was calculated as follows in table 6.

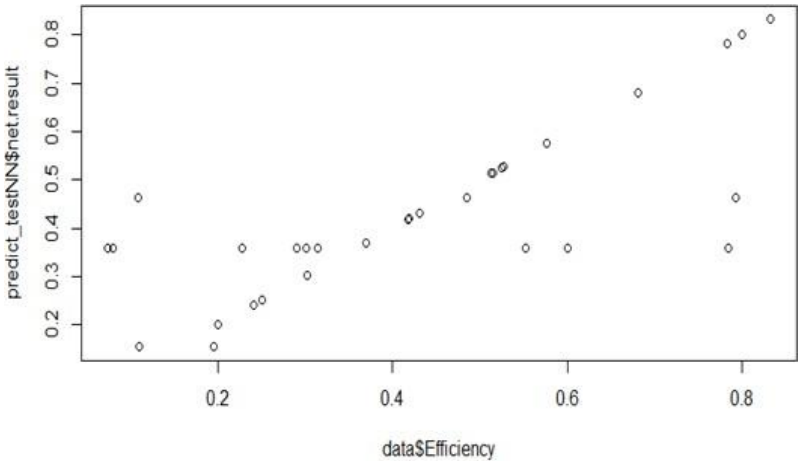
Table (6): Training Results Table Comparing Calculated and Predicted Performance with the Neural Network

Row	Province	Calculated Efficiency	Estimated Efficiency Using Neural Network
1	East Azerbaijan	0.109	0.4620
2	West Azerbaijan	0.431	0.4310
3	Ardabil	0.419	0.4190
4	Isfahan	0.290	0.3584
5	Alborz	0.201	0.2009
6	Ilam	0.241	0.2410
7	Bushehr	0.576	0.5759
8	Tehran	0.784	0.3584
9	Chaharmahal and Bakhtiari	0.525	0.5251
10	South Khorasan	0.513	0.5130
11	Razavi Khorasan	0.370	0.3700
12	North Khorasan	0.681	0.6809
13	Khuzestan	0.251	0.2509

Row	Province	Calculated Efficiency	Estimated Efficiency Using Neural Network
14	Zanjan	0.832	0.8320
15	Semnan	0.783	0.7830
16	Sistan and Baluchestan	0.303	0.3029
17	Fars	0.111	0.1535
18	Qazvin	0.792	0.4620
19	Qom	0.301	0.3584
20	Kurdistan	0.418	0.4179
21	Kerman	0.081	0.3584
22	Kermanshah	0.315	0.3584
23	Kohgiluyeh and Boyer-Ahmad	0.515	0.5148
24	Golestan	0.527	0.5270
25	Gilan	0.196	0.1535
26	Lorestan	0.485	0.4620
27	Mazandaran	0.075	0.3584
28	Markazi	0.552	0.3584
29	Hormozgan	0.228	0.3584
30	Hamadan	0.800	0.7999
31	Yazd	0.600	0.3584

Fig. 2 displays the results of comparing the training data and the neural network results. In addition, the MSE value is equal to 0.02254, and the RMSE value is equal to 0.15013.

Fig. 2. Training Data Results



4.7. Validation Data Simulation

The importance of validation data is to prevent overfitting. When the training process is performed by training data, we use validation data to examine that the system is not too dependent on the training data. The validation data table belongs to the 10-year insurance and medical performance of the Social Security Organization in Tehran province, which is shown in the table 7 below.

Table (7): Validation Data Table for the Neural Network Model.

Year	Province Population	Total Healthcare Costs (Million Rials)	Minimum Healthcare Costs (Million Rials)	Maximum Healthcare Costs (Million Rials)	Total Number of Insured (Primary and Secondary)	Number of Outpatient Visits to Paraklinik Centers	Number of Hospital Admissions	Calculated Efficiency
1390	12,474,845	27,395,349	19,113,034	31,855,057	6,592,547	8,976,760	108,590	0.66
1391	12,628,450	34,342,257	28,149,391	39,409,147	6,878,017	9,580,117	110,761	0.69
1392	12,784,656	40,519,752	35,031,486	46,708,648	7,132,989	9,924,345	107,069	0.71

Year	Province Population	Total Healthcare Costs (Million Rials)	Minimum Healthcare Costs (Million Rials)	Maximum Healthcare Costs (Million Rials)	Total Number of Insured (Primary and Secondary)	Number of Outpatient Visits to Paraklinik Centers	Number of Hospital Admissions	Calculated Efficiency
1393	12,943,020	41,953,459	26,893,243	53,786,486	7,385,375	9,831,857	119,013	0.74
1394	13,104,040	51,789,040	21,760,101	65,280,303	7,649,934	9,918,179	117,188	0.77
1395	13,267,761	52,029,357	28,905,198	86,715,595	7,685,432	9,715,732	118,411	0.77
1396	13,457,494	56,425,644	29,388,356	88,165,069	7,813,896	10,390,585	120,644	0.78
1397	13,625,817	58,799,476	47,114,965	65,960,951	7,735,496	10,181,465	116,332	0.77
1398	13,790,321	60,230,367	51,166,574	65,785,595	7,923,740	9,506,767	108,448	0.79
1399	13,950,178	67,503,033	55,634,367	74,179,157	7,845,889	12,502,381	78,547	0.78

The estimated performance level using the neural network is as follows in table 8.

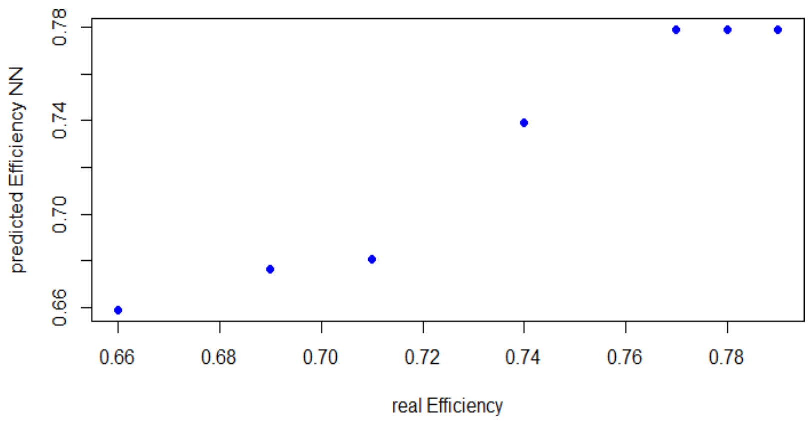
Table (8): Validation Results Table Comparing Calculated and Predicted Performance with the Neural Network.

Year	calculated performance value	estimated performance value using a neural network
1390	0.66	0.6590
1391	0.69	0.6764
1392	0.71	0.6805
1393	0.74	0.7390

Year	calculated performance value	estimated performance value using a neural network
1394	0.77	0.7789
1395	0.77	0.7789
1396	0.78	0.7789
1397	0.77	0.7789
1398	0.79	0.7789
1399	0.78	0.7789

Fig. 3 displays the results of comparing the validation data and the neural network results. In addition, the MSE value is equal to 0.00000012, and the RMSE value is equal to 0.00034.

Fig. 3. Validation Data Results.



4.8. Test Data Simulation

Test data refers to a set of data that includes unknown answers used after the neural network training process. This dataset is used to evaluate the performance of the trained model. To do this, first, using prediction functions in R, the values of other input and output variables for the insurance and medical centers of the Social Security Organization were estimated for six years from 2021 to 2026. Then, the level of performance was calculated based on these estimates.

The following table displays estimated test data related to the 6-year insurance and medical performance of the Social Security Organization in Tehran province.

The estimated performance level using the neural network is as follows in table 9.

Table (9): Test Results Table Comparing Calculated and Predicted Performance with the Neural Network.

alculated Efficiency Ratio	Number of inpatient admissions	Number of Visits to Paraclinical Centers	Total Number of Insured Persons (Primary and Secondary)	Maximum Medical Cost (Million Rials)	Minimum Medical Cost (Million Rials)	Total Medical Costs of Province (Million Rials)	Population of Province	Year
0.799	90,097	14,558,750	7,985,034	77,716,195	59,006,741	71,959,440	14,113,890	1400
0.795	101,586	13,369,150	7,947,249	82,529,161	62,661,030	76,415,890	14,277,780	1401
0.805	103,582	13,827,230	8,053,749	87,342,116	66,315,311	80,872,330	14,441,670	1402
0.804	105,578	14,285,310	8,042,579	92,155,082	69,969,600	85,328,780	14,605,560	1403
0.813	107,575	14,743,390	8,127,373	96,968,038	73,623,880	89,785,220	14,769,440	1404
0.813	109,571	15,201,470	8,133,904	101,781,004	77,278,169	94,241,670	14,933,330	1405

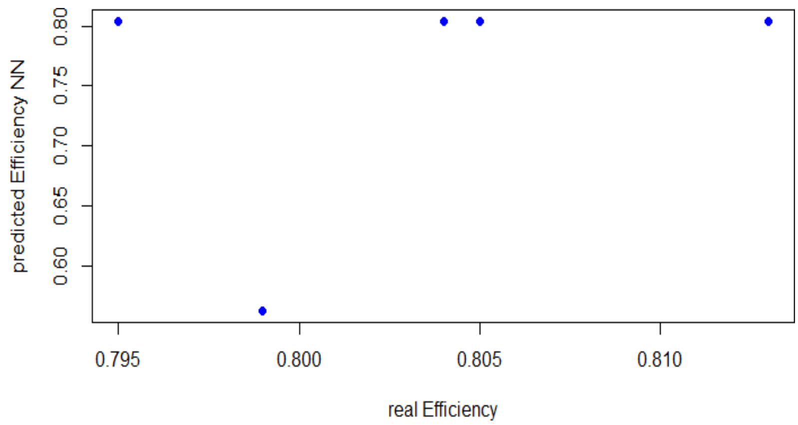
The estimated efficiency using a neural network is shown below in the following table 10.

Table (10): Comparison Table of Calculated Efficiency and Estimated Efficiency using a Neural Network.

Estimated Efficiency using Neural Network	Calculated Efficiency	Year
0.5632364	0.799	1400
0.8036098	0.795	1401
0.8036098	0.805	1402
0.8036098	0.804	1403
0.8036098	0.813	1404
0.8036041	0.813	1405

Fig. 4 displays the results of comparing the test data and the neural network results. In addition, the MSE value is equal to 0.0000147, and the RMSE value is equal to 0.00383.

Fig. 4. Test Data Results.



5. Research and Conclusion

Since measuring performance as a guiding light and compass for all management activities is essential, and sustainable growth and development of organizations and institutions in the country and its consequences, such as national economic growth, depend on measurement, analysis, comparison, and taking necessary and essential actions in this field. Therefore, the issue of performance measurement has become increasingly important day by day. In this regard, measuring the performance of companies, organizations, processes, units, and personnel is so important that we believe it is one of the main duties and responsibilities of every organization's management to address this issue. One of the suitable and effective tools in this field is data envelopment analysis (DEA), which is used as a non-parametric method to calculate the efficiency of decision-making units. The use of DEA models not only determines the relative efficiency but also identifies the weaknesses of the organization in various indicators and by presenting their desired level, it determines the organization's policy towards improving efficiency and productivity. In addition, efficient patterns that have been used to evaluate inefficient units are introduced to these units. Efficient patterns are those units that have produced more outputs or the same outputs with less inputs with similar inputs to the inefficient unit.

As mentioned, classical data envelopment analysis models are powerful in determining and identifying efficient units, but they sometimes have weaknesses in ranking inefficient units or, in other words, the majority of units. In this study, by using game theory methods, especially Nash bargaining and Stackelberg Analysis, and comparing the results, a suitable method has been provided for distinguishing the separability of the efficiency of a two-stage network."

5.1. Conclusion

The presentation of models for calculating the efficiency of network-structured processes has attracted a lot of attention from data envelopment analysis researchers in recent years. Considering the limitations of classical models in measuring the efficiency of network-structured processes, researchers have always been looking to develop suitable data envelopment analysis models to overcome this problem.

A multi-stage structure is a special type of network structure in which the outputs of each stage are used as inputs for the next stage. Two-stage data envelopment analysis models are the most commonly used types of models developed in this field to optimize the efficiency of dynamic network processes. These models are capable of calculating not only the overall efficiency score but also the efficiency scores for each stage. Various approaches exist for modeling two-stage processes.

Based on the results of this research, the following findings can be listed:

1- The use of a model based on two-stage fuzzy coverage analysis using the shuffling method enables appropriate discrimination and ranking for evaluating the performance of provincial insurance and healthcare centers under the supervision of the national social security organization.

2- According to the first case, ranking of the performance of provincial units under the jurisdiction of the national social security organization was carried out based on their insurance and healthcare status, and their performance was determined accordingly. The main point of this ranking was that smaller provinces such as Zanjan, Hamedan, and Qazvin were placed at a higher level of performance compared to larger provinces like East Azerbaijan, Kerman, and Mazandaran.

3- In conventional models of data envelopment analysis, they always assume one unit to be efficient and then evaluate its efficiency by comparing it to other units. This not only takes a lot of time but also leads to the determination of many efficient units. Therefore, sometimes it is not possible to determine the most efficient unit.

4- The use of analytical models such as data envelopment analysis, game theory, and data mining neural network models were among the other features of this research. The first part was used to evaluate the performance of existing social security centers based on available data, while the second part was used to predict the future performance of social security centers based on estimated data.

5- As the final innovation of this research, the use of a comprehensive combined model based on fuzzy data envelopment analysis with the shuffling method, along with a data mining neural network model, can be considered for evaluating the performance of provincial insurance and healthcare centers under the supervision of the national social security organization.

5.2. Suggestions for Future Research

In this section, the following suggestions are presented for future research:

1) Since the developed models in this research are under fixed scale return conditions, developing these models for variable scale return conditions could be a suitable research area for the future.

2) The proposed model for two-stage processes, in which the possibility of external outputs for the first and second stages or external inputs for the second stage exists, is not applicable. Therefore, developing models for evaluating processes with such structures is suggested as a research area for the future.

3) Developing proposed models of this research for evaluating processes with undesirable data can be suggested as a research area for the future.

4) Developing a model from a two-level state to a three-level state or higher can be one of the research areas in this field.

5) The method introduced in this research for prediction using time series function with artificial neural network approach is Perceptron. As a suggestion for future research, it is recommended to also experiment with Recurrent Neural Networks (RNNs) or Memory-Based Recurrent Neural Networks.

6) In addition to the above theoretical improvements, other practical areas can also be considered for the proposed methodology. Although this methodology has been used in the field of power networks in Iran, it can also be applied in all other fields.

Declarations

* There is no funding related to this work.

* The authors of this paper have no declaration of interest of any sort.

* The data related to this work is not available.

* The code related to this work is not available.

* Both of the authors of this paper have contributed equally in the writing of this paper including research, simulation and experimental test.

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