International Journal of Applied Operational Research
Vol. 9, No. 3, pp. 21-27, Summer 2019

Journal homepage: ijorlu.liau.ac.ir

Evaluation of performance of different units of Water and Wastewater Company using DEA

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Received: 1 March 2019 ; **Accepted:** 10 June 2019

Abstract In this paper, the performance of [different] units of Water and Sewage Company in Isfahan Province was evaluated using Data Envelopment Analysis (DEA). The purpose of this study was to provide a clear picture of the relative performance of Decision-Making Units (DMUs) in 2018. The advantage of using the DEA model over parametric models is to measure the performance of units using specific weights. In this study, data were collected through desk studies, and then, analyzed using mathematical modeling (linear programming). MATLAB was used to analyze the data indicating that 11 out of 30 units were efficient and the rest were inefficient.

Keyword: Data Envelopment Analysis, Performance Evaluation, Water and Wastewater Company.

1 Introduction

With the advancement of technology and the expanding role of factories and service organizations in today's human life follow the never-ending establishment of different and new organizational units in cities and villages. In multi-unit organizations, the first fundamental question formed in the minds of their senior executives is: Which unit performs the best? i.e., how is the performance of other units? [1].

In addition to increasing the motivation among employees and encouraging units to create added value in manufacturing goods and services, continuous assessment of the performance of units well illustrates the necessity of coming up with mechanisms to overcome the problems and obstacles on the way of units with poorer performance and preventing the loss of resources [2].

Performance management refers to the establishment of a system for the application of information about the measurement of the organization's performance through the use of performance evaluation results in setting goals, allocating resources, and informing managers to maintain or modify existing policies in order to achieve goals [3].

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2 Statement of the problem

According to definitions, efficiency shows that how good an organization (or an organizational unit) has taken advantage of its resources for the best production [4].

If the efficiency of the studied units is known, a clear picture of the status of decision-making units can be presented. However, the efficiency of decision-making units is influenced by several indicators (criteria or variables), causing the confusion of managers and decision makers of the organization [5].

Put simply, a unit may have a good status in a specific indicator (criterion) but it has a poor status in another indicator. In fact, with the help of the importance (weight) of each indicator as well as multi-criteria decision-making techniques (MCDM), the problem can be resolved to some extent. In this approach, the bias of the importance (weight) of decision-making criterion for some of the units is not much far-fetched. To solve this problem, nonparametric methods such as data envelopment analysis can be used.

2.1 The significance of research

The present research is of importance from the following perspectives:

- The number of decision-making units is not always constant. In other words, some new units may be added to previous ones over time.
- Even if the number of decision-making units remains constant over time, the performance of each unit may alter several reasons such as layoffs, reduced employee motivation, market demand changes, environmental conditions, and climatic conditions.
- Newer parameters may be raised as the indicators for performance assessment and some of the previous indicators play a less decisive role in determining the efficiency of the units.

2.2 Research questions

1- What are the most important factors in evaluating the efficiency of different units of Water and Wastewater Company?
2- How is the ranking of different units of Water and Wastewater Company using DEA?

2.3 Research objectives

Although many studies have been carried out on performance evaluation over recent years, it should be noted that they have mainly used parametric multi-criteria decision-making techniques which require the determination of the importance (weight) of each of the decision variables. In the present study, the constraint on the importance of each of the decision variables will be overcome and the options will be ranked using a mathematical programming model. Therefore, the present research aims to identify the most important factors in ranking the performance of different units of Water and Wastewater Company and rank the units of this company using the DEA model.

3 The concept of efficiency

Efficiency refers to the awareness of how to get things done. Correct conduction of works is realized when each input produces more useful output. If an organization can achieve a specific goal by spending a smaller amount of resources compared to another organization, it can be stated that the former organization has a higher efficiency. In other words, efficiency means the minimum amount of time or energy consumed for doing maximum works or the ratio of the amount of work done to the amount of work expected to be done [6].

3.1 Data envelopment analysis

DEA is a method used to measure the relative technical efficiency of different organizational units. This model was developed in 1976 and then introduced to the world of science by Charnes, Cooper, and Rhodes (CCR model) in 1978 in an article entitled “Measurement of Decision-Making Units”. In this model, the importance of each of the features is considered in a way to depict the best performance status for each of the decision-making units [7]. Hence, the CCR model will be used in this study in order to rank the decision-making units in Water and Wastewater Company.

3.2 DEA-CCR method

The CCR method aims to maximize the efficiency fraction of the studied units by choosing optimal weights for input and output variables in a way that the efficiency of other units does not exceed the upper limit of one. Constant returns to scale means that every set of inputs produces the same number of outputs. The CCR model assumes a constant value of returns to scale for units. Therefore, small and large units are compared with each other. This model can be established as follows for *n* decision units with *m* input indices and *s* output indices:

$$
\begin{aligned}
&\text{Max } \mathrm{E_o} = \sum_{r=1}^{s} u_r y_{ro} \\
&s.t. \textstyle\sum_{i=1}^{m} v_i x_{io} = 1, \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \qquad j = 1, \dots, n, \\
&u_r, v_i \geq 0.
\end{aligned}
\tag{1}
$$

As it can be observed, the above-mentioned mode is output-oriented. This means that the inputs are kept constant in order to maximize the outputs [8].

4 Organization studied

In this paper, the performance of thirteen units of the sub-units of Isfahan Water and Wastewater Company based on the indicators determined from the views of the experts of the organization will be performed. Due to the confidentiality of the information of the organization, mentioning names of all units is refused.

4.1 Identification of input and output indicators

Based on the experience of the experts of the organization, eight important indicators will be used to evaluate the decision-maker units. Two cases of these indicators are cost (input) and other cases are income (output). The title of these indicators is presented in Table 1.

Table 1 Inputs and outputs used in the evaluation of different units of the company

Inputs		**Outputs**					
I_1	I_2	O_1	O_2	O_3	O_4	O_5	O_6
Sewage maintenance and maintenance budget	Water maintenance and maintenance budget	The amount of sewage intubation	The amount of water intubation	The total discharge of sewage	The total discharge of water	The amount of performance to the discharge of sewage budget	The amount of performance to the discharge of water budget

4.2 Making decision matrix

In Table 2 and Table 3, data and information about 30 sub-units of Isfahan Water and Wastewater Company are presented. This table is the decision matrix in this research. The data were made available to the researcher by the [Isfahan] Water and Sewage Company using desk studies. In fact, Table 2 shows the performance of each unit on the basis of eight indicators, obtained from the opinions of the experts working in the [Isfahan] Water and Sewage Company.

Table 2 The decision matrix includes the performance of units in each of the indicators

	Inputs		**Outputs**					
	x_1	x_2	y_1	y_2	y_3	y_4	y_5	y_6
Dmu1	17.69	17.563	5.178	4.32	349447	387371	80	80
Dmu2	0.03	0.9	0.01	0.01	1871	13630	88	118
Dmu3	0.388	1.16	17.924	1.164	15708	39926	90	73
Dmu4	1.05	1.038	11.746	6.304	38639	51459	76	75
Dmu5	0.01	0.4	0.01	1.037	5	8288	1	95
Dmu6	2.5	1.825	0.01	0.42	92	7776	1	100
Dmu7	4.3	1.917	0.429	4.414	66946	92294	52	122
Dmu8	3.725	2.05	1.01	3.722	18572	32231	47	72
Dmu9	0.08	0.752	0.01	0.15	4750	11698	110	78
Dmu10	1.475	3.385	0.01	1.211	14045	50065	88	63
Dmu11	0.01	0.29	0.01	0.83	297	6570	1	116
Dmu12	0.625	1.345	0.313	2.148	11401	62943	25	53

Dmu13	3.6	1.425	0.01	2.82	2379	5009	56	121
Dmu14	3.89	1.574	4.097	0.042	1555	7550	55	106
Dmu15	0.013	0.58	0.01	0.245	2065	6461	47	95
Dmu16	0.5	4.325	0.01	0.635	5	25792	1	77
Dmu17	6	1.04	1.83	2.053	18330	47596	44	76
Dmu18	4.5	1.76	1.205	1.079	13786	39082	37	77
Dmu19	0.24	0.509	0.36	1.073	8707	12289	66	81
Dmu20	10	3.453	17.88	0.221	4534	93640	43	91
Dmu21	0.01	1.06	0.01	0.604	5	5124	1	29
Dmu22	0.04	0.133	0.01	0.078	4119	4444	50	116
Dmu23	0.5	0.18	0.01	0.01	1287	4884	27	88
Dmu24	6.75	0.55	5.531	0.106	815	13301	4	74
Dmu25	0.01	2.193	0.01	0.035	5	9085	1	108
Dmu26	0.01	0.442	0.01	0.01	5	8266	1	57
Dmu27	0.01	0.375	0.01	0.425	92	5417	1	58
Dmu28	0.01	1.063	0.01	6.92	5	6684	1	96
Dmu29	1.5	1.25	0.01	1.3	16516	16945	64	56
Dmu30	0.5	1.25	2.065	0.236	20105	20545	75	73

4.3 Output of all models in MATLAB software

In Table 3, the value of the efficiency of each decision unit is included. These weights were calculated based on the DEA model. Efficient units had an efficiency score of 1; while the inefficient units had an efficiency weight of less than 1.

Table 3 The efficiency of each decision making unit

DMU	Efficiency	DMU	Efficiency	DMU	Efficiency
1	0.535	11	1	21	0.616
2	1	12	1	22	1
3	1	13	0.389	23	0.725
4	1	14	0.233	24	0.758
5	1	15	1	25	1
6	1	16	0.219	26	0.995
7	0.97	17	0.926	27	0.701
8	0.322	18	0.452	28	1
9	0.845	19	0.68	29	0.368
10	0.333	20	0.547	30	0.534

In Figure 1, the value of the efficiency scores for all units examined is presented as a stem graph.

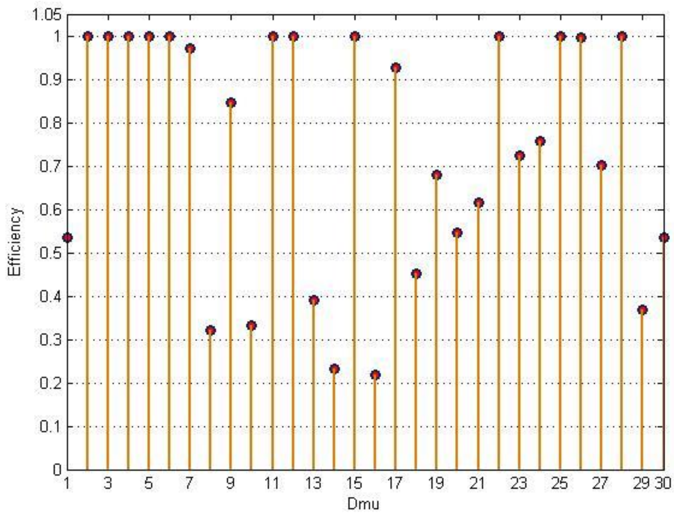

Fig. 1 The amount of efficiencies for all units examined as a stem graph

As shown in Figure 1, eleven units out of thirty units have achieved a 100% efficiency score, and the remaining units are inefficient. Figure 1shows the efficient units had a stem length of 1, while the inefficient units had a stem length of less than 1.

5 Conclusions

In this research, the performance of 30 decision-making units (sub-units of Isfahan Water and Wastewater Company) was evaluated in 2018. After determining the units by holding storm brainstorming sessions, eight important indicators in evaluating of decision making units agreed by managers and relevant experts, after categorizing the data for each unit in each of the eight indicators and evaluating them by the DEA model using MATLAB software, it was found that eleven units out of thirty units achieved a 100% efficiency score, and the remaining evaluated units are inefficient.

6 Suggestions for future researchers

Researchers are recommended to measure, in their future studies, the efficiency of the Water and Sewage Company in all provinces of Iran in order to provide a more comprehensive picture of the relative performance of DMUs.

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