Available online at http://ijdea.srbiau.ac.ir

Int. J. Data Envelopment Analysis (ISSN 2345-458X)

Vol.3, No.2, Year 2015 Article ID IJDEA-00324, 13pages

Research Article

International Journal of Data Envelopment Analysis Science and Research Branch (IAU)

Applying Network Data Envelopment Analysis to Determine a Criterion for Benchmarking in Regional Electricity Companies of Iran

Mohammad Reza Khosravi[a*], Kambiz Shahroodi[b]

(a) *Human Resources Expert of Guilan Regional Electricity Company PhD student of Business Administration, Islamic Azad University of Rasht, Iran*

(b) *Associate Professor of Business Administration, Islamic Azad University of Rasht, Iran.*

Received 5 March 2015, Revised 27 April 2015, Accepted 20 June 2015

Abstract

One of the effective methods for improving the efficiency of an organization is benchmarking against successful organizations. Not only benchmarking could be a technique for identifying problems but also it greatly helps managers in relations of the design of processes. Among strategic and infrastructure industries in each country, the electricity industry is one of the most important and critical industries. Besides, it is considered as a unique industry due to its capital-intensive and costly nature. Hence, increasing efficiency and productivity in this industry is very important. This study was aimed at investigating and evaluating the efficiency of the above-mentioned companies by using the nonparametric data envelopment analysis (DEA) method. Moreover, since power transmission operations are carried out by regional electricity companies during multiple processes, network models were used in this study to evaluate the efficiency of regional electricity companies in Iran. The required information for efficiency analysis was extracted from the performance of listed companies in statistical yearbook of Iran electricity industry in the year 2011. The results indicate that regional electricity companies in Isfahan, Zanjan and Kerman achieved similar efficiency in both phases of their work. Moreover, the results show that the use of network models in evaluating the efficiency of Iran's regional electricity companies enables researchers to investigate the efficiency of internal processes of companies and give a vivid picture of the performance of an organization. These models also help in finding reasons for inefficiency of companies.

Keywords: Performance evaluation, Efficiency, Network Data Envelopment Analysis, Iran's Electricity Industry, Regional Electricity Company.

[*] Corresponding Author: : M.khosravi@gilrec.co.ir

1. Introduction

In the modern era, dramatic changes in the science of management have necessitated the use of the evaluation system. The lack of evaluation in different dimensions of an organization such as resources and facilities, staff, goals and strategies is one of the signs of organization's_disease. Each organization is in urgent need of an evaluation system in order to recognize the utility and quality of its activities especially in complex dynamic contexts. On the other hand, the lack of an evaluation and control system in an organization means the lack of communications between inside and outside organizational contexts which leads to the aging and finally death of the organization.

The measurement of efficiency, as one of the most important methods of performance evaluation and productivity of a company, has always been studied by researchers. Efficiency means the extent to which an organization can use its resources for the purpose of production in a certain period of time. In other words, efficiency is the amount of the consumption of resources to produce a certain amount of a product [22]. The first step in improving efficiency is measurement. The measurement of efficiency and productivity creates conditions in which managers of the organization could recognize their situation and plan for improving the present conditions[7].

DEA is one of the most widely used nonparametric methods of efficiency evaluation. DEA is a method based on an optimization approach by using a linear programming. It is used for the relative evaluation of decision making units (DMU) that perform similar tasks.

Electrical energy (power) is of high importance and has a great role in development and prosperity of countries. That is why governments consider the electricity industry as one of the infrastructure industries. Thus, it is under special supervision by governments. Supplying one of the most important forms of energy, the electricity industry has an undeniable role in flourishing the national economy of countries. Power has some advantages over other kinds of energy including the relatively easy transmission to distant areas, ease of distribution to subscribers and conversion to other forms of energy [15].

Among the important and effective companies in the area of electricity industry are regional electricity companies whose main task is to transmit power. Regional electricity companies perform this task through posts, lines and power transmission network. They transmit electricity to power distribution companies by selling energy in Iran's power market. Since the process of power transmission has a multistage nature and conventional DEA models do not address internal DMU processes, network DEA models are used in this study to evaluate the overall efficiency and the efficiency of the internal processes of regional electricity companies. Network models enable researchers to investigate internal processes and procedures of DMU as well as the overall efficiency of each DMU [4].

Due to the key role of regional electricity companies in power industry and the need for increasing their efficiency, the main objective of the present study is to evaluate the efficiency of these companies in each phase of their work, rank them in every phase of their work and determine model units for inefficient companies in each phase.

2. Theoretical Foundations of the Study

Benchmarking is the continuous process of comparing the operations of the organization with the company or organization that has the best performance in such operations [1]. Providing a framework for organizations to be informed of the activities of the best organization and to determine distinctions between the current organization and the best one, benchmarking indicates the ways in which existing gaps could be bridged. In fact, benchmarking is a tool for continuous improvement and could be utilized by various manufacturing and service organizations [2].

As a classification, two general methods have been introduced for benchmarking. The first one is quantitative benchmarking which involves using measurement standards for quantitatively comparing the performance with model companies and organizations with regard to cost, quality and time. The second one is qualitative benchmarking which seeks to compare current operation methods, and not their results, with the employed methods by model companies and organizations [3]. DEA is one of the quantitative methods of benchmarking that aims at determining the efficiency of a decision making unit or system through the process of converting inputs to outputs. In other words, the goal is to recognize the units that obtain the maximum amount of output from the minimum amount of input. Such a unit that has efficiency equal to 1 is called an efficient unit and other units that have efficiency between 0 and 1 are called inefficient units. DEA enables managers to properly evaluate their units and make the right and logical decisions for optimized allocation of resources [27].

A criticism leveled at conventional DEA models by researchers is that these models consider systems as a closed set and ignore the processes within the system, their performance and relations with each other. This approach which is called black-box approach misses most of the valuable information about DMU and limits the efficiency analysis of DMUs to initial input and final output [2] [8] [10] [16] [17] [21] [29].

In fact, conventional DEA models have problems in calculating the efficiency of complex systems and the processes consisting of multiple phases and medium measures and cannot properly compute the efficiency of each one of internal processes [4]. Therefore, the results of efficiency calculated by conventional DEA methods may prevent accessing valuable managerial information.

To solve this problem, Far and Grosskopf (2000) presented an article and, while pointing out the weakness of the conventional DEA model, introduced network DEA. They highlighted the importance of the new model in more precise analysis of the efficiency of DMUs. This model considers a decision making unit with all its subunits and existing communications as a network structure. In this model, it is assumed that the system being evaluated consists of several similar decision making units. Each unit in turn is composed of several connected subunits [26]. Since network models provide the possibility of investigating the internal processes of each DMU, they give a more precise picture of the efficiency of DMUs [23].

3. Network Model of Li et al. (2012)

The framework for the present study is based on one of the newest proposed models in the field of network DEA models suggested by Li et al. in 2012 (Figure 1).

This model is based on the premise that in a process two-phase structure, one of the phases is more important for the management of the organization. This phase is called, "leader" and the other phase is called, "follower" by Li et al. Due to more significance attached to the leader phase, the efficiency of this phase should first be calculated and maximized. Then, based on the efficiency of the leader phase, the efficiency of the follower phase is determined. For example, if we consider phase 1 as the leader phase in figure 1, the efficiency of this phase is obtained by the following relation:

Relation(1)

$$e_1^{o*} = \max \sum_{d=1}^{D} w_d z_{do}$$

$$\text{s.t.} \quad \sum_{i=1}^{m} v_i x_{io} = 1$$

$$\sum_{d=1}^{D} w_d z_{dj} - \sum_{i=1}^{m} v_i x_{ij}$$

$$v_i, w_d, Q_h, u_r \geq 0, \qquad \forall i, d, h, r$$

Also, the efficiency of the second phase is obtained by the following relation:

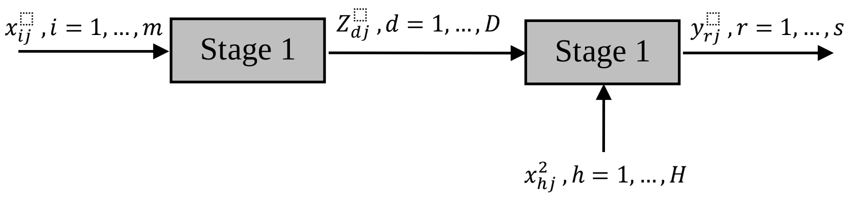

Figure1. Network Model (Li *et al*., 2012)

Relation (2)

$$e_2^{o*} = max \sum_{r=1}^{s} u_r y_{rj_0}$$

$$s.t. \quad \sum_{d=1}^{D} w_d z_{dj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \quad \forall j$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{h=1}^{H} Q_h x_{hj}^2 - \sum_{d=1}^{D} w_d z_{dj} \leq 0 \quad \forall j$$

$$\sum_{h=1}^{H} Q_h x_{ho}^2 + \sum_{d=1}^{D} w_d z_{do} = 1$$

$$\sum_{d=1}^{D} w_d z_{do} - e_1^{o*} \sum_{i=1}^{m} v_i x_{io} = 0$$

$$v_i, w_d, Q_h, u_r \geq 0, \forall i, d, h, r$$

In selecting this model, several measures were taken to evaluate the efficiency of the phases and internal processes of regional electricity companies of Iran:

First, the proposed models on network DEA such as those of Fare and Grosskopf (2000), Kao (2009), Cook et al. (2010), Chen and Yan (2011) and Li et al. (2012) were investigated. Then, missions, goals, tasks and work processes of regional electricity companies were studied and the extent to which work processes of regional electricity companies are consistent with the so-called network models was explored. Finally, university professors who are expert at DEA commented on the issue and taken together, the model of Li et al. (2012) was more consistent with the process of power transmission by regional electricity companies. Therefore, this model was used in the present study.

4. Methodology

The present study investigates the efficiency of the power transmission section in Iran's electricity industry. The data used in the study is related to the performance of regional electricity companies in the year 2011 and the required information was extracted from the statistical yearbook of Iran's electricity industry in power transmission section and reports about the current status of power industry.

5. Specifying Input and Output Variables of Regional Electricity Companies

The selection of input and output variables is one of the important steps in the evaluation of efficiency via DEA method. In other words, the lack of care in the selection of variables disparages results of the evaluation. Due to these reasons, three important points are taken into account in the selection of inputs and outputs: 1) the variables used in the previous studies of efficiency evaluation of power industry in the world, 2) the possibility of access to and collection of data concerning research variables and 3) integrating comments made by experts and masters of science in power industry.

Given the above-mentioned points, the synthesis of previous studies, examining the possibility of data collection and finally comments made by experts in power industry, input and output variables of the present study are given in Table 2:

Table1: Input and Output Variables of the Study

Type of Variable	Phase No.	Name of Variable
Input	1st phase	Cost of power transmission plans (Million Rial)
Input	1st phase	Number of plan and development staff (person)
Input	2nd phase	Capacity of current transformers (MVA)
Input	2nd phase	Length of current network (km)
Input	2nd phase	Total number of staff (person)
Mean	1st phase-2nd phase	Increase in the capacity of transformers (MVA)
Mean	1st phase-2nd phase	Increase in the length of the network (km)
Final-Output	2nd phase	The amount of energy delivered (Million KWH)

The point that regional electricity companies use what process to achieve their main goal, i.e. power transmission, is given in some sections of IEEE-1127 standard. This standard was codified by the Institute of Electrical and Electronics Engineers (IEEE) in 2004 to meet consistency in power transmission activities with the environment. According to this standard, power transmission activities include design (planning), construction (planning and development) and operations.

The structure of regional electricity companies in Iran is in line with the above-mentioned standard. These companies have three technical deputies namely, planning and research deputy, design and development deputy and operation deputy (Iran Monneko Consulting Engineers Company, 2013).

The planning and research deputy is in charge of preparing and codifying power production and transmission as well as planning and estimating the required amount of energy with a long-term approach. The design and development deputy designs and builds lines and posts of power transmissions based on the planning done by planning and research deputy with regard to the predicted need for energy consumption in future. And finally, the operation deputy operates the lines and posts of power transmission that have been put in orbit and provides maintenance on them.

A point worth mentioning in the efficiency analysis of internal units of regional electricity companies is that the task of planning and research deputy is a long-term one and due to the nature of the tasks of this deputy, no statistics and information about its activities are published. Therefore, efficiency evaluation of this phase and the comparing companies in this section were not possible. That is why in the present study the process of power transmission by regional electricity companies is considered as a two-phase process. In this process, Iran's regional electricity companies use two phases to transmit power from power stations to distribution centers and delivering to the final customer. In the first phase, the design and development unit builds transmission and distribution posts and lines by paying the costs, capital investment and employing expert staff. In the second phase, the posts and lines, that have been built, examined and run, are put into orbit by operation units. After making the necessary changes in power voltage, posts and lines transmit the required energy to the intended destinations. Based on the above explanations and the introduced variables, the two-phase process of power transmission and communications between input and output variables are presented in Figure 2.

After formulating the problem of linear planning for evaluating the efficiency of each company in both phases of design and development and operation, the data of the present study was analyzed by GAMS software.

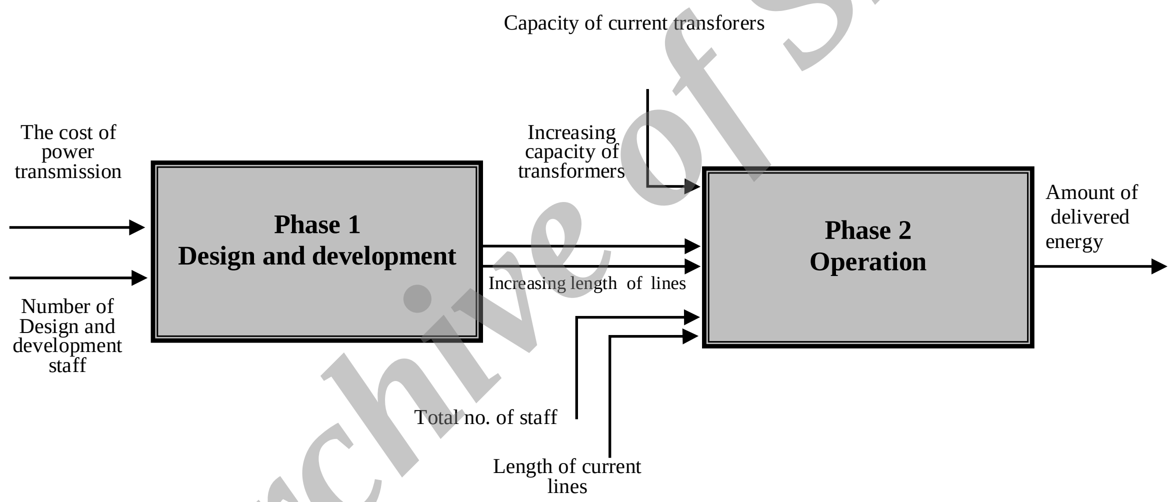

Figure 2: The Two-phase Process of Power Transmission

To calculate efficiency based on the model of Li, et al. (2012), the leader and follower units should be specified due to their importance in the process of power transmission.

In this study, both phases of design and development and operation have the capability of being the leader.

However, the first phase, i.e. design and development, is a prerequisite and it is introduced as the leader phase.

The values of input and output variables of the study in relation to first phase, i.e. design and development, are given in Table 3 for 16 regional electricity companies.

In Table 4, the values of input and output variables of the second phase, i.e. operation, of regional electricity companies are given:

Table 2: Values of Input and Output Variables of the Study in the First Phase

DMU No.	Name of Company	Cost of Power Transmission	Number of Staff	Increase in Capacity of Transformers	Increase in Network Length
1	Regional Electricity of Azarbayejan	353053	50	255	359/1
2	Regional Electricity of Isfahan	738382	53	910	517
3	Regional Electricity of Bakhtar	177737	28	245	117/3
4	Regional Electricity of Tehran	1247836	86	260	287
5	Regional Electricity of Khorasan	539445	38	650	7/7
6	Regional Electricity of Khouzestan	624911	152	1054	9/4
7	Regional Electricity of Zanjan	221529	40	580	313/8
8	Regional Electricity of Semnan	98624	10	1070	0
9	Regional Electricity of Sistan	239004	124	285	193
10	Regional Electricity of West	384345	55	1213	47/3
11	Regional Electricity of Fars	652974	71	2575	271/3
12	Regional Electricity of Kerman	87834	38	90	308/5
13	Regional Electricity of Guilan	223627	29	755	57/3
14	Regional Electricity of Mazandaran	524072	43	850	93
15	Regional Electricity of Hormozgan	548425	29	783	3009
16	Regional Electricity of Yazd	299270	25	350	103/5

Table 3: Values of Input and Output Variables of the Study in the Second Phase

DMU No.	Name of Company	Capacity of Current Transformer	Length of Current Network	Total Number of Staff	The Amount of delivered Energy
1	Regional Electricity of Azarbayejan	15031	7715/5	255	359/1
2	Regional Electricity of Isfahan	21305	53	910	517
3	Regional Electricity of Bakhtar	16863	28	245	117/3
4	Regional Electricity of Tehran	49334	86	260	287
5	Regional Electricity of Khorasan	17126	38	650	7/7
6	Regional Electricity of Khouzestan	34669	152	1054	9/4
7	Regional Electricity of Zanjan	6732	40	580	313/8
8	Regional Electricity of Semnan	3753	10	1070	0
9	Regional Electricity of Sistan	5464	124	285	193
10	Regional Electricity of West	10282	55	1213	47/3
11	Regional Electricity of Fars	26395	71	2575	271/3
12	Regional Electricity of Kerman	10967	38	90	308/5
13	Regional Electricity of Guilan	7554	29	755	57/3
14	Regional Electricity of Mazandaran	14934	43	850	93
15	Regional Electricity of Hormozgan	12746	29	783	3009
16	Regional Electricity of Yazd	5483	25	350	103/5

6. Results of the Study

6.1. Efficiency Values of Companies

Solving the linear planning model in relations 1 and 2, we can determine the percentage efficiency of regional electricity companies according Table 5 in both phases of design and development *and* operations. The total efficiency of each DMU is obtained from multiplying the efficiency of the first and second phases. In this table, the rank of each company in each phase and also the rank of the company in total efficiency are given.

The results of efficiency of companies in the first phase indicate that the phase of design and development of regional electricity company of Isfahan, Zanjan, Semnan, Kerman and Hormozgan have 100 percent efficiency.

In the second phase, the results show that the phase of operation for regional electricity companies of Isfahan, Bakhtar, Khorasan, Zanjan, Kerman and Guilan have 100 percent efficiency. Concerning total efficiency, only regional electricity companies of Isfahan, Zanjan and Kerman are efficient. In the first phase, i.e. design and development, regional electricity companies of Isfahan, Zanjan, Semnan, Kerman and Hormozgan have the same efficiency and therefore are ranked first. Moreover, in the second phase, regional electricity companies of Isfahan, Bakhtar, Tehran, Khorasan, Zanjan, Kerman and Guilan have the same efficiency and therefore are ranked first. On the other hand, regional electricity companies of Sistan and Balouchestan *and* Fars indicate the poorest performance.

Table 4: Values of Efficiency of Regional Electricity Companies

DMU No.	Company's Name	Efficiency of 1st phase	Rank of Company in 1st phase	Efficiency of 2nd phase	Rank of Company in 1st phase	Total Efficiency	Rank of Company in Total Efficiency
1	Regional Electricity of Azarbayejan	0.82	2	0.79	8	0.65	4
2	Regional Electricity of Isfahan	1	1	1	1	1	1
3	Regional Electricity of Bakhtar	0.53	4	1	1	0.53	5
4	Regional Electricity of Tehran	0.34	8	1	1	0.34	9
5	Regional Electricity of Khorasan	0.17	10	1	1	0.17	13
6	Regional Electricity of Khouzestan	0.16	11	0.98	2	0.16	14
7	Regional Electricity of Zanjan	1	1	1	1	1	1
8	Regional Electricity of Semnan	1	1	0.95	3	0.95	2
9	Regional Electricity of Sistan	0.32	9	0.65	10	0.21	12
10	Regional Electricity of West	0.32	9	0.87	5	0.28	11
11	Regional Electricity of Fars	0.72	3	0.67	9	0.48	6
12	Regional Electricity of Kerman	1	1	1	1	1	1
13	Regional Electricity of Guilan	0.46	6	1	1	0.46	7
14	Regional Electricity of Mazandaran	0.37	7	0.83	6	0.31	10
15	Regional Electricity of Hormozgan	1	1	0.83	7	0.83	3
16	Regional Electricity of Yazd	0.5	5	0.9	4	0.45	8

4.2. Introducing Model Units for Inefficient Companies

In this part, a model and reference unit is introduced for regional inefficient companies of Iran so that they could reach efficiency border by being compared to model companies and following the reference unit with regard to the rate of inputs and outputs. Table 5 introduces model and reference units for inefficient companies in the design and development phase:

For example, the regional electricity company of Azarbayejan, as an inefficient company in the design and development unit, can increase its efficiency by following models like regional electricity companies of Isfahan and Kerman. In Table 8, model and reference units for inefficient companies in the second phase, i.e. operation, are introduced.

In the second phase, i.e. operation, for instance regional electricity company of Azarbayejan, as an inefficient company, can follow the model of regional electricity companies of Bakhtar, Zanjan and Guilan.

5. Discussion and Conclusion

The rationale behind using network DEA models is that internal processes and phases in DMUs were previously ignored. In fact, conventional DEA models consider each company just as a DMU and limit their calculations to initial inputs and final outputs. The results of the current study suggest that we need to use network models and investigate the internal processes of companies to be able to carefully examine the reasons for insufficiency and efficiency status of regional electricity companies. That's because these companies use multiple phases transmit power in electricity industry and the efficiency of each one the phases is of high importance.

Given the results of the present study and the comparison of the efficiency of regional electricity companies in first and second phases and their total efficiency, if the goal of the researcher, in analyzing the efficiency of Iran's regional electricity companies, is to determine the total efficiency of companies without paying attention to their internal units, he or she cannot present a precise and real picture of the performance and efficiency of regional electricity companies. To elaborate more on the issue, following examples are given:

1. The efficiency of the regional electricity company of Khouzestan is equal to 16 percent among all 16 regional electricity companies throughout the country. This company has the lowest amount of efficiency among all companies. The low efficiency of the regional electricity company of Khouzestan compared to other companies could be interpreted and justified with two approaches:

A) At first sight and without analyzing the internal processes of this company, one may say that this company has the minimum amount of efficiency in all of its subunits and that, the management of this company should be advised to reconsider its work processes in

Table 5. Introducing Model Units in the First Phase (Design and Development)

Inefficient DMU No.	Name of Inefficient Company	Model DMU No.	Name of Model Company
1	Regional Electricity of Azarbayejan	12, 2	Regional Electricity of Isfahan and Kerman
3	Regional Electricity of Bakhtar	15, 8, 7	Regional Electricity of Zanjan, Semnan, and Hormozgan
4	Regional Electricity of Tehran	15, 2	Regional Electricity of Isfahan and Hormozgan
5	Regional Electricity of Khorasan	15, 8	Regional Electricity of Semnan and Hormozgan
6	Regional Electricity of Khouzestan	12, 8	Regional Electricity of Semnan and Hormozgan
9	Regional Electricity of Sistan	12, 8	Regional Electricity of Semnan and Hormozgan
10	Regional Electricity of West	12, 8	Regional Electricity of Semnan and Hormozgan
11	Regional Electricity of Fars	15, 8, 7	Regional Electricity of Zanjan, Semnan and Hormozgan
13	Regional Electricity of Guilan	15, 8, 7	Regional Electricity of Zanjan, Semnan and Hormozgan
14	Regional Electricity of Mazandaran	15, 8, 7	Regional Electricity of Zanjan, Semnan and Hormozgan
16	Regional Electricity of Yazd	15, 8, 7	Regional Electricity of Zanjan, Semnan and Hormozgan

Table 6. Introducing Model Units in the Second Phase (Operation)

Inefficient DMU No.	Name of Inefficient Company	Model DMU No.	Name of Model Company
1	Regional Electricity of Azarbayejan	13, 7, 3	Regional Electricity of Bakhtar, Zanjan and Guilan
6	Regional Electricity of Khouzestan	13, 4, 3	Regional Electricity of Bakhtar, Tehran and Guilan
8	Regional Electricity of Semnan	13, 7, 3	Regional Electricity of Bakhtar, Zanjan and Guilan
9	Regional Electricity of Sistan	7,3	Regional Electricity of Bakhtar and Zanjan
10	Regional Electricity of West	7,3	Regional Electricity of Bakhtar and Zanjan
11	Regional Electricity of Fars	7, 3, 2	Regional Electricity of Isfahan, Bakhtar and Zanjan
14	Regional Electricity of Mazandaran	13, 7, 2	Regional Electricity of Isfahan, Zanjan and Guilan
15	Regional Electricity of Hormozgan	13, 7, 3, 2	Regional Electricity of Isfahan, Bakhtar, Zanjan and Guilan
16	Regional Electricity of Yazd	7, 3	Regional Electricity of Bakhtar and Zanjan

different units of the company and follow the model of efficient companies to enhance the efficiency of its own.

B. Based on network model and by calculating the efficiency of the first phase, i.e. design and development, and the second phase, i.e. operation, we can observe that this company has a relatively good efficiency in the second phase, i.e. operation and with the efficiency of 98 percent is ranked as the second company among 16 regional electricity companies. In fact, the poor performance of the first phase, i.e. design and development, has minimized the efficiency of this company to the extent that it is placed as the last company among regional electricity company. Thus, the management of this company should be advised to reconsider work processes of the design and development phase.

2. A similar condition is observed in the efficiency analysis of regional electricity company of Guilan. This company has the efficiency of 46 percent and is considered as an inefficient company. It does not show a suitable performance compared to other companies. Upon closer inspection of internal processes, however, it is seen that the company has 100 percent efficiency in the second phase, i.e. operation, and the only reason for the (total) inefficiency of this company is insufficiency observed in the design and development phase.

Based on the results of the present study and the fact that many companies face with low sufficiency in the design and development unit despite suitable performance in operation units, it is suggested that power ministry and parent technical TAVANIR company consider suitable indexes for evaluating the performance of the design and development units of Iran's regional electricity companies so that these units could enhance their efficiency in line with operation units.

Moreover, it is suggested that in a separate study, the second phase, i.e. operation, could be considered as the leader and the results of the efficiency of companies and their work phases compared with the results of this study.

References

[1] Banker. R,D. Charnes, A., and Cooper,W,W. (1984). Some Models for Estimating Technical and Scale Efficiencies in Data Envelopment Analysis. *Management Science*, 30: 1078-92.

[2] Castelli, L., Pesenti, R. & Ukovich, W. (2004). DEA-like models for the efficiency evaluation of hierarchically structured units. *European Journal of Operational Research*, 154: 465–76.

[3] Charnes, A., Cooper, W. W., and Rhodes, E. (1978). Measuring the efficiency of decision- making units. *European Journal of Operational Research*, 2: 429–44.

[4] Chen, C. & Yan, H. (2011). Network DEA model for supply chain performance evaluation. *European Journal of Operational Research*, 213: 147–55.

[5] Chen, H.L. (2002). Benchmarking and quality improvement: A quality benchmarking deployment approach", International Journal of Quality & Reliability Management, 19 (6):757 – 773.

[6] Cook, W.D., Zhu, J., Bi, G. & Yang, F. (2010). Network DEA: additive efficiency decomposition. *European Journal of Operational Research*, 207: 1122–9.

[7] Emami Meybodi, A., Afghah, M., and Rahmani Sefati, M. H. (2009). Measuring the Technical Efficiency and Productivity in Steam, Gas and Combined Sycle Power Stations. *The Quarterly of Quantitative Economy*, (3) 6, 79-103.

[8] Fare, R., & Grosskopf, S. (2000). Network DEA. *socio-economic plannig science*, 34: 35-49.

[9] Farell, M. (1957). The measurement of productive efficiency. *Journal of the Royal Statistics Society*, Series A, 120 (3): 253-281.

[10] Fukuyama, H. & Weber, W.L. (2010). A slacks-based inefficiency measure for a two-stage system with bad outputs. *Omega*, 38: 398–409.

[11] Gao, X. & Malkawi, A., (2014). A new methodology for building energy performance benchmarking: An approach based on intelligent clustering algorithm. Energy and Buildings, 84: 607-616.

[12] Gonzalez,T., Akdenizb,B & Calantonec, R.j., (2014). Benchmarking sales staffing efficiency in dealerships using extended data envelopment analysis. Journal of Business Research, 67 (9): 1904-11.

[13] Goto M. & Tsutsui M., (2008). Technical efficiency and impacts of deregulation: An analysis of three functions in U.S. electric power utilities during the period from 1992 through 2000. *Energy Economics*, 30: 15–38.

[14] Hess B., Cullmann A., (2007). Efficiency analysis of East and West German electricity distribution companies e Do the ‘‘Ossis’’ really beat the ‘‘Wessis’’?. *Utilities Policy*, 15: 206-14.

[15] Iran Monneko Consulting Engineers Company. (2013). Restructuring in Power Industry. Tehran: *Shiveh Publications*.

[16] Kao, C. & Hwang, S.N. (2008). Efficiency de composition in two-stage data envelopment analysis: an application to non-life insurance companies in Taiwan. *European Journal of Operational Research*, 185: 418–29.

[17] Kao, C. (2009). Efficiency decomposition in network data envelopment analysis: A relational model. *European Journal of Operational Research*, 192: 949–62.

[18] Khodabakhshi, M. (2010), “An output oriented super-efficiency measure in stochastic data envelopment analysis: Considering Iranian electricity distribution companies”. *Computers & Industrial Engineering*,58: 663-71.

[19] Kuosmanen, T. (2012). Stochastic semi-nonparametric frontier estimation of electricity distribution networks: Application of the StoNED method in the Finnish regulatory model. *Energy Economics*, 34: 2189-99.

[20] Li, Y., Chen, Y., Liang, L. & Xie, J. (2012). DEA models for extended two-stage network structures. *Omega*, 40: 611–18.

[21] Liang, L., Yang, F., Cook, W.D. & Zhu, J. (2006). DEA models for supply chain efficiency evaluation. *Annals of Operations Research*, 145: 35–49.

[22] Mehregan, M. R. (2004). Quantitative Models for Performance Evaluations of Organizations. Teharn: Teharn *University Management College Publications*.

[23] Mo'meni. M. and Shahkhah, N. (2011). The Use of Communication Two-Phase Data Envelopment Analysis Model in Efficiency Evaluation. Daneshvar Raftar, (47-1), 333-344.

[24] Pe´rez-Reyes, R. & Tovar, B. (2009). Measuring efficiency and productivity change (PTF) in the Peruvian electricity distribution companies after reforms. *Energy Policy*, 37: 2249-61.

[25] Sadjadi, S.J., Omrani, H. , Makui, A. & Shahanaghi, K. (2011). An interactive robust data envelopment analysis model for determining alternative targets in Iranian electricity distribution companies. *Expert Systems with Applications*, 38: 9830-39.

[26] Salehzadeh, S. J., Hejazi, S. R., Arkan, A. V., and Hoseini, S. M. (2011). Presenting a Synthetic Method of Efficiency Measurement of Network Structures Including Allocated Revolution and Links. *Journal of Production and Operation*, (1), 47-60.

[27] Shahriari, S., Razavi, S. M., and Asgharizadeh, A. (2013). Fuzzy Data Envelopment Analysis and the New Approach FIEP/AHP to Complete Ranking of Decision Making Units. (Case Study: School of Humanities of Tehran University). Industrial Management, 5 (1), 21-42.

[28] Sueyoshi, T. & Goto, M. (2012). Efficiency-based rank assessment for electric power industry: A combined use of Data Envelopment Analysis (DEA) and DEA-Discriminant Analysis (DA). *Energy Economics*, 34: 634-44.

[29] Tone K. & Tsutsui M. (2009). Network DEA: a slacks-based measure approach. European Journal of Operational Research, 197: 243–52.

Applying Network Data Envelopment Analysis to Determine a Criterion for Benchmarking in Regional Electricity Companies of Iran

Mohammad Reza Khosravi, Kambiz Shahroudi

به کارگیری تحلیل پوششی داده‌های شبکه‌ای به منظور تعیین معیاری جهت الگوبرداری شرکت‌های برق منطقه‌ای ایران

چکیده: یکی از روشهای موثر ارتقاء کارایی سازمان، الگوبرداری از سازمان‌های موفق است. الگوبرداری نه تنها می‌تواند تکنیکی برای تشخیص مشکلات باشد، بلکه در روابط طراحی فرایندها نیز کمک شایانی به مدیران می‌کند. از میان صنایع راهبردی و زیربنایی موجود در هر کشور، صنعت برق از مهمترین و حیاتی‌ترین صنایع بوده که به دلیل سرمایه‌بر بودن و پرهزینه بودن، صنعتی انحصاری محسوب می‌شود. لذا افزایش کارآیی و بهره‌وری در این صنعت از اهمیت بسیار زیادی برخوردار است. این تحقیق با هدف بررسی و سنجش کارآیی شرکت‌های مزبور با استفاده از روش ناپارامتریک تحلیل پوششی داده‌ها صورت پذیرفته است. همچنین به دلیل اینکه عملیات انتقال نیرو توسط شرکت‌های برق منطقه‌ای طی فرآیندهای چندگانه توسط واحدهای مختلف صورت می‌گیرد در این تحقیق از مدل‌های شبکه‌ای در سنجش کارآیی شرکت-های برق منطقه‌ای ایران استفاده شده است. اطلاعات لازم جهت تجزیه و تحلیل کارآیی، از عملکرد سال 1390 شرکت‌ها مندرج در سالنامه آماری صنعت برق ایران استخراج شده‌اند. نتایج نشان می‌دهد شرکت‌های برق منطقه‌ای اصفهان، زنجان و کرمان در هر دو مرحله کاری دارای کارایی واحد می‌باشند. همچنین نتایج تحقیق بیانگر این موضوع است که استفاده از مدل-های شبکه‌ای در سنجش کارایی شرکت‌های برق منطقه‌ای ایران، این امکان را به محققان می‌دهد تا ضمن بررسی وضعیت کارایی فرآیندهای داخلی شرکت‌ها، تصویر روشن‌تری از عملکرد سازمان ارائه نمایند و به کمک این مدل‌ها می‌توان دلایل ناکارایی شرکت‌ها را تشخیص داد.

واژه‌های کلیدی: ارزیابی عملکرد، کارایی، تحلیل پوششی داده‌های شبکه‌ای، صنعت برق ایران، شرکت برق منطقه‌ای