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Efficiency Evaluation and Ranking of the Research Center at the Ministry of Energy: A Data Envelopment Analysis Approach

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A R T I C L E   I N F O

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A B S T R A C T

Evaluating the performance of the different departments in an organization or evaluating and comparing the performance of a single department over different time points may boost the organizational efficiency and the involved industry. Making the most efficient use of the existing resources to realize all the expected outcomes. Therefore, in their projected plans, the efficiency enhancement specialists have always attempted to measure the existing efficiency of an organization and estimate the room for improvement. A Data Envelopment Analysis (DEA) approach would be an appropriate model to measure efficiency and provide answers to the above questions. In order to estimate the efficiency of a research unit over a period of years, first different indicators were identified and then through a questionnaire their priorities were determined. Finally, using the CCR model the performance efficiency and the ranking of the research center over the years were conducted.

1. Introduction

Efficiency measurement has always been at the core of management issues. The Data Envelopment Analysis (DEA) for efficiency measurement was first proposed by Charnes, Cooper and Rhodes in 1978. DEA is today a widely recognized and adopted approach by managers for the purpose of acquiring a more precise and empirical knowledge over their managerial area. Numerous papers and reports have been published in the literature on the reliability and validity of DEA.

Since every department intends and plans to exploit the existing resources at the maximal efficiency, using state-of-the-art techniques, identifying the potential and enabled opportunities and knowing the limitations depend on our understanding of the status qua at our affiliated department.

Research at any organization provides the infrastructure to improve industrial knowledge and technology in quality and quantity. Research is a complicated and strategic endeavor with special requirements. Paying comprehensive and realistic attention to performance evaluation methods in these units may channel their potentials and powers in an optimal manner and help identify their strengths and weaknesses. Therefore, evaluating the performance of research units with respect to the resources available to them is a requirement. Accordingly,

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the resources available to these units and their contribution to the industry ought to be carefully examined and evaluated.

The present study evaluated and ranked the relative efficiency of the Energy Research Center over the period spanning from 2001 through 2007. The results of this study may greatly contribute to the efficiency of the said research center and help the management in their decision making process. This is for granted that unless the efficiency is measured and the points of strength and weakness are identified for an organization any measures taken for improving its performance will lead to a lower-than-expected result.

Today, DEA provides a powerful means to measure and evaluate the performance of educational institutions, banks, hospitals, and factories, to conduct profitability studies for projects and to locate the construction site for factories among other applications. Furthermore, the concept of method efficiency has become an integral aspect of engineering sciences. Hundreds of papers and study reports have established the usefulness of the DEA approach both in theory and in practice. In recent years, Iranian researchers have conducted various studies on the efficiency evaluation and ranking of industrial and educational centers. The DEA approach, which is now widely recognized and established, was first applied by Charnes, Cooper and Rhodes to evaluate students' achievement and progress in U.S. schools in 1978 in Carnegie University. Another study evaluating the performance of research units was conducted by the Australian researcher Kully in which he measured and compared the technical efficiency of 36 research units in Australia. In another research, published in Omega journal, Beasely (1990) compared the performance of different university departments. In this research, Beaseley presented a similar model to compare different university departments with similar research areas. What all studies applying DEA have emphasized is the selection of input and output variables in as much as quantitative and qualitative goals in the study area are indicated. The above studies are just a few instances of the effort in this area. There are numerous other studies showing the power of DEA in measuring efficiency.

Section 2 of the present paper discusses the basic concepts of DEA and the related techniques. Following that section is the presentation of the indicators used to measure the efficiency of a research unit through DEA techniques to identify the most efficient of the research units over a given period of time.

2. Significance of the study

Undoubtedly, the human progress over the past centuries is indebted to research. Research constitutes the driving force for development of human society. Research centers are the pioneers of this development. Proving successful at economic units, efficiency measurement is now embraced by different educational and research centers across the country as well and various studies have been conducted in this area.

Since the research unit studied was unique in the organization, only a comparison over time could be conducted through DEA. Through certain procedures, the research unit presents a given output using certain inputs. Therefore, appropriate indicators are needed to measure the efficiency and determine the level of inputs and outputs.

Measuring the efficiency of the research unit and identifying and explaining the inefficient periods may improve the future performance of the research center. A more efficient research unit will naturally incur less resource loss and will minimize losses due to its inefficiency. In other words, efficiency measurement may result in two different sets of contribution: one, it will improve the efficiency and performance of the research staff and two, it will provide a vision for the management and administration for improved planning.
The present study attempts to answer the following questions:

1. What is the relative efficiency of the Energy Research Center over different periods of time?
2. How well does the research unit fare in ranking over different periods of time?
3. If inefficient at the j_{th} year, how could the unit turn efficient at that point of time?

2.1.Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA), which is a new non-parametric estimation method for border functions, was originally proposed by Charnes, Cooper and Rhodes (CCR) in 1978. Later in 1984, Banker, Charnes and Cooper (BCC) developed the BCC model.
The efficiency of each Decision Making Unit (DMU) is a fraction planning problem, i.e. the efficiency of each DMU is the maximum ratio of weighted outputs to the weighted inputs under certain constraints. Inputs and outputs are normal numerals and weights are selected in a way as to maximize the efficiency of that DMU (Adler, Friedman & Sinuany, 2002).
Suppose there are n DMU's as $\{DMU_j : j = 1, \ldots, n\}$ each using m different inputs to produce s outputs. Denote Y_{rj} and X_{ij} as the r_{th} output, $r = (1, \ldots, s)$ and the i_{th} input, $i = (1, \ldots, m)$ respectively of the j_{th} DMU, $j = (1, \ldots, n)$.
Given u = $(u1, u2, \ldots, us)$ and v = $(v1, v2, \ldots, vm)$ as vectors for output and input weights, respectfully, then efficiency will be,

(1) Efficiency $= \frac{u_1 y_1 + \ldots + u_s y_s}{v_1 x_1 + \ldots + v_m x_m}$

The problem in estimating efficiency is that the required weights are unknown. Charnes et al. were able to solve this problem by proposing that each DMU may arbitrarily select input and output weights provided that when entered into the efficiency computation process for other units their efficiency must not exceed one. This is the underlying logic for DEA. The CCR model for evaluating the DMU is as follows,

(2) max $$e_p : \frac{\sum_{r=1}^{S} U_r \, y_{rp} u}{\sum_{i=1}^{m} V_i \, X_{ip}}$$

$$S.t \quad \sum_{r=1}^{S} u_r\, y_{rj} / \sum_{i=1}^{m} v_i\, x_{ij} \le 1 \qquad j = 1, \dots n$$

$$U \ge 0 \qquad , V \ge 0$$

With some modifications, the above problem can take a linear form. With writing its dual, the structure of the DEA will be,
(3) Envelopment form of CCR as input

$$min$$

$$s.t \qquad X_{ip} - \sum_{j=1}^{n} \lambda_j X_{ij} \ge 0 \qquad i{:}\, 1 \dots n$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rp} \qquad r{:}\, 1 .. s$$

$$\lambda_j \ge 0$$

In the envelopment form of the CCR model with input target, the maximum reduction for the input level is θ in a way that at least the same output may be produced which proves that if θ^* is the optimal value of our target function, $0 \le {}^* \le 1$(Jahanshahlou&Lotfi, 2006).

2.2. Ranking and efficient units

By measuring the efficiency of the research units of DMU's, they were classified into "efficient" and "inefficient" groups. Efficient units are those with an efficiency score of one and inefficient units are those with efficiency scores below one, which can then be ranked. However, units earning score one cannot be ranked through classic DEA methods. The method we used in this study for this purpose was Anderson and Peterson (AP) model. The AP model, presented in 1993, ranks units in two stages. At stage one, the model solves a product or envelopment of CCR for the units under the study to discriminate efficient and inefficient ones. At stage two, only those units with efficiency scores of one are taken into account and model (3) is solved again but this time with related constraints removed (note that all units, whether efficient or not, may be taken into account and implement the AP model).

(4) min

$$\boldsymbol{S.t} \quad \sum_{\substack{j=1 \\ j \ne p}}^{n} \lambda_j y_{rj} \qquad \ge \boldsymbol{y}_{rp} \boldsymbol{j} = \boldsymbol{1}, \dots . \boldsymbol{s}$$

$$- \sum_{\substack{j=1 \\ j\neq p}}^{n} \lambda_j X_{ij} + X_{ip} \geq 0 \qquad i = 1, \dots . m$$

$$\lambda \geq 0 \qquad j = 1, \dots n, \quad j \neq p$$

3. Research variables

The most important part of the research is identifying the inputs and outputs for the evaluation from among a set of indicators. Note that, setting different evaluation goals leads to different input and output indicators. On the other hand, the indicators in fact have the role of alerting the decision makers about the latent weak points in certain areas or ensuring them of the maintenance of the current good practice.

The Energy Research Center (of the Ministry of Energy) is tasked with research studies and enhancement of the quality in all areas of the activity of the Ministry. There are several research sub-units covering the following areas: power, energy and environment, power generation, power transmission and distribution, power control, grid management, and chemicals.

With respect to raw data, different indicators were developed in order to combine two or more variables and improve the precision of the evaluation. Note that since the data were not grouped by sub-units, no comparison was possible to be performed across them. Therefore, this study evaluated the performance of the Energy Research Center in its entirety and over time. Figure 1 shows the evaluation model with given inputs and outputs.

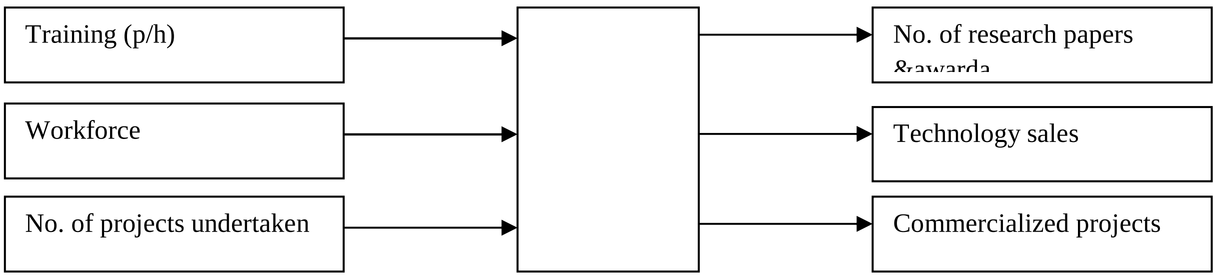

Figure 1. Performance evaluation model used in the study

The inputs included:

1. Number of staff at different projects.

This includes the total number of staff contracted annually for different projects. Note that these staff may have been engaged in more than one project at the same time. The overlap issue has been taken into account, however.

Table 1. Number of staff at projects

Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
No. of staff	163	210	290	249	278	167	145

2. Number of projects undertaken.
This refers to the total annual number of projects contracted by the research center.

Table 2: Number of assigned projects

Year	2001	2002	2003	2004	2005	2006	2007
No. of assigned projects	110	115	107	128	123	150	104

3. Training (h/p)
This indicator refers to the total hour/person training at the center.

Table 3: Staff training (h/p)

Year	2001	2002	2003	2004	2005	2006	2007
Total h/p	4840	5008	4760	3231	4911	4900	6169

The outputs included:
1. Total number of published research papers and awards received.
The papers were first grouped by local or international presentations/publication. Awards were also grouped by different innovation award occasions. The papers were scored using the following formula:

$$\sum_{i=1}^{n} \alpha_i x_i$$

where α_I is the significance coefficient of the paper.

Table 4: Number of papers and awards

Year	2001	2002	2003	2004	2005	2006	2007
Total number of papers and awards	50	69	78	134	107	103	143

2. Technology sales to private sector
This indicator refers to the number of technologies licensed to the private sector.

Table 5: Technology sales

Year	2001	2002	2003	2004	2005	2006	2007
Technology sale volume	4	4	4	4	6	5	4

3. Commercialized projects

As an objective outlined in the economic development plan and in order to increase the quality of domestic products, some research projects at the research center of the Ministry of Energy were commercialized.

Table 6: Number of commercialized projects

Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
No. of commercialized projects	45	53	57	59	71	71	42

4. Results

The results of the efficiency evaluation will have two major advantages:

1. The administration and personnel can gain an overview of the performance of their organization.
2. Efficient periods may be set as benchmark to evaluate the future performance of the center.

Based on the theoretical issues and empirical studies, the relative efficiency of the research center over the years was calculated through the CCR model in two modes of efficiency on a fixed scale and efficiency on a variable scale. Table 7 shows the results of this calculation.

Table 7: Efficiency calculation results over the years

Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Efficiency on fixed scale	0.732	0.727	0.751	1	0.916	1	1
Efficiency on variable scale	1	0.918	0.83	1	1	1	1

The benchmark years are those reflecting the highest efficiency with respect to collected data. In other word, these years have a uniform efficiency and can be used as benchmark to compare the future performance of the center.

In the efficiency on a fixed scale mode, the technical efficiency is calculated ruling out the scale effect. Therefore, years measured on a variable scale may not be as reliable as the ones measured on a fixed scale.

The findings show that years 2004, 2006 and 2007 scored the highest on both fixed and variable scales. However, years 2001 and 2005 were efficient on the variable scale and inefficient on the fixed scale. The efficiency mean scores for fixed and variable scales were 0.875 and 0.96 respectively.

In simple words, in variable efficiency mode (where technical efficiency is unaffected by the measurement scale), the center was efficient in years 2001, 2004, 2005, 2006 and 2007 while in fixed efficiency mode years 2001 and 2005 showed inefficiency. The inefficiency could be due to non-optimal performance of the center. The inefficiency is especially evident in 2001. To rank the center over the years we used the AP method. The AP analysis results are shown in Table 8 below.

Table 8: Results of AP analysis

Year	2001	2002	2003	2004	2005	2006	2007
Efficiency (AP) on fixed scale	0.77	0.776	0.782	1.83	0.973	1.541	1.705
Efficiency (AP) on variable scale	0.77	0.78	0.782	1.83	2.64	1.65	1.87

Table 9 below shows the ranking of the center in terms of efficiency over time.

Table 9: Ranking results in efficiency over years.

Year	2001	2002	2003	2004	2005	2006	2007
Efficiency (AP) on fixed scale	7	6	5	1	4	3	2
Efficiency (AP) on variable scale	7	6	5	3	1	4	2

As can be seen in the above table, there are differences in ranking compared between the fixed and variable scales. As a matter of fact, in the fixed scale mode, year 2004 ranked the highest while in the variable scale mode year 2005 ranked top. In the inefficient years, the two modes stood similar rankings.

5. Conclusion

The results of the study show that in terms of technical efficiency, out of 7 possible units in the fixed scale mode 3 units were efficient and 4 units were inefficient. In the variable scale mode, 5 units were efficient and only 2 units were inefficient. The present study aimed to evaluate the efficiency (performance) of the Energy Research Center over years in order to develop an appropriate plan for the future. Considering the involved inputs and outputs and the information obtained from the evaluation one may analyze and explain the inefficiency of the center in certain years and use the results to improve the performance in the future years. In this way, the efficiency of the center would be ensured with a higher reliability. The results could manifest in the forms of economy in resources use and costs and boost in outputs.

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