International Journal of Data Envelopment Analysis

Science and Research Branch (IAU)

Evaluation and Complete Ranking of Islamic Azad University Unit Golestan Province with DEA Approach and a New Way of OEP / AHP[+]

Sima Madadi [a], Masoume Yazdanpanah Maryaki [b]*, Mohammad Reza Moazami Goudarzi [c]

(a) *Ph.D. Student Applied Mathematics, Operation Research trends, Department of Mathematics, Islamic Azad University, Gorgan Branch, Gorgan, Iran.*

(b) *Ph.D. Student Applied Mathematics, Operation Reasearch trends, Department of Mathematics, Lahijan Branch, Islamic Azad University, Lahijan, Iran.*

(c) *Assistant Prof, Department of Mathematics, Borujerd Branch, Islamic Azad University, Borujerd, Iran.*

Abstract

Data envelopment analysis provides a theoretical framework for analyzing performance and measuring efficiency. Using data envelopment analysis, we can evaluate units and organizations and discuss about their efficiency or inefficiency. In performance assessment of organizations, the most important goal is to rank the units according to their efficiency. Since ranking decision making units in data envelopment analysis may lead us to several efficient units, choosing the best efficient unit is very important. This study evaluates the research efficiency of Islamic Azad University of Golestan province applying DEA, and a new method «OEP / AHP» and finally offers a full ranking with respect to the exit.

Keywords: Data Envelopment Analysis (DEA), Output Efficiency Profile (OEP), Analytical Hierarchy Process (AHP), Ranking, OEP/AHP Approach, Islamic Azad University Unit Golestan Province.

1. Introduction

In addition to teaching at different educational levels and offering specialized services, universities are responsible for research and technology as well. Hence in all universities, research and technology are of serious attention and great facilities are anticipated for them. Obviously, success of the university in this section requires performance assessment of important factors. Nowadays research performance assessment and improvement to promote academic research level and to produce knowledge, is very important and essential in the Ministry of Higher Education.

Several performance assessment systems have been proposed up to now. Among these systems we can refer to balanced scorecard, business performance excellence model in Europe, the Malcolm Baldrige model, Analytic hierarchy process and Data envelopment analysis. Determining the best performance assessment strategy is the main concerns of researchers and managers of organizations. In the current competitive environment for which resource scarcity is one of its significant features, management and performance assessment plays a vital role for the organization. The establishment of a performance assessment system for measuring the performance is one of the conditions for the survival of an organization.

Since in the primary models of DEA first: measure of efficiency is a radial measure, second: a full ranking of units is not considered and these models classify units into just two categories, efficient and inefficient, third: These models do not have the ability to separate and distinguish between results, sufficiently. Hence this article aims to solve these problems simultaneously. We tried to use DEA in order to improve the discrimination, using output efficiency profile and integrating the model with Analytic Hierarchy process to provide a full ranking of DMUs. Then we proceeded to evaluate the research performance of Islamic Azad University of Golestan province with the mentioned model and presented full ranking model using the new method OEP / AHP for arithmetic average of the 5 years (2009-2010 to 2013-2014)

2. Analytic Hierarchy Process (AHP)

Multiple Criteria Decision Making (MCDM) is a decision making tool for complex multi-criteria problems that involves the qualitative and quantitative aspects of problem in the decision-making process. Multi-criteria techniques are tools that have been created in the field of decision theory to help solve the problem. By using this techniques a decision maker's preferences to select one option among the several options, that usually have different topics, are systematically modeled [1].

Analytic Hierarchy Process (AHP) is a mathematical technique for multi-criteria decision making [2] that enables one to make decisions such as: planning, prioritizing and choosing the best option [3]. AHP is used to

determine relative weights of evaluation criteria. AHP provides decision making about important parts of problem with a hierarchical structure [3]. This method converts complex decisions to simple paired comparisons. By analyzing these comparisons, AHP can lead us to the best decision [3].

We can refer to some advantages of AHP as follows:

1. It has the ability to formulate the problem and revise it.

2. It considers various options.

3. It considers various criteria (which are often in conflict).

4. It involves qualitative and quantitative criteria in decision-making.

5. It considers views of different people about the options and criteria and it is based on strong theory.

The method consists of four main steps:

Step 1: definition of problem.

Step 2: determination and selection of criteria.

Step 3: calculating relative weights (1- doing pair comparisons (Table 1), 2- calculating relative weights).

Step 4: comparing decision options.

Calculating the relative weights consists of three stages. In the paired comparison matrix, the sum of each column is calculated, then the matrix is normalized by dividing each element by the sum of corresponding column and finally the average of components of each row of the normalize matrix is calculated as the relative weight of each criterion.

Table 1. Preference Scale

Verbal Judgment of Preference	Numerical Rating
Extremely preferred	9
Very strongly to extremely preferred	8
Very strongly preferred	7
Strongly to very strongly preferred	6
Strongly preferred	5
Moderately to strongly preferred	4
Moderately preferred	3
Equally to moderately preferred	2
Equally preferred	1

Source: (Saaty, 1980)

For evaluating the compatibility of pair Judgments, compatible vector is calculated and its eigenvector λ is obtained then the compatibility ratio is determined from the equation (1):

$$CR = \frac{(\lambda - n)}{RI(n-1)} \quad (1)$$

Where RI is a random index, for n=3, 8 it is 0.58 and 1.41 respectively [2].The compatibility ratio should be less than 0.1, otherwise deciding makings should be revised [3].

3. Output Efficiency Profile (OEP) Method

As we mentioned the DEA is a radial measure of efficiency which assumes that an inefficient unit must decrease (increase) all of its inputs (outputs) with the same proportion to become efficient. It is obvious that this assumption is unnecessary, false and unreal. So, to solve this weakness and to raise awareness of how to use

the resources, it is more real to expect that different outputs have different efficiency [4]. Also, when the number of units is low and the number of inputs and outputs are high, a large number of units will be fully efficient and this is the fundamental problem of DEA, namely the ability to create results without discrimination and technique [5].

Lack of discrimination in DEA is because of that decision making units have a lot of flexibility in choosing their weights. In other words, the small number of decision-making units and the large number of inputs and outputs increases the valid region and due to the flexibility of weights a lot of decision making units will become efficient.

Various methods have been proposed for restricting the flexibility of weights as "weight restriction". Here we don't discuss these methods and their problems [6].

In what follows we state profile model for the following purposes, then by considering obtained efficiencies from the profile model and by using the AHP and calculating paired comparison matrix, OEP/AHP technique is applied.

1. Increasing the ability of discrimination, especially when the number of decision-making units is low compare to the number of inputs and outputs, and the empirical relationship $n \geq 2(m \times s)$ *or* $n \geq 3(m+s)$ is not satisfied (m is the number of inputs, s is the number of outputs and n is the number of decision making units).

2. Setting sample decision-making units for inefficient units in order to determine the amount of sources that is used by each decision making unit.

1-3. Mathematical model

Suppose that the ith source (input), $x_i, i = 1,...,m$ is used for producing s output $y_r, r = 1,...,s$ and also assume that s is a subset of all t outputs, ($s \leq t$).

Kumbhakar believes that "Knowing the magnitude of (overall) technical efficiency is not enough. It is important to know which of the outputs (products) are causing the inefficiency and how much it can be improved" [7].

So, in this model for each production an efficiency value is obtained based on the fact that the production consumes for which inputs, for example the relative efficiency of the ith input $(i = 1,...,m)$ of kth unit (E_{ik}) is obtained from the following linear programming:

$$Max \quad E_{ik} = \frac{\sum_{r=1}^{s} u_{irk} y_{rk}}{x_{ik}} \qquad (2)$$

$$s\,t \quad \frac{\sum_{r=1}^{s} u_{irk} y_{rj}}{x_{ij}} \leq 1, \quad j = 1,...,n$$

$$u_{irk} \geq \varepsilon > 0, \qquad i = 1,...,m$$

S is the number of outputs that consumes *ith* source [4].

Using this model, significant improvement achieved in the discrimination of DEA results. For example Tofallis says when the DEA was

used to calculate the efficiency of 14 airports more than half of them were fully efficient while by solving the problem with the profile model, none of the airports was fully efficient in all factors. This shows the significant improvement and strong discrimination of the model as well as its preference compare with other classical models of DEA.

On the other hand, by evaluating the use of any input individually, we will be able to identify best practice in each area. It is quite possible that no unit demonstrates best practice in every area therefore each unit will have targets to work towards [4].

It should be noted that despite all the identified strengths, the Profile model still does not provide a full ranking although it operates DEA, considering classification of tradition efficient / inefficient and previous models. But ultimately this model does not identify the priority and ranking of units with respect to each other in terms of all factors and all aspects in a comprehensive way and does not give a full ranking of them.

Tofallis also refers to the basic problem of profile model indirectly "It can be possible that the proposed profile model does not lead to a clear winner." To fix this problem he states that "value judgment is still necessary." He says if for example the decision-maker determines a condition of gaining minimum efficiency of 50 percent in every area for choosing place, then Portugal will be chosen as the first priority [4]. The question is: if more

than one decision making unit have the efficiency of determined condition (in this example 50%) in every area, what should we do? The following technique called OEP / AHP is proposed to solve this fundamental problem and to perform full ranking of units.

2-3. OEP/AHP method

For calculating efficiency and performing full ranking of units, the following steps should be taken:

1. Solving the problem by using the output efficiency profile model and obtaining the efficiency of each output.

2. Applying AHP

a) Using the results of the previous stage, we calculate paired comparisons matrix of units based on each criteria.

b) We also calculate paired comparisons matrix of indicators.

c) Now by obtaining paired comparisons matrices we perform different steps to obtain weights and to rank units with AHP.

4. Choosing input and output variables

The most important step in output efficiency profile (OEP) technique to measure the relative efficiency of each organization or institution, is selecting suitable and homogenous inputs and outputs. For this purpose all aspects must be considered. Efficiency assessment in one and two years or comparing the beginning and end of the period may be randomly, we use the arithmetic average of the 5 years period. It should be

mentioned that the main input and output variables are chosen from questionnaire according to academic purposes, research literature and by field study and related expert opinion of Ministry of Science.

Two main entrances of research are

a) Number of faculty members which has the following sub-indexes itself

1. Instructor training

2. Instructor

3. Assistant Professor

4. Associate Professor

5. Professor

We provided a questionnaire to determine the number of faculty members and for a correct choice of indexes related to number of faculty members, AHP group was used.

Since the AHP method uses numbers 1- 9 for ranking the results of comparison, in the questionnaire a 9 rating scale was determined for each indicator and the ratings spread from non-preferred to highly-preferred. Questionnaires were given to 10 experts. After explaining about the questionnaire, they were asked to rank each indicator in comparison carefully. Then from the questionnaires, table of paired comparisons was prepared and by using geometric average method, paired comparisons tables of decision makers were combined and the next steps were taken by Expert Choice software. Finally, the relative weights obtaining from the results of Expert Choice software were used to calculate the number of faculty members.

Table 2. The questionnaire was designed to determine the relative weight of indicators related to the number of faculty members using AHP

Number of faculty members	Instructor training	Instructor	Assistant Professor	Associate Professor	Professor
Instructor training	1				
Instructor		1			
Assistant Professor			1		
Associate Professor				1	
Professor					1

Table 3. The relative weight of indicators related to the number of faculty members of AHP using the software Expert Choice

	The relative weight of the AHP
Instructor training	0.033
Instructor	0.051
Assistant Professor	0.121
Associate Professor	0.280
Professor	0.515

Source: research findings

The number of faculty members = [(Instructor education) * 0.033] + [(Instructor) * 0.051] + [(Assistant Professor) * 0.121] + [(Associate Professor) * 0.280] + [(Professor) * 0.515];

By adopting the same procedure and using the Expert Choice software, corresponding relative weights for other indexes have been obtained which is visible in the table (4).

Table 4. Input and output and relative weights of Software Expert Choice

Input			Output		
The main input index	sub-indexes	The relative weight of Expert Choice Software	The main output index	Sub-indexes	The relative weight of Expert Choice Software
Number of Faculty members	Instructor training	0.033	Factor books (writing and translation), papers and inventions	Total number of books (written and translated) published	0.154
	Instructor	0.51			
	Assistant Professor	0.121		The total number of articles indexed scientific research	0.087
	Associate Professor	0.280			
	Professor	0.515		The total number of papers presented at national conferences	0.028
The total number of postgraduate students and PH.D.	The number of master students	0.125		The total number of papers presented at international conferences	0.019
	The number of PH.D. students	0.875		per capita of journal articles published in valid international journals	0.472
				per capita Scientific -Research and Science - Promote internal papers	0.040
				The total number of patents separation (home and abroad)	0.200
			Factor seminars and publications	The number of scientific - specialized seminars and conferences held in national and international level	0.175
				Number of Persian and Latin publications available in university libraries	0.041
				The number of scientific - Research journals	0.571
				The number of scientific-promoting journals	0.132
				The number of public scientific journals	0.081

Source: research findings

So according to table (4) other benchmark indexes are determined as follows:

- Total number of post graduate and PH.D. students = [(number of master students) * 0.125] + [(number of doctoral students) * 0.875];

- Factor books (writing and translation), papers and inventions index = [(total number of published books (written and translated)) * 0.154] + [(The total number of articles indexed scientific research) * 0.087] + [(The total number of papers presented at national conferences) * 0.028] + [(total number of papers presented at international conferences) * 0.019] + [(per capita of journal articles published in valid international journals) * 0.472] + [(per capita Scientific -Research and Science - Promote internal papers) * 0.040] + [(The total number of patents separation (home and abroad)) * 0.200];

- Factor seminars and publications index= [(The number of scientific - specialized seminars and conferences held in national and international level) * 0.175] + [(Number of Persian and Latin publications available in university libraries) * 0.041] + [(The number of scientific -Research journals) * 0.571] + [(The number of scientific-promoting journals) * 0.132] + [(The number of public scientific journals) * 0.081];

The final input and outputs are stated in table (5):

Table 5. The final table of input and output units Islamic Azad University of Golestan province

Name of university Unit	The number of criterion faculty member (i1)	The total number of criteria Post graduate and PH.D. students (i2) - modified	Factor criteria books(O1)	Factor criteria seminars and publications(O2)
DMU01[†]	9.63	34.325	34.052	151.442
DMU02	0.204	1	1.51	1
DMU03	1.773	6	3.957	2.111
DMU04	10.95	172.2	27.469	6.189
DMU05	0.561	1	0.501	1
DMU06	0.163	1	0.328	1
DMU07	0.12	1	0.482	1.189
DMU08	2.639	7.65	10.835	7.584
DMU09	0.061	1	0.048	1.343
DMU10	14.252	59.05	17.719	16.224

5. The results of OEP Model

By using efficiency profile model with respect to the first and second output, efficiency of Islamic Azad University units of Golestan province with respect to the first and second output are given in table (6):

[†] Because of the reluctance of universities in Golestan province has avoided mentioning the name of the relevant research projects and insert the names of the units is available.

Table 6. The results Profile input efficiency (efficiency for each input)

DMU (Name of university Unit)	% Inverse Efficency-OEP-o1	% Inverse Efficency-OEP-o2
DMU01	67.659	100
DMU02	100	31.017
DMU03	43.668	10
DMU04	33.647	3.333
DMU05	33.135	22.66
DMU06	27.167	38.655
DMU07	53.908	61.958
DMU08	93.721	22.467
DMU09	10	100
DMU10	19.869	10

Results of table indicates that only DMU02 is efficient with respect to first output (Factor criteria books index) and other units are inefficient so only 10% of the units are efficient with respect to the benchmark Factor criteria books index. In the above table the percentage of efficiency for each unit with respect to first output is given. Inefficient DMU08, achieved the highest percentage of efficiency (93.721%) among the inefficient units.

The important point is that most of the units have achieved a low level of efficiency with respect to the benchmark Factor criteria books index and this shows the poor performance of most of the units with respect to the benchmark Factor criteria books index. DMU02, which becomes 100% efficient, can be a pattern for them to get to efficiency.

The table indicates that in the second output, means benchmark Factor criteria seminars and publications index, only two DMU01 and DMU09 have operated efficiently which is equal to 20% of units, other units are inefficient. Value and percentage of efficiency associated with other units are evident from the table. Again most of units have achieved low level of efficiency and they should see pattern units with 100% efficiency.

In the above table it can be seen that for most units there isn't a same balance for percentage of efficiency between first and second output.

For example, DMU09 has the efficiency of 100% with respect to first output and the efficiency of 10% with respect to second output. By seeing the above table we can compare the efficiency with respect to the first and second output for other units.

1-5. Results of OEP\AHP

OEP model does not provide a full ranking of units just like IEP model. Therefore we use OEP / AHP method. In OEP\AHP method we take the same steps as the steps of IEP\AHP.

Paired comparison matrix of units with respect to each output criterion is calculated using the results of the previous stage.

Then paired comparisons matrix of output criterion with respect to each other according to experts opinion was defined as follows:

Table 7. Pairwise comparison matrix of indicators of outputs relative

Pairwise comparison matrix outputs to each other	Factor criteria books index (O1)	Factor criteria seminars and publications (O2)
Factor criteria books index (O1)	1	2
Factor criteria seminars and publications (O2)	0.5	1

When the pair comparison matrix was determined, we do the necessary steps in order to obtain weights and to rank units using AHP. After this process the following results were obtained:

a) Calculating the relative importance of units from outputs view

$$\begin{bmatrix} 0.140 \\ 0.207 \\ 0.090 \\ 0.070 \\ 0.069 \\ 0.056 \\ 0.112 \\ 0.194 \\ 0.021 \\ 0.041 \end{bmatrix} \qquad \begin{bmatrix} 0.250 \\ 0.078 \\ 0.025 \\ 0.008 \\ 0.057 \\ 0.097 \\ 0.155 \\ 0.056 \\ 0.250 \\ 0.025 \end{bmatrix}$$

The relative importance of units in terms of output 1   The relative importance of units in terms of output 2

So the final matrix would be as follows:

DMU(Name of university Unit)	O1	O2
DMU01	0.14	0.25
DMU02	0.207	0.078
DMU03	0.09	0.025
DMU04	0.07	0.008
DMU05	0.069	0.057
DMU06	0.056	0.097
DMU07	0.112	0.155
DMU08	0.194	0.056
DMU09	0.021	0.25
DMU10	0.041	0.025

b) Calculating output indicators relatively with respect to each other which were obtained by using experts opinion in Expert Choice Software:

$$\begin{bmatrix} 0.667 \\ 0.333 \end{bmatrix}$$

The relative weight to each output

By multiplying the above two matrices, prioritizing of options is calculated as follows:

$$\begin{bmatrix} 0.140 & 0.250 \\ 0.207 & 0.078 \\ 0.090 & 0.025 \\ 0.070 & 0.008 \\ 0.069 & 0.057 \\ 0.056 & 0.097 \\ 0.112 & 0.155 \\ 0.194 & 0.056 \\ 0.021 & 0.250 \\ 0.041 & 0.025 \end{bmatrix} \times \begin{bmatrix} 0.667 \\ 0.333 \end{bmatrix} = \begin{bmatrix} 0.177 \\ 0.164 \\ 0.0686 \\ 0.049 \\ 0.0646 \\ 0.070 \\ 0.126 \\ 0.148 \\ 0.097 \\ 0.036 \end{bmatrix}$$

Table 8. The final weight of Islamic Azad University Golestan Province using OEP / AHP

DMU01	DMU02	DMU03	DMU04	DMU05	DMU06	DMU07	DMU08	DMU09	DMU10
0.177	0.164	0.0686	0.049	0.0646	0.07	0.126	0.148	0.097	0.036

So the final weight of Azad University units of Golestan province is as follows:

Finally Ranking of decision making units based on OEP / AHP is as follows:

DMU01☐ **DMU02**☐ **DMU08**☐

DMU07☐ **DMU09**☐ **DMU06**☐

DMU03☐ **DMU05**☐ **DMU04**☐

DMU10

6. Conclusion

In a world that competition, change and ongoing challenges are its significant features, only organizations are able to Survive and continue living that allocate their limited resources and facilities efficiently in this complex and unstable conditions and identify obstacles of efficiency and do performance based on scientific approaches to remove these obstacles, hence performance assessment and identifying strengths and weaknesses in this matter plays an important role.

One of the known techniques in the literature of performance assessment is data envelopment analysis. This technique calculates efficiency of units by dividing the sum of outputs to inputs and classifies them to two categories, efficient and inefficient. Numerous articles have been published, particularly on the various applications of this technique. But in general, there are some limitations in relation to the results and outputs of this technique as follows:

1. This technique classifies the units to only two categories, efficient and inefficient and does not determine priority for them.

2. If the number of units is low and the total number of inputs and outputs is high, most units will be efficient. This lack of discrimination between units is a weakness.

Due to the above limitations, in this research, a technique called Output Efficiency Profile/ Analytic Hierarchy Process (OEP / AHP) is proposed which tries to resolve the above two limitations by combining two methods OEP and AHP. This technique investigates the associate units carefully by using abilities of OEP and even involves small differences between units in their evaluation and then AHP is applied for full ranking of units. In the proposed technique (OEP / AHP) first using OEP, the units are investigated and paired comparison matrix required for AHP is calculated, then AHP provides the final priority.

References

[1] Garfi M, Tondelli S, Bonoli A. Multi-criteria decision analysis for waste management in Saharawi refugee camps. Waste management. 2009;29(10):2729-39.

[2] Saaty TL. The Analytic Hierarchy Process: Planning, Priority Setting, Resource

Allocation: McGraw-Hill; 1980.

[3] Carlsson C, Walden P. AHP in political group decisions: A study in the art of possibilities. Interfaces. 1995;25(4):14-29.

[4] Tofallis C. Input efficiency profiling: an application to airlines. Computers & Operations Research. 1997;24(3):253-8.

[5] Sinuany-Stern Z, Friedman L. DEA and the discriminant analysis of ratios for ranking units. European Journal of Operational Research. 1998;111(3):470-8.

[6] Doyle J, Green R. Data envelopment analysis and multiple criteria decision making. Omega. 1993;21(6):713-5.

[7] Kumbhakar SC. Estimation of input-specific technical and allocative inefficiency in stochastic frontier models. Oxford economic papers. 1988:535-49.

[8] Ali AI, Seiford LM. Translation invariance in data envelopment analysis. Operations Research Letters. 1990;9(6):403-5.

[9] Ertay T, Ruan D, Tuzkaya UR. Integrating data envelopment analysis and analytic hierarchy for the facility layout design in manufacturing systems. Information Sciences. 2006;176(3):237-62.

[10] Pastor JT. Translation invariance in data envelopment analysis: A generalization. Annals of Operations Research. 1996;66(2):91-102.

[11] Sinuany-Stern Z, Mehrez A, Hadad Y. An AHP/DEA methodology for ranking decision making units. International Transactions in Operational Research. 2000;7(2):109-24.

[12] Tofallis C. Improving discernment in DEA using profiling. Omega. 1996;24(3):361-4.

[13] Witzel M. A short history of efficiency. Business Strategy Review. 2002;13(4):38-47.