

Efficiency Evaluation of International Airports in Iran using Data Envelopment Analysis

Mahroo Pedram and Ali Payan*

Department of Mathematics, Zahedan Branch, Islamic Azad University, Zahedan, Iran; payan_iauz@yahoo.com, apayan_srb@yahoo.com

Abstract

This paper follows two main purposes. These two purposes include the analysis of the efficiency and ranking 7 domestic airports in Iran that have international airlines during 2010 - 2013. However, the indicated airports are under the ownership of the main company of the airports in the country and do not include all Iranian airports. On the other hand the Data Envelopment Analysis (DEA) is used as a non-parametric mathematical programming technique to evaluate the performance of international airports. Basically, regarding the first purpose an overall assessment of the efficiency of the airports is followed and the amount of the airport efficiency is measured and compared based on Russell's model in DEA. Then in line with the second purpose the efficient airports are ranked based on the super-efficiency method. The structure of international airports as decision making units in DEA has been obtained by four inputs and three outputs. The results indicated that the Mehrabad, Mashhad and Bandarabbas airports had the full efficiency during all periods and these units have the first, second and third ranks, respectively. The Malmquist index of airports in these four periods can be obtained in order to better understanding of the productivity and performance of international airports.

Keywords: Data Envelopment Analysis, Efficiency, International Airports, Ranking, Russell Model

1. Introduction

Data Envelopment Analysis (DEA) is an approach to relatively evaluate the set of Decision-Making Units (DMU) in the manufacturing process. Various methods are introduced for measuring the efficiency of decision making units that can be divided into two broad categories: parametric methods and nonparametric methods. Farrell¹ raised the nonparametric methods for the first time. Using the outputs and the inputs of the decision-making units he fitted a function into the outputs and the inputs sets in which all the decision-making units are under the function diagram. The result of the mentioned fitness was a continuous fragmented function. This boundary is called Farrell boundary. Charnes et al.² generalized the primary analysis of Farrell which was presented in the form of one input and one output into multi-input and multi-input mode and presented the CCR model for the

evaluation of the decision making units. Then Banker et al.³ presented a model in the form of variable returns to scale mode called the BCC. The efficiency scores obtained from the DEA model (even if the production function is unknown), can evaluate the efficiency of the decision-making units based on a multiple inputs and outputs. Most of the evaluation scores of DEA models are between zero and one. The preliminary results of the DEA models grouped the decision-making units into the efficient and inefficient sets. The DMUs that are not located on the boundary have the efficiency score below 1 and they are considered inefficient and the DMUs located on the boundary have the efficiency score of 1 and they are considered efficient and (theoretically) there is no distinction among them. For the better assessment of the efficiency of DMUs most decision makers are after a full ranking of the DMUs⁴. In some methods of ranking the DMU omission from the production set method and the analysis of other

*Author for correspondence

DMUs in the new Production Possibility Set (PPS) is used. These methods are called super-efficiency methods⁵. Nowadays the efficiency and efficiency of air transport industry goes beyond providing transportation services when compared with other forms of transportation because the air transports has affected our economic, social and cultural attitudes and historical and political communities. This industry offers new solutions for business and occupation and provides good opportunities for the permanent exchange of information and facilitates the relationship between peoples from different cultures. The airports are known as the most fundamental part of the air transportation infrastructure because the rapid growth of traffic volume and demand for air travel and transfers, consistent with international rules and standards and strict requirements for flight operations have led these infrastructures to be considered as complex and dynamic systems and one of the main elements of the air transport industry. In this study the data envelopment analysis is used as a tool for evaluating and ranking the country's airports' system. The DEA identifies the efficient units and helps to reduce the waste of resources in the airports' system. The airports in the country affect the economic development of the country due to their valuable nature. Today, in order to increase revenue and reduce the losses caused by the sudden accidents the constant improvement of the efficiency of airports is necessary. One of the requirements for the improvement in this context is the continuous efficiency assessment using appropriate tools. The purpose of this study was to evaluate the efficiency and rating the country's airports system.

2. Data Envelopment Analysis

Consider a decision-making unit such as Figure 1. Suppose that n DMUs are evaluated that each DMU has m input and s output represented as x and y respectively.



Figure 1. Decision making unit.

The following model is called CCR cover model which was presented to calculate the efficiency of the DMUs.

for $\min(\theta)$:

$$s.t \quad \sum_{j=1}^n \lambda x_{ij} + s_i^- = \theta x_{ip}, \quad i = 1, \dots, m \quad (1)$$

$$\sum_{j=1}^n \lambda y_{rj} + s_r^+ = y_{rp}, \quad r = 1, \dots, s \quad (2)$$

$$\lambda_j \geq 0 \quad j = 1, \dots, n \quad (3)$$

$$s_i^- \geq 0 \quad i = 1, \dots, m \quad (4)$$

$$s_r^+ \geq 0 \quad r = 1, \dots, s \quad (5)$$

Definition 1. DMUP CCR is efficient if $\theta^0 = 1$.

The DEA models can be divided into two categories of radial and non-radial models.

In the models introduced so far the contraction of inputs and the expansion of the outputs have been performed with the same rate which are called the radial model. One of the non-radial models is the Russell model in which the i -th input is reduced proportionate to θ and the j -th output is increased proportionate to ϕ_m the general form of which is as follows:

$$\text{Min} \frac{1}{m} \sum_{i=1}^m \theta_i + \frac{1}{s} \sum_{r=1}^s \frac{1}{\phi_r} \quad r = 1, \dots, s \quad (6)$$

$$s.t \quad \sum_{j=1}^m \lambda_i x_{ij} \leq \theta_i x_{ij}, \quad i = 1, \dots, m \quad (7)$$

$$\sum_{j=1}^m \lambda_i y_{rj} \geq \phi_r y_{ro}, \quad r = 1, \dots, s \quad (8)$$

$$\theta_i \leq 1 \quad i = 1, \dots, m \quad (9)$$

$$\phi_r \geq 1 \quad r = 1, \dots, s \quad (10)$$

$$\lambda_j \geq 0 \quad j = 1, \dots, n \quad (11)$$

The non-linearity of the objective function creates problems to solve it that based on the problems of the Russell model, a new model is introduced as follows in which the objective function is the ratio of the mean input size to the mean output size.

$$\text{Min} \quad \text{Re} = \frac{\frac{1}{m} \sum_{i=1}^m \theta_i}{\frac{1}{s} \sum_{r=1}^s \varphi_r} \quad (12)$$

$$\text{s.t.} \quad \sum_{j=1}^m \lambda_j x_{ij} \leq \theta_i x_{i0}, \quad i = 1, \dots, m \quad (13)$$

$$\sum_{j=1}^m \lambda_j y_{rj} \geq \varphi_r y_{r0}, \quad r = 1, \dots, s \quad (14)$$

$$\theta_i \leq 1 \quad i = 1, \dots, m \quad (15)$$

$$\varphi_r \geq 1 \quad r = 1, \dots, s \quad (16)$$

$$\lambda_j \geq 0 \quad j = 1, \dots, n \quad (17)$$

This model is known as modified Russell model⁶. In this model the maximum reduction of the inputs and the maximum increase in the outputs are obtained. Each input is contracted θ_i^* and expanded. φ_r^* . We put

$$\beta = \frac{1}{\left(\sum_{r=1}^s \frac{\varphi_r}{s} \right)} \quad \text{Therefore all the variables used in model (3) are transformed as follows:}$$

$$u_i = \beta \theta_i \quad i = 1, \dots, m \quad (17)$$

$$v_r = \beta \varphi_r \quad r = 1, \dots, s \quad (18)$$

$$t_j = \beta \lambda_j \quad j = 1, \dots, n \quad (19)$$

By applying these transformed variables, the formulation of the model (3) becomes as follows:

$$\text{Min} \sum_{i=1}^m \frac{u_i}{m} \quad (20)$$

$$\text{s.t.} \quad \sum_{r=1}^s \frac{v_r}{s} = 1 \quad (21)$$

$$\sum_{i=1}^m t_i x_{ij} \leq u_i x_{i0}, \quad i = 1, \dots, m \quad (22)$$

$$\sum_{j=1}^m t_j y_{rj} \leq v_r x_{r0}, \quad r = 1, \dots, s \quad (23)$$

$$u_i \leq \beta \quad i = 1, \dots, m \quad (24)$$

$$\beta \leq v_r \quad r = 1, \dots, s \quad (25)$$

$$t_j \geq 0 \quad j = 1, \dots, n \quad (26)$$

$$\beta \geq 0 \quad (27)$$

Now the Russell's model has changed into a linear programming model while the principle of constant returns to scale is confirmed.

3. Airports in Iran

As it is inferred from the term evaluation and measurement of the companies, organizations and businesses, the power to change the current rules by managers is the greatest help of the evaluators to the managers.

The elaborative assessment is like an honest mirror that reflects all the strengths and weaknesses of a company and truly represents the condition of the company compared to other competitors and in order to obtain power in the market giving value to the creativity of the staff, the emphasis on productivity and the change of previous rules are among the measures taken after the assessment. Generally during 2010 - 2013 there were 82 operational and operational airports under study in the buildings and infrastructure sector among which 7 airports were international and the rest were the local airports and the airports with airlines. In addition, among 82 airports existing in the country, 54 airports are own and managed by the airport company of the country. But according to the Islamic Republic of Iran's Shipping Reform Act the airport company is appointed as the policy maker and the beneficiary of the mentioned airports and based on the Airport laws of the country it is under the command of the commands and laws of the airport organization of the country and the International Civil Aviation Organization ICAO. Also this company is the official representative of our country in the Airport Council International ACI which supports the international field applied research and activities. Basically, the scientific communities around the world play an important role between the industry and universities and their main purpose is to use the creativity of researchers and scientific and to be consistent with

those scientific pioneers, but the application of scientific research is the final goal in these institutes.

Nowadays the motto of the international institutes such as ICAO is summarized inefficient, safe and high quality aviation and they have the greatest responsibility regarding the aviation in the international community.

The ICAO is obliged to implement and refine the formulation of international standards and criteria and it has never neglected the previous standards and guidelines and approves new guidelines and audits in line with globalization. But ICAO has always been negligent and carefree about the influential university research in the process of improving airport efficiency which has made the International Association of Airports and the International Air Transport Association must identify such issues and implement them.

But what is evident in the aviation industry of the country is paying low attention to creativity and the loss of intellectual, financial and social resources. However, our country has always been in compliance with international standards and criteria and considered as role model in the Middle East region and has made ICAO to use its theoretical experiences to the point that Iran is the Secretary of the Executive Committee to perform the aviation guidelines in the area, however, its practical and professional activities have been much less evident than the theoretical ones and it has never has a prominent role in this realm so that our country is settled down to the minimum immunity standards, the customer's satisfaction, efficient services and does not understand the customers dissatisfaction.

This part is about the analysis and comparative evaluation of airports performance in which some deficits and in some cases the lack of systematic information in the airports are evident. So the researcher has decided to select 7 international airports. In this part 7 international airports are analyzed and evaluated and we hope that the airport company would achieve bigger successes through planning in qualitative and quantitative dimensions.

4. Airports as DMUs

The population being studied in this research is the international airports in the country and in this study each one of the airports is considered as one DMU as shown in Figure 2.

The data are the input and outputs of the airports as the DMUs during 2010-2013, which are stated in Tables 1, 2, 3, and 4. The inputs of this study are divided into four categories, namely:

- The number of staff working in airports (x1).
- The domestic terminal area in square meters (x2).
- The external terminal area in square meters (x3).
- The number of terminals (x4). And output variables are:
- The number of takeoffs and landings of the aircrafts at the airport based on the flight (y1).
- The sending and reception at the airport in terms of passengers (y2).
- The sending and acceptance of loads in every airport in terms of tonnage (y3).

About selecting the inputs in must be noted that the two inputs of the domestic and international terminals are among the uncontrollable inputs and the number of personnel are controlled or partly controlled inputs and these conditions are also true for some of the outputs as well.

It must be noted that the input variable are the same during all 4 periods.

5. Result

5.1 Efficiency and Ranking Airports

Based on the material presented in the previous sections the Data Envelopment Analysis (DEA) is used in this study to measure efficiency in the airports. Among the models of the method the modified Russell model will be used. Also in order to compare the efficiency of the airports and their ranking the AP model will be devised. The positive point in using the modified Russell model is that the model supervises the reduction in the input and the increase in the output variable simultaneously.

The modified Russell model calculated the efficiency of each DMUs assuming the constant returns to scale. In the Russell model the focus is on the inputs and the outputs simultaneously in other words by utilizing this model besides calculating the efficiencies we are able to answer the question that how it is possible to use fewer inputs and obtain higher outputs compared to the present condition. Table 5 presents the results of Russell model for 7 DMUs. The results of Table 5 indicate that among 3 out of 7 airports have been able to use the resources optimally and reach the highest efficiency level and act efficiently within all periods.



Figure 2. Airport instruction as DMU.

Table 1. The inputs and outputs of the airports in 2010

Airport	Data				Outputs		
	X1	X2	X3	X4	Y1	Y2	Y3
Mehrabad	9447	39830	13500	5	109055	13163368	112394
Mashhad	4007	14528	33800	3	44749	5983227	56533
Esfahan	1560	13750	7300	2	17722	1902552	17825
Shiraz	2022	11200	12000	2	24187	2438387	25332
Tabriz	887	8000	5800	3	11592	1376655	12020
Bandarabbas	811	7708	2700	2	10590	1132341	10528
Zahedan	359	4200	4742	3	4186	484572	6524

Table 2. The inputs and outputs of the airports in 2011

Airport	Data				Outputs		
	X1	X2	X3	X4	Y1	Y2	Y3
Mehrabad	9447	39830	13500	5	108553	13569573	112465
Mashhad	4007	14528	33800	3	43874	6173898	53155
Esfahan	1560	13750	7300	2	17782	1968529	19029
Shiraz	2022	11200	12000	2	23977	2404817	24891
Tabriz	887	8000	5800	3	11650	1387680	11658
Bandarabbas	811	7708	2700	2	10893	1146365	9423
Zahedan	359	4200	4742	3	5099	524190	4997

Table 3. The inputs and outputs of the airports in 2012

Airport	Data				Outputs		
	X1	X2	X3	X4	Y1	Y2	Y3
Mehrabad	9447	39830	13500	5	108291	13446918	107074
Mashhad	4007	14528	33800	3	47053	6773968	58811
Esfahan	1560	13750	7300	2	17071	1965662	18799
Shiraz	2022	11200	12000	2	24328	2329702	25199
Tabriz	887	8000	5800	3	10391	1261822	10004
Bandarabbas	811	7708	2700	2	9812	1043115	9262
Zahedan	359	4200	4742	3	4938	465578	4230

Table 4. The inputs and outputs of the airports in 2013

Airport	Data				Outputs		
	X1	X2	X3	X4	Y1	Y2	Y3
Mehrabad	9447	39830	13500	5	108614	13106391	99638
Mashhad	4007	14528	33800	3	51345	7321371	65685
Esfahan	1560	13750	7300	2	17335	2103633	20701
Shiraz	2022	11200	12000	2	24633	2329428	24835
Tabriz	887	8000	5800	3	9778	1235403	9823
Bandarabbas	811	7708	2700	2	9860	953366	7590
Zahedan	359	4200	4742	3	4432	408453	3732

Table 5. Efficiency of airports

Airport	2010	2011	2012	2013
Mehrabad	1	1	1	1
Mashhad	1	1	1	1
Esfahan	0.51483	0.61052	0.59008	1
Shiraz	1	1	1	0.68634
Tabriz	1	1	0.58823	0.47244
Bandarabbas	1	1	1	1
Zahedan	1	1	1	0.36216

Table 6. Super-efficiency of airports

Airport	2010	2011	2012	2013
Mehrabad	1.37593	1.37593	1.37593	1.37593
Mashhad	1.11526	1.09363	1.17463	1.2771
Esfahan	0.51473	0.61052	0.59008	1.06454
Shiraz	1.01326	1.00851	1.02489	0.68634
Tabriz	1.03476	1.03576	0.58823	0.47244
Bandarabbas	1.07866	1.07022	1.03831	1.03746
Zahedan	1.13012	1.05902	1.04998	0.36216

Also Table 5 indicates that Shiraz, Tabriz and Zahedan airports did not have a good performance during the 4 periods which has made them an inefficient unit but the Esfahan Airport has been able to improve in these periods through the correct use of the resources and become an efficient unit. So Shiraz, Tabriz and Zahedan must emulate the values airports

of the inputs and outputs like the Esfahan Airport to become efficient units. In order to answer the second question of the research using the AP super-efficiency and utilizing the results of devising Russell's model the ranking of the DMUs is performed. The results of using super-efficiency of the Russell's model are presented in Table 6.

The results of the model indicate that the Mehrabad airport is with super-efficiency of 37.1 is at the first place in all periods and in 2010 the Zahedan airport with super-efficiency of 13.1 was in the second place and the Mashhad airport with super-efficiency of 11.1 was in the third place but in 2011 - 2012 the Mashhad airport was in the second place with higher super-efficiency.

Table 7 shows the ranking of units according to the second research question which is as follows:

In 2010 the Mehrabad, Zahedan, Mashhad, Bandarabbas, Tabriz, Shiraz and Esfahan Airports were ranked respectively from the 1st to the 7th places.

In 2011 the Mehrabad, Mashhad, Bandarabbas, Zahedan, Tabriz, Shiraz and Esfahan Airports were ranked respectively from the 1st to the 7th places.

In 2012 the Mehrabad, Mashhad, Zahedan, Bandarabbas, Shiraz, Esfahan and Tabriz Airports were ranked respectively from the 1st to the 7th places.

In 2013 the Mehrabad, Mashhad, Esfahan, Bandarabbas, Shiraz, Tabriz and Zahedan Airports were ranked respectively from the 1st to the 7th places.

Table 7. Ranking of airports

Airport	2010	2011	2012	2013
Mehrabad	1	1	1	1
Mashhad	3	2	2	2
Esfahan	7	7	6	3
Shiraz	6	6	5	5
Tabriz	5	5	7	6
Bandarabbas	4	3	4	4
Zahedan	2	4	3	7

Table 8. Overall ranking of airports

Airport	Ranking Number	Ranking
Mehrabad	1	1
Mashhad	25/2	2
Esfahan	75/5	6
Shiraz	5/5	5
Tabriz	75/5	6
Bandarabbas	75/3	3
Zahedan	4	4

In this level using a criterion we presented a general ranking for the DMUs which is based on the total ranks of a DMU within all periods divided by the number of the periods the results of which are presented in Table 8.

The findings of this table indicate that, in general, for all periods the airports of Mashhad, Bandarabbas, Zahedan, Tabriz, Shiraz and Esfahan are placed in 1st to 6th places respectively.

6. Conclusion

The purpose of this study was to calculate the efficiency and ranking of the international airports as the DMUs. To calculate the efficiency of each of the units the Russell model was utilized and then by using the super-efficiency model the ranking of the airport was performed. The results of the model in Figure 3 indicated that the Mehrabad, Mashhad and Bandarabbas Airports had the necessary efficiency during all periods but the Shiraz, Tabriz and Zahedan with a weak performance have become inefficient units and the Esfahan Airport has become an efficient unit through god performance. The results of super-efficiency of the Russell model ranked the efficient airports as Mehrabad, Mashhad and Bandarabbas airports which are in the 1st to 3rd places. Figure 4 presents the ranking of DMUs during the 4 periods.

Based on Figure 4 and Table 8 about the ranking of the airports, the Esfahan Airports which was inefficient in the 3rd period and has higher ranks during these 3 periods but due to a great performance in the 4th period it is placed in the thirds place before Tabriz Airport. However, Tabriz had a good performance during the first two periods but due to weak performance in the later periods it is located in higher ranks. In the overall ranking of Esfahan is placed in 6th place. In fact the Esfahan Airport's performance in considered as a compensatory function because according to the obtained results it is determined that the Esfahan Airport wanted to compensate its poor efficiency during the periods but Zahedan airport in the first three periods has a relatively good efficiency but since it was inefficient in the 4th period, it is placed in the 4th rank.

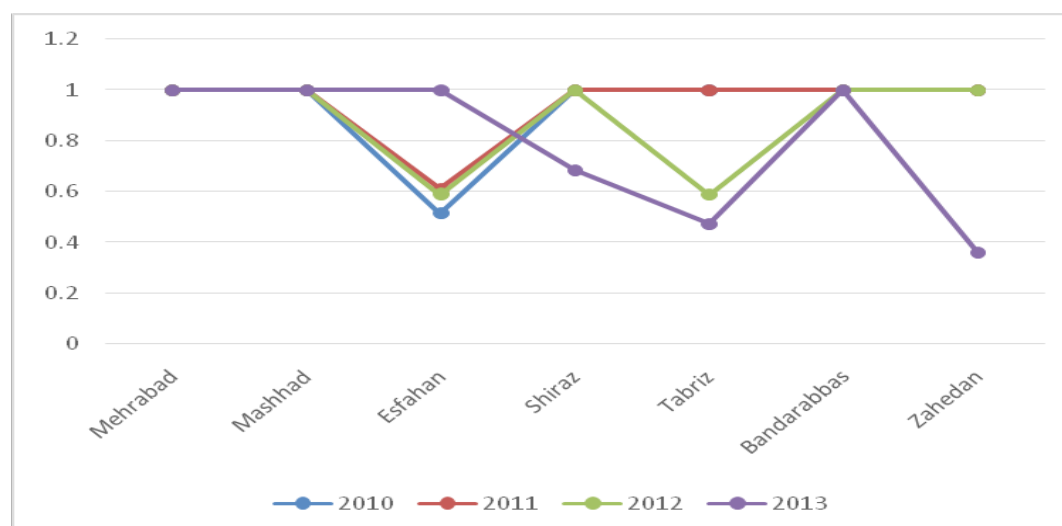


Figure 3. Efficiency of airports.

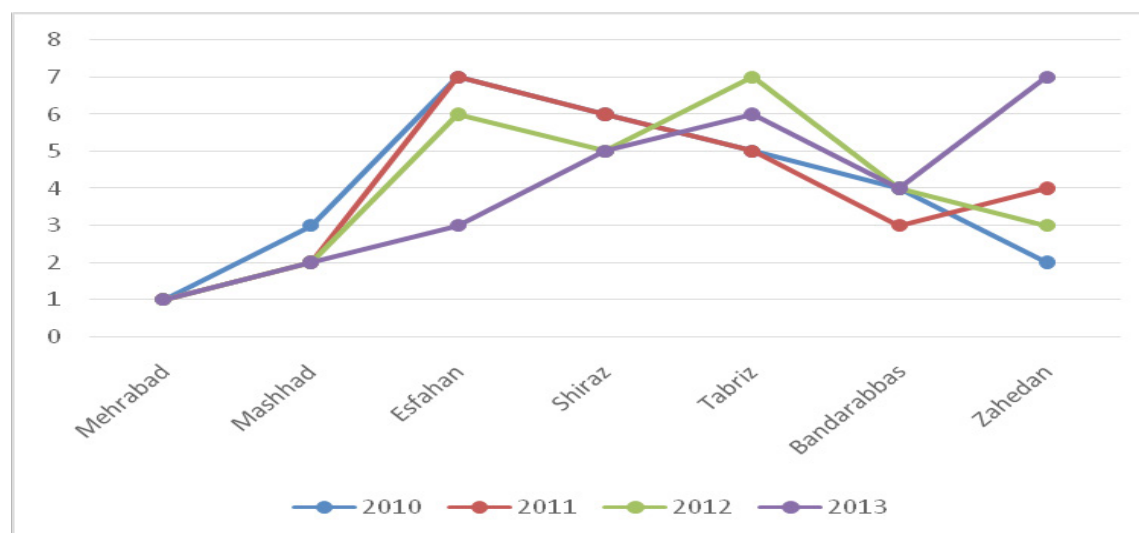


Figure 4. Ranking of airports.

7. References

- Farrell MJ. The measurement of productive efficiency. *J Roy Stat Soc.* 1957; 120:253–90.
- Charnes A, Cooper WW, Rhodes E. Measuring the efficiencies of DMUs. *Eur J Oper Res.* 1978; 2:429–44.
- Banker RD, Charnes A, Cooper WW. Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Manag Sci.* 1984; 30:1078–92.
- Adler N, Friedman L, Sinuanny-Stern Z. Review of ranking methods in the data envelopment analysis. *Eur J Oper Res.* 2002;140:249–65.
- Anderson P, Peterson NC. A procedure for ranking efficient units in data envelopment analysis. *Manag Sci* 1993; 39(10):1261–4.
- Jahanshahloo, Gh, Hosseinzadeh Lotfi F. *Ranking in the DEA*, Tehran: Nafis; 2006.