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ASSESSMENT OF TURKISH AIRPORTS' EFFICIENCY USING DATA ENVELOPMENT ANALYSIS

After the second half of the 20th century, airline transportation increased its influence very rapidly having become the today's most important transportation sector. Consumer demand for airline transportation was increasing during several decades. Accordingly, airports which are the infrastructure centres of the aviation sector became crucially important for maintaining such growing demand. In this context, the assessment of efficiency of Turkish airports becomes pivotal, in particular with the increasing demand and air transaction movements. In this study, Turkish airports' efficiency will be evaluated through the data envelopment analysis.

Keywords: *data envelopment analysis; decision-making units; efficiency; airports.*
JEL Classification: L25, L33, L90.

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ОЦІНЮВАННЯ ЕФЕКТИВНОСТИ РОБОТИ ТУРЕЦЬКИХ АЕРОПОРТІВ МЕТОДОМ АНАЛІЗУ СЕРЕДОВИЩА ФУНКЦІОНУВАННЯ

У статті показано, що починаючи з другої половини XX століття повітряний транспорт став відігравати все суттєвішу роль, відповідно зростав і споживчий попит протягом декількох десятиліть. Аеропорти являють собою інфраструктурні центри галузі, отже мають розвиватися у відповідності до зростаючого попиту на дану транспортну послугу. Саме тому оцінювання ефективності їх роботи має важливе значення як у контексті зростаючого попиту, так і для забезпечення повітряного транспорту в цілому. Ефективність роботи аеропортів досліджено за даними Туреччини методом аналізу середовища функціонування.

Ключові слова: *аналіз середовища функціонування; центри прийняття рішень; ефективність; аеропорти.*
Рис. 3. Табл. 2. Літ. 19.

Уджур Гьок, Севин Угурал

ОЦЕНИВАНИЕ ЭФФЕКТИВНОСТИ РАБОТЫ ТУРЕЦКИХ АЭРОПОРТОВ МЕТОДОМ АНАЛИЗА СРЕДЫ ФУНКЦИОНИРОВАНИЯ

В статье показано, что начиная со второй половины XX века воздушный транспорт стал играть всё более возрастающую роль, соответственно рос и потребительский спрос в течение нескольких десятилетий. Аэропорты являются инфрастуктурными центрами данной отрасли, они должны развиваться в соответствии с растущим спросом на данную транспортную услугу. Именно поэтому оценивание эффективности их работы имеет важное значение как в контексте растущего спроса, так и для обеспечения воздушного движения в целом. Эффективность работы аэропортов исследована по данным Турции методом анализа среды функционирования.

Ключевые слова: *анализ среды функционирования; центры принятия решений; эффективность; аэропорты.*

1. Introduction

Turkey is the 6th largest economy in Europe and according to the current growth trend and statistical predictions, in a few decades Turkish economy will be the third

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largest economy in Europe after Germany and Russia. In this context, Turkish infrastructure (especially the transportation one) becomes crucially important in providing sustainable economic development. As a result of increasing commercial and political relations with other countries, transportation infrastructure gained an important role for the development of Turkey.

For a country to compete economically with other countries, transport networks and infrastructure must be advanced enough for this competition. Harbors, railroads, roads and airports therefore become a vital part of the development process of the countries. Ribeiro and Kobayashi (2007) pointed out that "transport activity is a key component of development and human welfare". From past to present with the increasing trade, globalization and human needs, airline transportation became crucial in delivering transportation services of today's world. Especially after the second half of the 20th century, airports have been the essential transport infrastructure for the development of commercial, social and political relations in the global context. Therefore, operating airports more effectively will become a new phenomenon in the near future since continuous growth of air traffic and network expansions depends on the physical structure of buildings, runways, technological situation and operation of airports. For this reason, measuring the airports' efficiency is crucial. As Martin and Roman (2001) pointed out, "it is necessary to evaluate if a fixed physical capacity is able to provide services to more air transaction movements and passengers".

With the increasing air traffic in Turkish aviation, problems faced by airports are expected to increase in the next decade. The solution of these problems will necessitate a clear understanding of the current structure, suitably based on the efficiency analysis. However, until now the efficiency analysis of Turkish airport infrastructure has not been elaborated. Accordingly, our main aim in this study is to analyze the efficiency and the overall performance of Turkish airports using the data envelopment analysis (DEA).

2. Literature Review

After the World War II, aviation industries have been under the state control all around the world and airport operations were the state monopoly. But it is known that there is a productivity bias for state owned operated airports. Government investments do not depend on demand since governments do not behave like the private sector (Ozenen, 2003). Accordingly, airport efficiency started to attract attention of researchers and academics especially at the end of the 1990s. In the first decade of the 21st century the efficiency of airports became a popular issue among researchers and a number of academic studies have been conducted. These studies can be divided into two groups in terms of the methods used, namely, parametric and non-parametric ones.

Stochastic frontier analysis (SFA) is the method that measures the airport efficiency under the parametric method. SFA was first introduced by Aigner and Chu in 1968 and it became a widely used method for efficiency tests. But the test was mainly used for evaluating the efficiency of profit and non-profit organizations. Some studies related to the application of SFA for measuring the airport efficiency are Pelset et al. (2001, 2003), Oum and Yu (2004), Yoshida and Fujmoto (2004) and Barros (2008).

Another non-parametric method is data envelopment analysis (DEA). DEA is a method of measuring efficiency of a decision-making unit, DMU, for public sector and non-profit organizations. DEA was first introduced by Farrell (1957). Afterwards Charnes, Cooper and Rhodes (1978) reshaped his study under constant returns to scale and this was accepted as the basic method of DEA. It is the most widely used method among researchers in the last decade since it is suitable to test different aspects of airports efficiency (Yang, 2010). For example, Gillen and Lall (1997) tested the overall performance of 21 US airports. They showed that, demand for airport services are inelastic because airports have limited potential to attract other airports' customers. In other words, one airport holds the monopoly power in the region in terms of transportation. Especially if there is only one airport in a city or a region, it is not possible to prefer other airports. For this reason, monopolistic power of airports has eliminated the competition and this might be the reason behind some airports' inefficiency. Oum et al. (2003) pointed out that, ignoring non-aeronautical services in the research leads to biased empirical results because in some airports those services have a very big share in total revenues. Yoshida and Fujimoto (2004) showed that, regional airports are expected to be less efficient, because demand for regional airports is small as compared to international airports. Barros (2008) argues that state owned and operated airports are less efficient because there is no pressure on managers to demonstrate positive financial results. Since pressure on the managers of state controlled and private firms have found not to be the same over the years, it is inevitable for state controlled firms to be less efficient as compared to the private ones. In general, most studies conclude that the state owned and operated airports are less efficient than the privatized airports. They point out that privatization of state owned airports is one of the ways to reach the desired level of quality and efficiency. Parker (1999) tested technical efficiency of the UK airports before and after privatization and Sarkis (2000) tested operational efficiency of 44 US airports. While some researchers used common inputs and outputs, some scholars tested airport efficiency by segments, mainly known as "terminal services" and "movement model." For each segment they used different inputs and outputs. Pelset et al. (2003) tested the airport efficiency in these two segments. For testing terminal services they used terminal size and the number of aircraft parks as inputs and aircraft movements as output. For a movement model they used the number of check-in desks and the number of baggage claims as inputs and the number of passengers as output. There are some studies that compare SFA and DEA. For example, Pelset et al. (2003) and Yang (2010) explain the differences between these methods by using the same inputs and outputs in them. According to the conclusion of these studies, both methods are roughly in the same order.

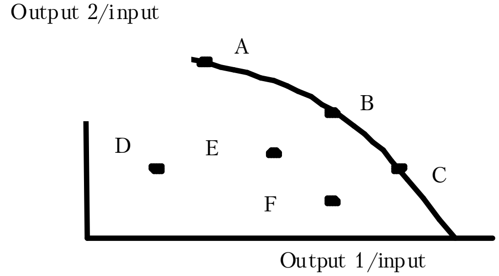
With regard to non-parametric methods, they have similarities with parametric methods. In general, both methods use almost the same inputs and outputs. For instance, the number of employees, runway lengths and terminals' sizes are the common inputs for DEA and SFA. From the output side, the number of passengers, cargo and the number of aircraft movements are the same outputs for both methods.

3. Methodology

3.1. Data Envelopment Analysis. DEA analysis has been developed for determining the efficiency of a group of profit and non-profit institutions (DMUs). It analyzes the efficiency of a DMU by comparing it with the best DMU in the group under evaluation. The main idea is to produce an efficiency score for each DMU by evaluating the inputs used to produce the output. The starting point is the assumption that if a specific amount of output can be produced with a certain amount of inputs by one DMU, then, other DMUs should be able to produce that specific amount also with the same amount of inputs. However, if they use more inputs to produce the same amount, then they are not efficient, and thus must reduce the inputs. Similarly, a given amount of inputs should be able to produce the same amount of output in each DMU. If with the same inputs, a smaller amount of output is produced, then that DMU is not efficient and must find ways to increase the output to be efficient. So a certain DMU is said to be efficient if when compared to other DMUs, its inputs cannot be improved without decreasing its outputs (or its outputs cannot be increased without increasing its inputs), hence the technical efficiency. This definition of efficiency does not necessitate a full set of strict and formal assumptions. To be able to conduct a data envelopment analysis the required assumption is that the data reveal the performance of DMU in the most accurate way and the returns to scale in the production is accurately determined. Determination of returns to scale is necessary to decide the envelopment of the data under analysis. For this issue DEA is commonly conducted under both constant return to scale (CRS) and variable return to scale (VRS).

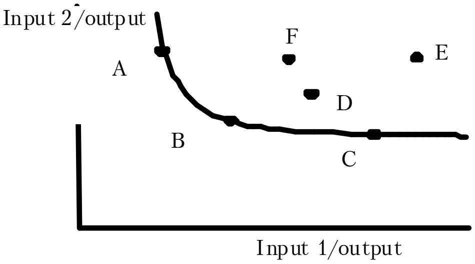
Data envelopment analysis creates a frontier (an envelope), which passes through the strictly dominating DMUs and performance of each DMU can be compared with those of the ones on the frontier. In Figures 1 (and 2) below each point refers to a DMU's output/input (input/output) ratio for 2 outputs.

Figure 1 illustrates the output maximization. It shows efficient and inefficient DMUs. (Figures are taken from Pacheco and Fernandes (2002)). Points A, B and C reflect the efficient DMUs, whereas points D, E and F are inefficient. The frontier that joins A, B and C represents the full efficiency.



Source: Partly Adapted from Fernandes and Pacheco (2002)

Figure 1. **Efficiency Envelope; Output Maximization**

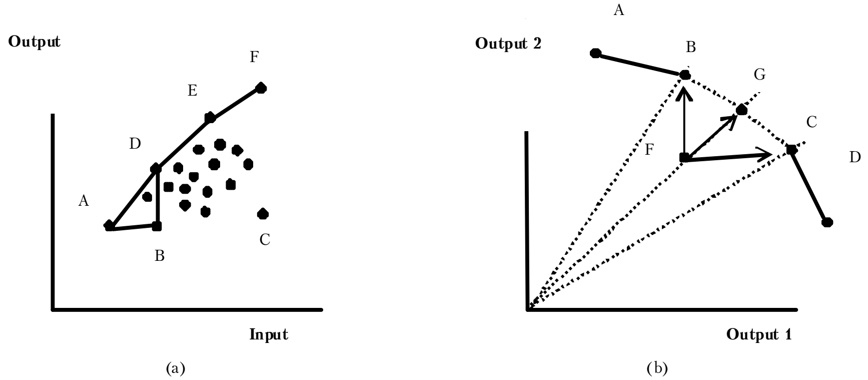


Source: Partly Adapted from Fernandes and Pacheco (2002)

Figure 2. **Efficiency Envelope; Input Minimization**

Figure 2 is the example of graphical illustration of input minimization approach. Each DMU uses the same amount of inputs and produce different level of outputs. Points A, B and C are the most efficient points as compared to points D, E and F under the input minimization approach.

Figure 3 shows the process of reaching the efficiency envelope. In (a) DMUs A, D, E, and F lie on the efficiency frontier and are efficient, whereas DMUs B and C fall inside the frontier and they are inefficient. An inefficient DMU can be compared with the one on the frontier and also on the same activity line. Then DMU (B) can reach the efficient DMU (A) on the frontier by decreasing inputs or the efficient DMU (D) by increasing its outputs. Figure 3(b) shows DMUs producing outputs 1 and 2 and using exactly the same inputs. Figure shows that A, B, C and D are strictly dominating DMUs and are the efficient ones. DMU (F) is inefficient but can increase its output to reach C or B. DMU (F) is not strictly dominated by either B, or C but it can be compared with the hypothetical DMU (G), which is a combination of B and C with certain weights, created by DEA. This way it can be seen that DMU (F) is relatively inefficient.



Source: Authors' construction

Figure 3. **Reaching Efficiency Envelope**

DEA utilizes 3 approaches to produce the efficiency scores. These approaches are "input oriented", "output oriented" and "output/input oriented". For each of these approaches a linear programming model is constructed. In more technical illustration under output oriented maximization the efficiency score of a DMU is calculated through:

$$DMU = \frac{Weighted\ Sum\ of\ Outputs}{Weighted\ Sum\ of\ Inputs}$$

And for input oriented minimization:

$$DMU = \frac{Weighted\ Sum\ of\ Inputs}{Weighted\ Sum\ of\ Outputs}$$

In the output oriented model optimization is done by maximizing the objective function, the ratio of weighted sum of outputs to the weighted sum of inputs, of the specified DMU. According to Charneset et al. (1978), the constraints are such that the ratio of sum of weighted outputs to sum of weighted inputs for all DMUs should be less than or equal to 1. Precisely, the model is written as:

$$\text{Maximize } (h_0) = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}}$$

$$\text{Subject to: } \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1$$

$$u_r, v_i \geq 0$$

For $j = 1,...,n$, $r = 1,...,s$, $i = 1,...,m$

$y_r = output$, $x_i = input$

$u_r, v_i = weights$ that will be determined by the model.

In the dual problem of maximization, the input oriented model, optimization is carried out by minimizing the objective function, the ratio of sum of weighted inputs to the sum of weighted outputs, of the DMU whose efficiency will be calculated. Opposite to the primal problem, the constraints of the dual require the ratio of sum of weighted inputs to the sum of weighted outputs to be not less than 1. The model is illustrated as:

$$\text{Minimize } (f_0) = \frac{\sum_{i=1}^{m} v_i x_{i0}}{\sum_{r=1}^{s} u_r y_{r0}}$$

$$\text{Subject to } \frac{\sum_{i=1}^{m} v_i x_{ij}}{\sum_{r=1}^{s} u_r x_{rj}} \geq 1$$

$$u_r, v_i \geq 0$$

For $j = 1,...,n$, $r = 1,...,s$, $i = 1,...,m$

The model used in this study is input oriented; it shows how a DMU should move towards the efficient frontier by reducing its inputs proportionally to those of an efficient DMU. In addition, the efficiency scores for both constant returns to scale (CRS) and variable returns to scale (VRS) cases are calculated for each airport. DEA frontier software is used for calculations.

3.2. Data. In Turkey there are 43 airports. After 2000 Turkish airports are subject to modernization. In this context between 2007 and 2010 some airports were under modernization and the data on those airports are lacking. In this study we analyze 20 Turkish airports. All of the required data are taken from the annual reports of the Turkish State Airport Authority (DHMI). The data refer to the 2007–2009 annual data.

Two inputs are used – terminal size (square meter) and runway length (meter) and 3 outputs: the number of passengers, the number of aircraft movements and the tons of cargo carried.

4. Results

The efficiency scores calculated for these 20 airports are given in Table 1.

Table 1. **Efficiency Scores Under Constant Returns to Scale (CRS)**

DMU	DMU Name	2007	2008	2009	2010
1	Istanbul Ataturk	1,00000	1,00000	1,00000	1,00000
2	Izmir Adnan Menderes	0,44198	0,40490	0,44132	1,00000
3	Mugla Dalaman	0,39396	0,35461	0,35437	0,37165
4	Adana	1,00000	1,00000	1,00000	0,75715
5	Erzurum	0,40325	0,34556	0,35694	0,23140
6	Ankara Esenboga	0,33018	0,32355	0,32353	0,35610
7	Antalya	1,00000	1,00000	1,00000	1,00000
8	Mugla,Milas, Bodrum	0,81049	0,84697	0,82355	0,65514
9	Trabzon	0,47148	0,43837	0,46079	0,42785
10	Gaziantep	0,44036	0,46350	0,50349	0,18997
11	Adiyaman	0,17068	0,26747	0,23700	0,06614
12	Diyarbakir	1,00000	1,00000	1,00000	0,32896
13	Hatay	0,00243	0,11544	0,24173	0,17463
14	Kars	0,17354	0,44057	0,43626	0,08009
15	Konya	0,29815	0,32969	0,34778	0,15342
16	Mardin	0,35661	0,33582	0,38380	0,12775
17	Van Ferit Melen	1,00000	1,00000	1,00000	0,27186
18	Elazig	0,21097	0,23537	0,39653	0,13310
19	Kayseri	0,67193	0,60238	0,66537	0,27052
20	Mus	0,10337	0,33518	0,39322	0,04540

Source: Authors' construction.

In general, from 2007 to 2009 most of the airports' efficiency scores increased by small amounts but in 2010 especially regional airports efficiency scores decreased very sharply. According to the results, Istanbul Ataturk and Antalya airports maintain their position on the efficiency frontier in 2007—2010. Adana, Diyarbakir and Van-Ferit-Melen were efficient for the first 3 years but then became inefficient in 2010, whereas Izmir Adnan Menderes showed the efficient performance in the last year of the period. The least efficient airports in the period are Hatay, Adiyaman and Mus.

Table 2. **Efficiency Scores Under Variable Returns to Scale (VRS)**

DMU	DMU Name	2007	2008	2009	2010
1	Istanbul Ataturk	1,00000	1,00000	1,00000	1,00000
2	Izmir Adnan Menderes	0,53440	0,48757	0,50814	1,00000
3	Mugla Dalaman	0,88317	0,84865	0,84884	0,86187
4	Adana	1,00000	1,00000	1,00000	1,00000
5	Erzurum	0,76055	0,73520	0,74328	0,75694
6	Ankara Esenboga	0,38329	0,36928	0,37281	0,41537
7	Antalya	1,00000	1,00000	1,00000	1,00000
8	Mugla, Milas, Bodrum	0,92776	0,92910	0,90470	0,89970
9	Trabzon	0,83245	0,78451	0,79115	0,81807
10	Gaziantep	0,50707	0,52369	0,53762	0,43573
11	Adiyaman	1,00000	1,00000	1,00000	1,00000
12	Diyarbakir	1,00000	1,00000	1,00000	0,69343
13	Hatay	0,56444	0,57135	0,59326	0,62866
14	Kars	0,67101	0,75326	0,73921	0,63746
15	Konya	0,60290	0,60560	0,61269	0,58865
16	Mardin	0,91505	0,88541	0,90507	0,89419
17	Van Ferit Melen	1,00000	1,00000	1,00000	0,79338
18	Elazig	0,62487	0,61422	0,69212	0,63714
19	Kayseri	0,80256	0,75066	0,78677	0,69998
20	Mus	1,00000	1,00000	1,00000	0,98277

Source: Authors' construction.

According to the efficiency results of VRS in Table 2, most efficient airports are Istanbul Ataturk, Adana, Antalya and Adiyaman, throughout the whole period. On the other hand, Diyarbakir, Van-Ferit-Melen and Mus became inefficient in the last year. The least efficient airports in these years are Ankara Esenboga, Gaziantep and Izmir Adnan Menderes.

From both tables we see that some airports showed a negative trend in 2010. In general, these are regional airports. The reason behind the negative trend in both CRS and VRS inefficiencies is that some outputs such as cargo and aircraft movement shows decline in 2010 as compared to the previous years. Moreover, passenger transportation is limited with the inhabitants of the region and very few non-Turkish citizens use regional airports whereas millions of non-Turkish citizens travel through Turkish international airports.

5. Conclusion

In this study 20 Turkish airports are analyzed in terms of efficiency using the data envelopment analysis. The results show that Turkish international airports' efficiency scores are higher than the ones of regional airports. In other words, international airports are more efficient relative to regional airports and this result is consistent with the results of Gillen and Lall (1997), who found that international airports operate at a higher level of efficiency than the regional ones. In addition to the inefficient use of inputs, one of the reasons behind the inefficient scores of most regional airports might be the limited number of international passenger transportation. Also government control over the aviation sector creates monopolistic power and it is commonly stated that lower efficiency level of government-operated institutions is not an unexpected outcome. Therefore, the role of government in airport management needs to be revised.

It should be noted that the estimates in the study depend on the available data. Labor and capital inputs are not included because they were not available for 2007 and 2008. For this reason, our estimates could better be interpreted as "assessment" of the efficiency level of the aviation infrastructure in Turkey. With the availability of the missing data, reassessment of efficiency will be very useful for further studies. In addition, to increase the efficiency of regional airports, optimal policy options need to be developed. Therefore, further studies about the optimal policy would be very helpful.

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