ASSESSMENT OF EFFICIENCY OF GREEK AIRPORTS

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Abstract

In this paper the efficiency of Greek airports is assessed using Data Envelopment Analysis (DEA). First, appropriate inputs and outputs describing airport primary airport functions are identified. Then the technical characteristics of the airports are assessed in terms of the movements served in 2007. Two functional areas are considered: the landside and the airside. In each case, different inputs and outputs are used and alternative DEA models are applied. The paper reports on pure technical efficiency, scale efficiency, airport potentiality and peer airports. The time period when the inefficient airports will become efficient is estimated. The airports that serve more movements are found to be more efficient than those that serve fewer movements. Moreover cases where specific improvements in the passenger building enhance airport efficiency are indicated. Furthermore it is shown that the airside is better managed. The majority of airports have adequate terminal infrastructure to accommodate passenger traffic for the next 20 years.

Keywords: Data Envelopment Analysis, Airport efficiency, Benchmarking

INTRODUCTION

In the last 20 years, benchmarking has received increased attention as a useful management tool for airports. In the past, there were no commercial pressures on the aviation sector as all airports were under state control with strictly regulated operations. Furthermore, the benchmarking process was complex because of the variety and diversity of input and output data as well as the operating environment. In recent years many airports have adopted an entrepreneurial management philosophy. The change in perception resulted in the need to evaluate the profitability between similar airports. In some cases, the commercialization of airports has led to the division of management and even ownership among public and private companies and marked the beginning of a period of "globalization" of airports. A distinct characteristic of these new conditions is the emergence of global companies that have acquired several airports (Graham, 2003). Airports are no longer considered by their managers as mere infrastructure that is a part of the wider transport system and serves the citizens needs. Instead, they are viewed as a mix of competent and competitive individual segments which strive to constantly improve performance. Recent developments are characterized by the dynamic presence of low cost carriers, an increase in air movements and the privatization of many airports. New technologies and other innovations resulting from the competition between airports require that airport managers and planners develop dynamic strategies and adapt flexible detailed plans that allow them to control the latent risks and uncertainties. Thus, there is a need for continuous evaluation of the effectiveness of airports operation. Evaluation helps to identify the changes needed to achieve efficiency of operation. Such changes may involve upgrade or expansion of existing infrastructure, management of operations in passenger buildings, adjustment of labor levels etc. More generally, the design has become the product of a broader systemic process. Technical issues need to be considered as part of a larger system that evolves over time so that it can accommodate changing demand and volumes.

Many regional airports such as the airports in the Greek islands are characterized by strong tourist traffic with seasonal demand. The efficiency of these airports directly affects the quality of service offered to passengers who use it as a basic means of transport to reach their destination. Airport services affect the overall attitude of travelers regarding their tourist destination as they provide the first and last point of contact. The satisfaction of tourists helps the airport to effectively compete with airports serving alternate touring destinations (Fuchs and Weiermair, 2004). Moreover, when privatization is under consideration, investors and bankers interested in ownership and control issues want to identify potential business opportunities and latent risks.

Airport efficiency has been studied by a variety of econometric methods, both parametric and nonparametric. Parametric methods employ regression techniques to estimate a relevant production or cost function, Pets et al. (2001, 2003), Oum et al. (2003), Yoshida (2004) and Yoshida and Fujimoto (2004). DEA is a popular non parametric method that was initiated in Doganis et al. (1978) and since then applied to several settings. Gillen and Lall (1997, 2001), Parker (1999), Fernandes and Pacheco (2002, 2003), Pels et al. (2001, 2003) and Barros and Sampaio (2004), Murillo-Melchor (1999) and Abbott and Wu (2002), Vanessa Kamp (2003), Sarkis, (2000, 2004), Malighetti-Martini-Paleari and Renondi (2007), Martin and Roman (2001), Barros and Dieke (2007, 2008).

The Data Envelopment Analysis (DEA) estimates the efficiency of decision-making units (DMU) such as a company or a public service. Each DMU unit uses a set of resources called “inputs” .These resources are transformed by the operation of the unit into a set of “outputs”. Efficiency of the DMU is assessed by the capability of the DMU to maintain or increase the outputs.

In this paper the efficiency of Greek airports is assessed using Data Envelopment Analysis (DEA). First, appropriate inputs and outputs describing primary airport functions are identified. Then the technical characteristics of the airports are assessed in terms of the movements served during the period 2004-2007. Two functional areas are considered: the landside and the airside. In each case, different inputs and outputs are used and alternative DEA models are applied. In contrast to previous studies, special emphasis is focused on the passenger building and its potential to serve passenger traffic. In this study, efficiency of airports is determined by the BCC model (Banker, Charnes, Cooper, 1984). The BCC model expresses the (local) pure technical efficiency (PTE) under variable returns to scale circumstances. The (global) technical efficiency (TE) score, that takes no account of the scale effect (constant returns to scale), is also computed via the CCR model (Charnes, Cooper, and Rhodes, 1978). Both models can be expressed as linear programs and solved by standard linear programming methods (W.W.Cooper, L.Seiford and K.Tone (2007)). We shall consider the output oriented form which maximizes outputs while using no more than the observed amount of any input. More precisely, the output-oriented BCC model evaluates the efficiency of a DMU by solving the following (envelopment form) linear program:

$$
\begin{array}{ll}
(\text{BCC-}\ O_o) & \max_{(\eta_B,\ \lambda)} \quad \eta_B \\
\text{Subject to} & X * \lambda \leq x_o \\
 & \eta_B * y_o - Y * \lambda \leq 0 \\
 & e * \lambda = 1 \\
 & \lambda \geq 0.
\end{array}
$$

where X is the vector of inputs used by DMUs, Y the vector of outputs, η_B a variable that represents the efficiency score, x_o and y_o the variables for the inputs and outputs of the examined DMU, e is a row vector with all elements unity and λ a column vector with all elements (non-negative) whose optimal values form a set of units that determine the final efficiency score of the DMU under study.

The dual multiplier form of this linear program (BCCo) is expressed as:

$$
\begin{array}{ll}
\min_{(\upsilon,\ u,\ \upsilon_o)} & z = \upsilon * x_o \\
\text{Subject to} & u * y_o = 1 \\
 & \upsilon * X - u * Y - \upsilon_o * e \geq 0 \\
 & \upsilon \geq 0,\ u \geq 0,\ \upsilon_o \text{ free in sign}
\end{array}
$$

where X is the vector of inputs used by DMUs, Y the vector of outputs, u and υ are vectors, z a scalar and υ_o is a scalar associated with " $e * \lambda = 1$ " in the envelopment model.

The excesses of the input and output variables, known as "slacks" quantify the potentiality of the DMUs to exploit their inputs in order to produce the maximum quantity of outputs.

A DMU is considered to be BCC-efficient (or CCR-efficient) when it is proved that its efficiency score is 1 and it has zero slacks. If a DMU is fully efficient in both TE and PTE scores, it is operating in the most productive scale size. If a DMU has full PTE efficiency but low TE score, then it is operating locally efficiently but not globally due to the scale size of the DMU. Thus, it is reasonable to characterize the scale efficiency SE of a DMU by the ratio of the two scores:

$$SE = \frac{TE}{PTE}$$

This decomposition, explains whether the inefficiency is caused by inefficient operation (PTE) or by disadvantageous conditions displayed by the scale efficiency (SE) or both.

THE DMU STRUCTURE OF THE GREEK AIRPORT SYSTEM

Air transport is a key pillar of economic growth in the Greek economy since the vast majority of tourism movements (approximately 75%) take place by air. The air transport network of Greece includes 60 airports of different types (state owned, military and private). 39 airports are state owned and are classified by the Hellenic Civil Aviation Authority (HCAA) to International airports, Designated Points of Entry-Exit, Ad Hoc Designated Points of Entry-Exit and Domestic Airports according to traffic type. According to the EU classification (article 13 of the Decision No 1692/96/EC of the European Parliament and of the Council of 23 July 1996 on Community guidelines for the development of the trans-European transport network), airports are designated in response to their annual passenger traffic as follows:

- International Association points: airports with annual traffic of more than 5,000,000 passengers, category (1).
- Community connecting points: airports with annual traffic of more than 1,000,000 passengers, category (2).
- Regional Access Points: airports with annual traffic of more than 250,000 passengers, category (3).
- Airports with annual traffic of more than 100,000 passengers and airports with annual traffic of less than 100,000, serving mostly domestic flights because of the limited available runway length, category (4).

A comparative assessment of Greek airports using DEA is next undertaken. 27 airports serving both domestic and international flights were considered. The airports of Athens and Thessaloniki were excluded from the study. Compared to other airports, the Athens airport is new, serving more than half of the total traffic. All airport categories are represented in the sample. The study period was 2004-2007 and the reference year was 2007. Data collected by the Hellenic Civil Aviation Authority were used. Table I summarizes some basic characteristics of the airports considered in this study. Given the differences in traffic levels, the output oriented BCC model was applied to explore the dynamic view of airports'

Table I– Sample of Greek Airports and their characteristics (Source: HCAA)

Airports	ICAO Code	Aircraft Movements	Passenger Movements	Category
Heraklio	HER	46.012	5.438.369	2
Rhodes	RHO	32.776	3.625.962	2
Corfu	CFU	15.638	1.999.457	2
Chania	CHQ	15.430	1.882.834	2
Kos	KAW	14.524	1.641.681	2
Zakynthos	ZTH	7.046	988.947	2
Santorini	JTR	8.966	746.674	3
Mytilene	MJT	8.876	550.594	3
Samos	KASM	7.480	481.987	3
Mykonos	JMK	6.874	427.458	3
Kefalonia	EFL	4.108	369.702	3
Kavala	KVA	4.196	344.575	3
Aktio	PVK	3.260	321.761	3
Alexandroupolis	AXD	3.512	305.143	3
Skiathos	JSI	2.526	255.664	3
Chios	JKH	5.266	248.543	4
Karpathos	AOK	3.588	178.853	4
Ioannina	IOA	2.308	140.874	4
Araxos	GPA	1.344	127.536	4
Limnos	KALM	3.572	123.318	4
Kalamata	KLX	980	111.198	4
Paros	PAS	1.664	37.072	4
Sitia	KASD	1.806	35.232	4
Milos	MLO	1.320	33.557	4
Naxos	JNX	884	28.957	4
Aghialos	VOL	206	14.053	4
Kastoria	KSO	208	3.806	4

infrastructure. The effectiveness of airport operations was examined from two different perspectives: landside and airside. In each case a different combination of inputs was used based on their impact on movements, passenger or aircraft. The selection of inputs relied on the requirement to cover all resources utilized by the DMUs to produce movements.

The selection of inputs relied on the requirement to cover all resources utilized by the DMUS to produce movements. The passenger and aircraft movements were chosen as outputs because they represent the major outcome resulted from airport operations. The input variables employed for landside operations were the following:

1. Total area (m^2) of the passenger building
2. Ground floor area
3. Departure area
4. Arrival area
5. Check-in area
6. Number of employees[1]

The input variables associated with airside operations are the apron area and the number of employees, excluding ground handling staff and employees of other organizations performing functions at the airport. The output is the annual number of aircraft movements that landed and took off, serving international, domestic scheduled and charter flights. The total area of the airport was rejected as an input variable because it has very low correlation with the number of aircraft movements (0.04). The chosen input variables are well correlated with a correlation coefficient greater than 0.75.

The specification of the DMU's and the associated variables are indicated in Table II together with some statistical parameters across the ensemble of airports.

Table II– Statistical characteristics of input and output variables

LANDSIDE					
	Max	Min	Average	SD	Correlation
Terminal Area	41.800	265	6.830	9.177	0.921
Ground floor Area	20.753	214	4.152	4.640	0.864
Departure Area	3.973	26	1.014	1.168	0.868
Arrival Area	5.020	24	1.157	1.204	0.862
Check-in Area	5.959	55	838	1.174	0.772
No of employees	152	4	33	33	0.994
No of passengers	5.438.369	3.806	757.919	1.223.004	

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[1] Ground handling staff and employees of other organizations performing functions at the airport are not included

AIRSIDE					
	Max	Min	Average	SD	Correlation
Apron Area	140.000	4.000	42.505	34.415	0.794
No of employees	152	4	33	33	0.949
No of aircraft movements	46.012	206	7.569	10.154	

ASSESSMENT OF AIRPORT EFFICIENCY

Assessment of landside operations

The efficiency of landside operations is pictorially shown in Figure 1. The x axis represents values of the pure technical efficiency score (PTE) and the y axis represents values of the technical efficiency score (TE). Both variables vary in the range [0 1]. The airports in the sample are designated by the codes displayed in Table I and are indicated in Figure 1 as points. Their coordinates are the respective PTE and TE scores. Thus the airport of Rhodes has PTE 1 and TE 0.936. The average PTE over the airport sample is 0.635 and the average TE is 0,571. The latter value is indicated by the horizontal line in Figure 1. The scale efficiency is computed by the ratio TE/PTE. The average scale efficiency is 0.891. The line with average scale efficiency, TE=0.891*PTE is also depicted in Figure 1. The two ‘average’ efficiency lines divide the square into 4 regions. Inspection of Figure 1 leads to the following observations.

1. Five out of the 29 airports are located on the point (1,1) and thus operate in the efficient frontier as far as the passenger building infrastructure is concerned: Chania, Zakynthos, Heraklion, Kos, Karpathos. These DMUs were efficient under the assumption of both constant and variable returns to scale and consequently fulfilled the expectations of their designers. Somewhat more generally, Chios, Rhodes, Corfu, Mytilene and Santorini airports are located in the high TE-high SC region. These airports have exploited well their landside infrastructure and at the same time served a large number of passengers.

2. The second region consists of airports with high pure technical efficiency and low scale efficiency (compared to average value). Paros and Aktio airports belong to this category.

3. The third region consists of airports with low technical efficiency and high scale efficiency. It includes Limnos, Kalamata, Ioannina, Skiathos, Mykonos, Samos, Kavala, Alexandroupolis and Kefalonia. These airports serve a large number of passengers with limited performance.

4. The fourth region encompasses airports serving low passenger traffic with low operational efficiency in terms of passenger building facilities, Kastoria, Sitia, Aghialos, Araxos, Milos and Naxos airports. These airports need to attract more passengers in order to improve their efficiency.

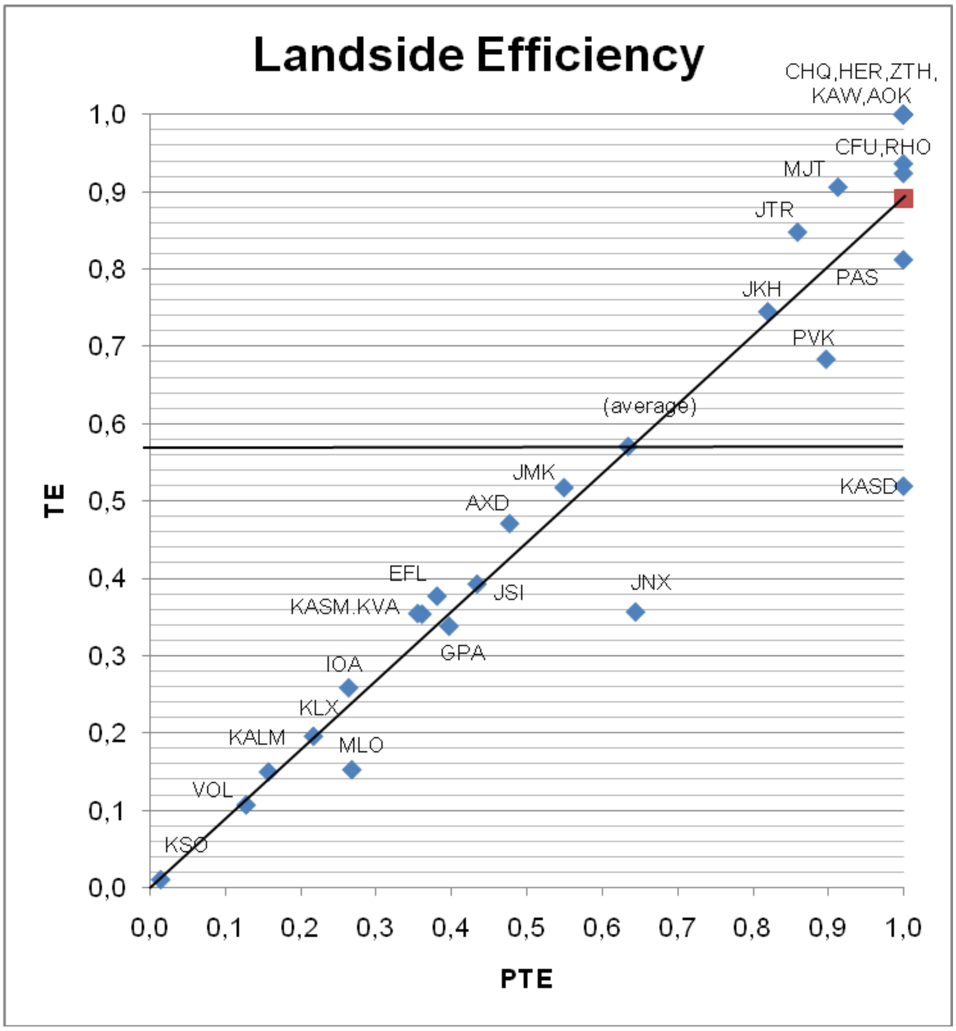

Figure 1 – Classification of airports in terms of Landside Efficiency

The BCC model and its dual formulation enable us to calculate the so called slack variables. The output slack variable describes the potential of the airport during the reference year to serve the demand expressed in total passenger volumes. The slack variable associated with each input indicates the capacity excess with respect to this particular input.

Slack variable information is summarized in Table III. Airports are grouped according to their location in the four regions of Figure 1. The airports with PTE and TE equal to 1 are not included as the slack variables are 0 in this case. The meaning and significance of slack variables is further clarified by considering the airport of Skiathos. This airport was found to operate inefficiently. The slack variables imply that the airport could serve 130% more passengers as its terminal building is bigger than required by 43%, the ground floor area by 22%, the departure area by 11% and the check-in area by 38%.The airports with significant output slacks are: Kalamata, Limnos, Aghialos and Kastoria. Airports like Limnos and

Aghialos serve more military than civilian movements. Aghialos is also an intermediate stop for refueling purposes. Thus the passenger movements are not as many as the airport could serve. Furthermore, the wider catchment area is also served by the airport of Skiathos. The airport of Kastoria used to have more traffic in the past when the trade of fur was flourishing in the area. Later the trade declined and airport operations shrunk.

Sixteen airports have slacks of the floor area, twelve of the departure area, fourteen of the arrival area and fourteen of the check-in area. In many cases, these slacks represent over 30% of the existing areas. Overall, no significant slacks show up for the total area of the terminal. The airports however that experience slacks in the total terminal area have high slack values. More specifically, Aktio, Mikonos and Kavala were three airports that could serve the same number of passengers with less than 70% of their total area. The allocation of the floor surface in these airports is also excessive.

It is noted that all big airports have zero slacks and thus fully exploit their potential. A smaller size airport with zero slacks is Karpathos.

Table III– Slack variables and airport potential

Airports	Passengers	Total Area of terminal building	Groung floor Area	Departure Area	Arrival Area	Check-in Area	No of employees
Chios	22%	0%	-4%	-13%	-17%	-32%	-59%
Santorini	16%	0%	-49%	0%	-54%	-41%	-14%
Mytilene	10%	0%	-29%	-53%	-21%	0%	-55%
Aktio	11%	-57%	-61%	-38%	-73%	-64%	0%
Limnos	536%	0%	0%	0%	0%	0%	0%
Kalamata	361%	0%	-56%	-56%	-67%	-43%	0%
Ioannina	279%	0%	-10%	-14%	0%	-26%	-9%
Samos	181%	-11%	-4%	0%	-19%	-4%	0%
Kavala	177%	-38%	-61%	-12%	-70%	-55%	-12%
Kefalonia	162%	-30%	-24%	0%	-34%	-13%	0%
Skiathos	130%	-43%	-22%	-11%	-38%	0%	0%
Alexandroupolis	110%	0%	-25%	-64%	0%	-25%	-53%
Mykonos	82%	-41%	-15%	-1%	-45%	0%	0%
Kastoria	1000%	0%	-50%	-49%	-57%	-32%	0%
Aghialos	684%	0%	-4%	-53%	-7%	0%	-14%
Milos	273%	-23%	-44%	-42%	-63%	0%	0%
Araxos	152%	0%	-29%	-34%	0%	-31%	0%
Naxos	55%	-15%	0%	-40%	-40%	-25%	-10%

An interesting observation derived from the DEA modeling of the landside operations is that all inefficient airports have excess capacity to serve passenger demand in 2007. The time span over which existing capacity will maintain its ability to serve future demand can be determined from forecasts of passenger traffic. Simple forecasts were developed using linear regression techniques using data on the annual number of passengers for the period 1992-

2007. It was deduced that for most airports no passenger building expansions are needed until 2030. 3 airports only (Aktio, Mytilene and Santorini) need infrastructure upgrades after 2020. In fact building expansions are already planned for these airports.

Assessment of airside operations

The efficiency of airside operations is shown in Figure 2. The average PTE over the airport sample is 0.687 and the average TE is 0,656. The average scale efficiency is 0.96. Six out the 29 airports are located on the point (1,1) and thus operate in the efficient frontier as far as the airside infrastructure is concerned: Chania, Sitia, Paros, Mykonos, Heraklion, and Chios. Rhodes, Zakynthos, Skiathos, Aktio, Mytilene, Kos and Santorini airports are located in the high TE-high SE region. These airports have exploited well their airside infrastructure and at the same time served a large number of passengers. Milos and Karpathos have high PTE and below the average SE. Limnos, Kalamata, Kastoria, Ioannina, Araxos, Samos, Alexandroupolis, Kefalonia and Corfu serve a large number of passengers with limited

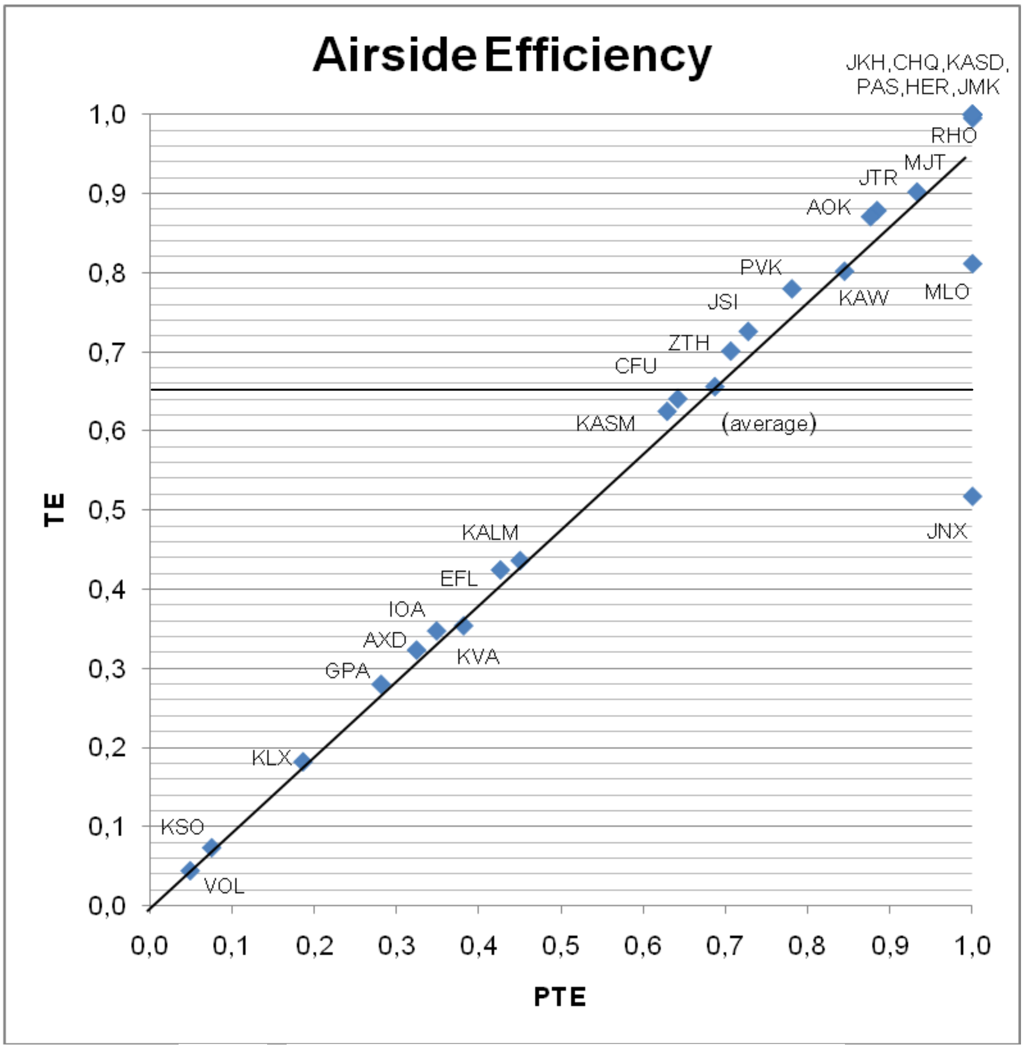

Figure 2– Classification of airports in terms of airside efficiency

performance. Aghialos, Kavala, and Naxos serve low passenger traffic with low operational efficiency.

Slack variable information is summarized in Table IV. Airports in the third and fourth region (low PTE score) can serve more aircraft movements with the available facilities. Most airports demonstrate balanced use of employees.

Table IV– Slack variables and airport potential

Airports	Aircrat movements	Apron Area	No of employees
Zakynthos	38%	-6%	0%
Skiathos	38%	0%	0%
Aktio	28%	0%	0%
Kos	14%	0%	0%
Santorini	13%	0%	0%
Karpathos	18%	0%	0%
Mytilene	7%	0%	-5%
Kastoria	1000%	0%	0%
Kalamata	437%	0%	0%
Araxos	256%	0%	0%
Alexandroupolis	208%	0%	0%
Ioannina	187%	0%	0%
Kefalonia	135%	-4%	0%
Limnos	122%	-20%	0%
Samos	59%	0%	0%
Cortu	56%	0%	0%
Aghialos	1000%	-42%	0%
Kavala	162%	-41%	0%

Peer airports

Peer airports have similar infrastructure characteristics. This means that they use inputs of the same scale in order to produce outputs. Each cluster of airports includes both efficient and less efficient airports. Then the efficient airports can serve as best practice cases for their peers. They can be viewed as a benchmark of operations for the airports that have not achieved yet the best performance because either they did not exploit appropriately their resources or they did not serve the movements they could afford. DEA modeling and its BCC implementation provide the inefficient airports with a set of peers. Each peer is considered to be more or less important for the inefficient airport according to the weight it receives by the linear programming procedure. In the BCC model this weight is expressed through the "λ" value. For example, the airport of Limnos is an inefficient airport and the set of its peer airports consists of Zakynthos (λ_1=0.533), Sitia (λ_2=0.337) and Chania (λ_3=0.130). The airports that are assigned a higher value of ''λ'' dictate the ways that will help the inefficient airport improve performance. Thus Skiathos airport could analyze Zakynthos and Sitia airports and adopt successful practices. It should be noted that the mere adaptation of the characteristics of the peer airports is not enough for the improvement of the performance of inefficient airports.

Table V indicates the airports belonging to the high efficiency regions for the two operation areas, landside and airside. The number next to each airport shows the number of times that each airport appears as peer to this specific airport. For instance, Zakynthos is a peer to 15 other airports and can serve as best practice for less efficient peers.

Table V– Peer airports

LANDSIDE		AIRSIDE	
Zakynthos	15	Chania	10
Sitia	9	Mykonos	9
Kos	8	Sitia	9
Chania	8	Paros	7
Karpathos	6	Heraklio	6
Paros	4	Chios	4
Heraklion	1	Rhodos	3
Corfu	0	Naxos	0
Rhodos	0	Milos	0

CONCLUSIONS

In this paper the efficiency of Greek airports was assessed using Data Envelopment Analysis (DEA). Landside and airside were studied separately. The airports that serve more movements were found to be more efficient than those that serve fewer movements. Some of the big airports are located near some mid and small size airports and a type of combined transportation including aviation and coastal navigation can be planned in order to improve the performance of the smaller and less efficient airports. The majority of airports have adequate infrastructure to serve future passenger demand. Future work is required to address parametric methods such as the stochastic frontier model to account for random effects in the modeling exercise. Moreover the financial performance of airports need to be considered.

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