Measuring the efficiency of Greek regional airports prior to privatization using Data Envelopment Analysis

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Abstract: - Greek airports constitute an important infrastructure asset for regional development and the promotion of the domestic touristic product. However, many regional airports suffer from economic difficulties due to the lack of high volume of traffic, while others provide poor quality services during the commercially critical summer months. In this paper, data envelopment analysis is applied to analyze and benchmark the technical efficiency of the 14 Greek regional airports during 2016, just before their privatization. An output-oriented DEA model is used to assess separately the efficiency of the main infrastructural elements of the airports (terminal and airside area) on an annual and seasonal basis. The key factors influencing efficiency are investigated to suggest necessary improvements or upgrades and compare them with existing investment plans in the currently privatized airports. Results can be used in the future in order to extract some considerations about the privatization of Greek regional airports.

Key-Words: - Airport Efficiency, Privatization, Performance Benchmarking, Data Envelopment Analysis

1 Introduction

In modern times, air transport is one of the most “globalized” industries. It connects people, cultures, businesses of different continents and contributes to economic growth by creating jobs and facilitating trade and tourism. Airports form transport hubs of vital importance which facilitate the passengers’ movement as well as the global supply chain offering flexibility, speed, and accessibility. According to Air Transport Action Group – ATAG (2016), the total economic consequences (direct, indirect, related to tourism) of the global air transport industry acceded to 2.7 trillion USD, which equivalents to 3.5% of the global gross domestic product (GDP) in 2014. Air transport industry supported 62.7 million jobs globally and created 9.9 million direct jobs.

In Greece, airports form substantial infrastructures for regional growth. However, many regional airports suffer from financial difficulties due to lack of year-round traffic, while others suffer in the summer season from poor service levels due to exceptionally high passenger traffic. In this respect, and with a view to the efficient management of regional airports, it was considered necessary to assess the efficiency of their scarce infrastructure and resources.

Since airports are complex organizations, it is difficult to assess them based on a single criterion. Therefore, the use of the Data Envelopment Analysis (DEA) was considered to be the most suitable because of its ability to consider the effect of multiple criteria. Using DEA and based on a data set obtained by the

Hellenic Civil Aviation Authority (HCAA), the efficiency of the 14 regional airports is analyzed for the year 2016, the year just before their privatization. This is done both to investigate the factors that affect airport efficiency and to highlight the necessary improvements in airport infrastructure.

The present work is an attempt to investigate the factors that affect the efficiency of Greek regional airports either positively or negatively. It aims to measure the efficiency of 14 airports from two operational points of view: the first is related to terminal infrastructure and services, while the second considers the airside area where airplanes are served. This breakdown can provide support for decisions regarding the effective utilization of airport infrastructure, identify infrastructures and services that are less efficient, and highlight appropriate interventions using DEA models.

There are numerous studies in international literature dealing with this subject. However, the number of studies on Greek airports remains limited, and there are no published studies about Greek regional airports whose ownership status has changed.

In what follows, we first describe the Greek airport industry (Section 2), then briefly discuss the literature review regarding benchmarking of airport infrastructure, as well as the theoretical background of DEA, the models, data and methodology used in the current research (Section 4). In Section 5, the study's results and selected comments are presented, with concluding remarks offered in Section 6.

2 The Greek airport system

This section refers to all Greek airports while focusing on the 14 regional airports. It is worth noting that due to the abundance of data and the complexity of their collection, direct communication and the provision of integrated floor plans by the Hellenic Civil Aviation Authority was crucial for the inclusion of all necessary data in the research. The analytical data are presented in Section 4.

Greece is considered a global tourist destination and Europe's Southeast gate, with more than 5,000 years of history. Its geomorphology contains about 1,400 islands, from which about 227 are inhabited, having diversities on size, population, and economic growth. It is hence rational that air transport plays a key role in Greece's national economy (Fragoudaki and Giokas, 2016).

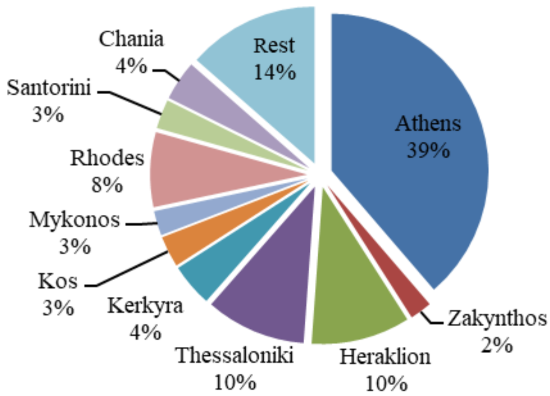

Fig. 1. Percentage (%) of total flights for 2016

In recent years, the number of visitors has increased significantly, outreaching even the country's population. According to the Hellenic Statistical Authority (2017), the number of domestic and international flights in 2016 acceded to 469,533, displaying a 5.70% increase compared to 2015 with 444,249 flights. That year, Athens airport represented 38.70% of the flights, followed by Thessaloniki and Heraklion airports which represented 10.35% and 10.18% respectively (Fig. 1). The number of passengers in 2016 acceded to 52,992,396, while in 2015 it was 48,811,600. From the total number of passengers in 2016, the 18,865,911 correspond to domestic flights, while the 37,126,485 to international flights. The majority of the "domestic" passengers traveled in Athens, Thessaloniki, and Heraklion airports, whereas in international flights, the frontrunners were Athens, Heraklion, and Rhodes airports.

According to the available monthly data, it can be observed that the busiest period is between May and October, which represents 76.01% of the total passenger traffic. Focusing more on summer months (June – September), it can be observed that they represent 57.79% of the total passenger traffic, with August holding the highest share with 16.27%. Statistical data from 2007 – 2016 shows that passenger traffic during summer is significantly increased, indicating the increase of passengers/tourists in our country (ELSTAT, 2017)

2.1 Fourteen (14) Regional Airports

All airports in Greece belonged and were managed by the Hellenic Civil Aviation Authority (HCAA). HCAA established in 1926 with objectives, the management, development, and control of air transports. Despite the entrance in the E.U. in 1981, the Greek state kept the full responsibility of developing and managing of the airports, except Athens airport which was the first Greek airport run under non-public management in 1995 (Fragoudaki et al., 2016).

Aktion	PVK	Aktion National Airport
Zakynthos	ZTH	National Airport "Dionysios Solomos"
Thessaloniki	SKG	International Airport "Makedonia"
Kavala	KVA	National Airport "Megas Alexandros"
Corfu	CFU	National Airport "Ioannis Kapodistrias"
Kefalonia	EFL	National Airport "Anna Pollatou"
Kos	KGS	National Airport "Ippokratis"
Mykonos	JMK	Mykonos National Airport
Lesvos/Mytilene	MJT	National Airport "Odysseas Elytis"
Rhodes	RHO	National Airport "Diagoras"
Samos	SMI	National Airport "Aristarchos of Samos"
Santorini	JTR	Santorini National Airport
Skiathos	JSI	National Airport "Alexandros Papadiamantis"
Chania/Crete	CHQ	International Airport "Ioannis Daskalogiannis"

Table 1. Fourteen (14) Regional Airports

On the 14th of December 2015, Fraport Greece, Hellenic Republic Asset Development Fund (HRADF) and the Greek State signed the 40-year concession agreement, for the upgrade, maintenance, management, and operation of the 14 Greek Regional Airports. The concession commenced on the 11th of April 2017 (HRADF, 2017).

3 Literature review

This section outlines a part of the previous airport efficiency research using DEA. Based on the fact that there is a lot of literature regarding benchmarking of airport infrastructure, Table 2 highlights some principal cases.

The first extensive research effort has been carried out by Gillen and Lall (1997) who studied 21 of the top 30 American airports for the period 1989-1993 by evaluating both terminal and airside operations. In this effort, according to Gillen (1994), movements exhibit constant returns to scale (CRS), while terminal services exhibit variable returns to scale (VRS). The DEA models used were output-oriented for convenience as the orientation was not critical and more suited to the second phase of analysis which included the use of the Tobit model. Later, Sarkis (2000) also studies efficiency at 44 major US airports during the period 1991-1994, using multiple DEA models to assess parameters that affect efficiency (e.g. whether an airport is a hub to a major air carrier, is in a snowbelt [regions with more than 10 in. of snow per year] and part of a multiple airport system [MAS]).

In the same period, Parker (1999) made a remarkable research effort to study the efficiency of former British Airports Authority (BAA) before and after privatization. This concerns the periods 1979/80 and 1995/96, with each year being treated as a separate Decision – Making Unit (DMU). In the second part, 22 UK airports (including those of BAA) are compared, but it is limited to years 1988/89 and 1996/97. Each airport per year being a separate DMU. Because it was likely that there will be scale effects, CRS and VRS models were used in both cases. In the second stage of the analysis, however, only the results of the VRS were considered realistic because of the large heterogeneity in the size of the airports. The same, due to the different scales of airports, was also made in the work of Martin & Roman (2001) and Fernandes & Pacheco (2002). The former investigates the efficiency of all airports in Spain in 1997, the period before the privatization of the Spanish airport system, while the latter examines 35 airports in Brazil with domestic flights for the year 1998. The orientation of the models is based on inputs. This is followed by a comprehensive multi-model DEA (DEA BCC-CCR, DEA Cross-efficiency DEA) work by Barros & Dieke (2007) for assessing economic and operational efficiency. The model is output-oriented and covers 31 Italian airports over a three-year period, 2001-2003. According to the authors, the CCR and BCC models are powerful in identifying inefficient DMUs, but insufficient to distinguish between efficient ones. To overcome this, the 2 other models mentioned above were used. Subsequently, a similar work published by Curri et al. (2011) for 18 Italian airports over the period 2000-2004.

In conclusion, with regard to the case of Greek airports, relevant research efforts are those of Psaraki & Kalakou (2011), Tsekeris (2011) and more recently by Fragoudaki et al. (2016). The first evaluated the efficiency of 27 Greek airports in the period 2004-2007 while the two functional airport areas (i.e., landside, airside) are studied with separate data. The second survey evaluates the total of 39 airports in the year 2007, considering determinants such as the seasonality, location, size and operational characteristics of the airport. In both cases, both BCC and CCR are used. Finally, Fragoudaki et al. (2016) study the efficiency of 38 airports in the early years of the most severe economic crisis, using the BCC model and the Malmquist productivity index. In all three cases, output-oriented models are used, while the scope for airport improvement is highlighted in terms of both infrastructure use efficiency and passenger traffic increase.

Author(s), Year	Methodology (models)	Research Topic	Inputs	Outputs
Gillen & Lall (1997)	DEA-BCC, DEA-CCR & Tobit model	21 U.S. airports over a five-year (1989-19993) period.	Terminal services: i) Number of runways ii) Number of gates iii) Terminal area iv) Number of employees v) Number of baggage collection belts vi) Number of public parking spots Movements: i) Airport area ii) Number of runways iii) Runway area iv) Number of employees	Terminal services: i) Number of passengers ii) Pounds of cargo Movements: i) Air carrier movements ii) Commuter movements
Parker (1999)	DEA-BCC, DEA-CCR	~ British Airports Authority (BAA) for years 1979/80-1995/1996 ~ 22 U.K. airports for years 1988/89-1996/1997	i) Number of employees ii) Capital Inputs iii) Other Inputs iv) Changes in GDP	i) Number of Passengers ii) Cargo and Mail Business
Sarkis (2000)	DEA-BCC, DEA-CCR Mann-Whitney U-test	44 major airports in U.S. during the period 1991-1994	i) Airport Operational Costs ii) Number of employees iii) Number of gates iv) Number of runways	i) Operational revenue ii) Passenger flow iii) Commercial movement iv) General Aviation Movement v) Total cargo transportation
Martín & Román (2001)	DEA-BCC, DEA-CCR	37 airports in Spain in 1997 (prior privatization)	i) Labor ii) Capital iii) Materials	i) Air traffic movements, and ii) Number of passengers iii) Number of tons of cargo
Gillen & Lall (2001)	DEA- Malmquist	22 major airports in U.S., over a five-year (1989-19993) period.	Terminal Services: i) Number of runways ii) Terminal Area iii) Number of gates iv) Number of employees v) Number of baggage collection belts vi) Number of public parking spots Movement: i) Airport area ii) Number of runways iii) Runway area iv) Number of employees	Terminal Services: i) Number of passengers ii) Pounds of cargo Movements: i) Air carrier movements ii) Commuter movements
Pels et al. (2001)	DEA-BCC	34 European airports during the period 1995-1997	Terminal Services: i) Terminal area ii) Number of baggage claims iii) Aircraft parking positions iv) Remote aircraft parking positions v) Number of check-in desks Movement: Input data same as terminal services	Terminal Services: i) Number of passengers Movement: i) Number of aircraft movements
Fernandes & Pacheco (2002)	DEA-BCC	35 Brazilian domestic airports in 1998	i) Area of apron ii) Departure lounge iii) number of check-in counters iv) Length of curb frontage v) Number of vehicle parking spaces vi) Baggage claim area	i) Number of Domestic passengers
Bazargan & Vasigh (2003)	DEA-CCR	45 airports in U.S. during the period 1996-2000. The top 15 large, medium, and small hub airports	i) Operating expenses ii) Non-operating expenses iii) Number of runways iv) Number of gates	i) Numbers of passengers ii Number of air carrier operations iii) Number of other operations iv) Aeronautical revenue v) non-aeronautical revenue vi) Percentage of on time operations
Barros and Sampaio (2004)	DEA	13 airports in Portugal for years 1990-2000	i) Number of employees, ii) Book value of physical assets iii) Price of capital iv) Price of labor	i) Number of passengers ii) Number of planes iii) General cargo iv) Mail cargo v) Sales to planes vi) Sales to passengers
Yoshida & Fujimoto (2004)	DEA-BCC, DEA-CCR	67 Japanese airports for year 2000	i) Runway length (total length of runways) ii) Terminal size iii) Access cost iv) Labor	i) Passenger loading ii) Cargo handling iii) Aircraft movement
Lin and Hong (2006)	DEA-BCC, DEA-CCR, DEA-FDH	20 major airports around the world for year 2003	i) Number of employees ii) Number of runways iii) Number of Aircraft Parking Positions (apron) iv) Number of baggage collection belts v) Number of boarding gates vi) Terminal area vii) Number of parking spaces viii) Number of checks in counters	i) Number of passengers ii) Cargo iii) Aircraft movement
Barros & Dieke (2007)	DEA-CCR, DEA-BCC, Cross-efficiency DEA, Super-efficiency DEA	31 Italian Airports, during the period 2001-2003	i) Labor costs ii) Capital invested iii) Operational costs excluding labor costs	i) Number of passengers ii) Number of planes iii) General cargo iv) Handling Receipts v) Aeronautical sales vi) Commercial sales
Fung et al. (2007)	DEA-Malmquist	25 regional airports in China during the period 1995–2004	i) Total length of runways ii) Terminal size	i) Passenger throughput ii) Cargo throughput iii) Aircraft movements
Barros & Weber (2009)	DEA-Malmquist	27 airports in U.K., during the period 2000-2005	i) Labor ii) Capital iii) Other costs	i) Passengers ii) Cargo iii) Aircraft movements
Kocak (2010)	DEA-BCC, DEA-CCR	40 Turkish airports in 2008	i) Operational expenses (materials, personnel, benefit services, taxes etc.) ii) Number of personnel iii) Annual flight traffic iv) Number of passengers	i) Number of passengers/area (passengers per each m^2) ii) Total flight traffic/runway iii) Total cargo traffic iv) Operational revenues
Psaraki & Kalakou (2011)	DEA-BCC	27 Greek airports during the period 2004-2007	Landside Inputs i) Total area (m2) of the passenger building ii) Ground floor area iii) Departure area iv) Arrival area v) Check-in area vi) Number of employees Airside Inputs i) Apron Area ii) Number of employees	Landside Output i) Number of passengers Airside Output ii) Number of aircraft movements
Tsekeris (2011)	DEA-BCC, DEA-CCR	39 Greek airports in 2007 (considering seasonality)	i) Airport runways ii) Terminal area iii) Airplane parking area iv) Airport operating hours	i) Number of passengers and ii) Amount of cargo iii) Number of flights
Curi et al. (2011)	Bootstrap-DEA analysis	18 Italian airports during the period 2000-2004	Operational efficiency i) Number of employees ii) Number of runways ii) Apron Size Financial efficiency i) Labor cost ii) Other costs iii) Airport area (m^2)	Operational efficiency i) Number of movements ii) Number of passengers iii) Amount of cargo Financial Efficiency i) Aeronautical revenue ii) Non- aeronautical revenue)
Chang et al. (2013)	DEA-imposed quasi-fixed input constraints method	41 Chinese airports in 2008	i) **Business hour** ii) Terminal area iii) Runway area	i) Aircraft movement ii) Number of passengers iii) Tons of Mail/Cargo
Fragoudaki et al. (2016)	DEA-BCC, Malmquist	38 Greek airports during the crisis period, 2010-2014	i) Runway length ii) Apron size iii) Passenger terminal size	i) Total aircraft movements ii) Total number of passengers

Table 2. International studies concerning the evaluation of airports' efficiency using DEA

4 Data Envelopment Analysis models & data

In this section, the theoretical background of DEA is analyzed, and the models, data and methodology used are presented.

2.1 Theoretical Background

The DEA principles lead us back to Farrel (1957) and later a series of debates begins by Charles et al. (1978). A detailed introduction to DEA is available for Norman and Stoker (1991), while more detailed and recent material is provided by Cooper et al. (2000).

DEA is a non-parametric method that is able to evaluate quantitively the maximum value of relative efficiency of DMUs. Data Envelopment Analysis requires a set of units (DMUs) which operate in a similar context, they are comparable, homogeneous and utilize the same multiple inputs to produce the same multiple outputs (Charnes et al., 1978)

Furthermore, a significant number of inputs and outputs, compared to the number of DMUs, may reduce the power of DEA. A proposed rule stated that the number of DMUs should be at least two times higher than the total number of inputs/outputs (Golany & Roll, 1989). On the other side, Banker et al. (1989) consider that the number of DMUs should be at least three times higher than the number of inputs/outputs. Although, such a rule is neither imperative nor has a statistical basis but is often adopted for convenience.

The two main models for implementing this method are CCR and BCC. Their name derives for the initials of the researchers who created them. The CCR model was developed by Charnes, Cooper, and Rhodes (1978) for constant returns to scale (CRS), and then expanded with the BCC model by Banker, Charnes, and Cooper (1984) for variable returns to scale (VRS). All of them, depending on their target, can be distinguished into output maximization models (output-oriented) and input minimization models (input-oriented). In order to assess the overall technical efficiency into pure technical efficiency and scale efficiency, Banker et al. (1984) introduced the BCC model.

The selection of homogeneous DMUs is considered of high importance, as well as the selection of suitable inputs and outputs. The DMUs must perform the same operations, having similar targets. For example, we cannot compare the efficiency of an airport and a port due to the significant differences between the input and output variables.

Finally, for the selection of inputs and outputs, all the variables affecting the efficiency of the DMUs must be studied, and the one related to the targets of the research should be selected (Ramanathan, 2003).

4.2 Data

Based on similar studies, such as Gillen & Lall (1997), Pels et al. (2001, 2003), Psaraki & Kalakou (2011), two different models are adopted in order to evaluate the efficiency of regional airports. The selection of two models is due to the fact that data relates to two different operating areas with different infrastructures and services.

These models refer to the two operational areas of the airport. The terminal area (Terminal Model) where the passengers departing or arriving at the airport are mainly served and the airside area where airplanes are served (Airside Model).

From earlier researches (e.g. Gillen & Lall, 1997; Parker, 1999; Sarkis, 2000; Martin & Roman, 2001; Pels et al, 2001; Fernandes & Pacheco, 2002; Yoshida & Fujimoto, 2004; Lin & Hong, 2006; Barros & Dieke, 2007; Fung et al, 2007; Kocak, 2010; Psaraki & Kalakou, 20011; Tsekeris, 2011; Curi et al, 2011; Chang et al, 2013; Fragoudaki et al., 2016), it can be observed that inputs and outputs vary through literature. Typical inputs are the number of runways, the area of runways, terminal and airside, the number of aircraft parking positions, check-in counters, boarding gates, and baggage collection belts. Inputs could also include the cost of labor and capital, number of employees, airport operation hours, etc. On the other hand, the most common outputs consist of the total number of passengers and flights, as well as the tons of cargo handled. Even if the use of cargo handled as output is common in international literature, it is not considered in this research because some airports do not handle cargo.

Terminal Model:

Refers to the departure and arrival terminal area where passengers are mainly served. Four (4) inputs and one (1) output are used.

Inputs:

1. Terminal Area (m2)
2. Number of baggage collection belts
3. Number of Gates
4. Number of check-in counters

These data concern the flow of passengers inside the airport taking into consideration the safety standards. These elements are often affected by queues and delays.

Outputs:

1. Total number of passengers. This number refers to arrivals and departures for domestic and international flights, intra- and extra-Schengen.

Airside Model:
Refers to the airside area where aircrafts are mainly served. Four (4) inputs and one (1) output are used
Inputs:
1. Number of runways: it affects the number of aircrafts that can land/take off to/from the airport
2. Length of the main runway: it determines the size of the aircrafts that can use the runway
3. Apron area
4. Number of parking positions.

Input data 3 and 4 determine the number of aircrafts that can be accommodated at the airport. They refer to space where boarding, supply of fuel, cargo, etc. operations are being performed.
Outputs:
1. The total number of flights. This number refers to arrivals as well as departures for domestic and international, intra- and extra-Schengen flights.

As input, in both models, data related to the service of passengers and aircrafts in the two operational areas (terminal and airside) are used. As output, the number of passengers and flights that can be serviced are used. In conclusion, a selection of data reflecting the operations on both airport areas is carried out.
The variables selected, the DEA models and the sources of data are summarized in Table 3 below.

Table 3. Brief presentation (DEA models and data)

Models	Methodology	Input	Output	Source
Model 1 **Terminal**	DEA-CCR, DEA-BCC	Terminal Area Number of baggage collection belts Number of Gates Number of Check-in counters	Total Number of Passengers	*Hellenic Civil Aviation Authority*
Model 2 **Airside**	DEA-CCR, DEA-BCC	Number of Runways Main Runway Length Apron Area (m^2) Number of Aircraft Parking Positions	Total Number of Flights	*Hellenic Civil Aviation Authority*

The selection of the above-mentioned data was carried out after examining the scheduled infrastructural upgrades at the 14 airports under consideration. Most of the data selected will be modified during the upgrade of the airports, a fact that increases the interest and usefulness of this research.
Hence, this research constitutes a comparative tool able to explore if the changes carried out at the airports were necessary and necessary. Tables 4 and 5 below present the total data used in this research.

Table 4. Terminal and Airside Input Data (source: HCAA)

Airports (Airside Model)	Number of Runways	Main Runway Length (m)	Apron Area (m^2)	Number of Aircraft Parking Positions
Aktion	1	2,871	34,075	5
Zakynthos	1	2,228	58,500	7
Thessaloniki	2	2,440	200,000	22
Kavala	1	3,000	100,000	13-15
Corfu	1	2,373	70,450	11
Kefalonia	1	2,436	56,000	6
Kos	1	2,390	71,000	7
Mykonos	1	1,902	24,000	5
Mytilene/Lesvos	1	2,406	21,600	4
Rhodes	1	3,305	110,600	13
Samos	1	2,044	45,600	9
Santorini	1	2,125	36,800	6
Skiathos	1	1,628	7,800	2
Chania/Crete	1	3,348	74,400	8
Airports (Terminal Model)	**Terminal Area (m^2)**	**Number of baggage collection belts**	**Number of Gates**	**Number of Check-in Counters**
Aktion	6,848	2	5	8
Zakynthos	25,356	4	8	15
Thessaloniki	26,527	4	16	30
Kavala	6,614	2	3	8
Corfu	21,162	3	9	22
Kefalonia	6,848	2	3	7
Kos	8,369	3	7	16
Mykonos	8,959	2	6	12
Mytilene/Lesvos	2,718	2	4	7
Rhodes	47,291	4	16	40
Samos	8,065	2	4	10
Santorini	4,657	1	5	8
Skiathos	6,827	1	3	9
Chania/Crete	35,588	5	8	22

Table 5. Output data in annual and seasonal basis (source: HCAA)

	Number of flights (aircrafts)			*Number of passengers (domestic and international)*		
Airports	**Winter Period**	**Summer Period**	**Sum**	**Winter Period**	**Summer Period**	**Sum**
Aktion	492	4,018	4,510	3,793	469,077	472,870
Zakynthos	686	9,910	10,596	23,487	1,392,225	1,415,712
Thessaloniki	19,324	29,284	48,608	2,222,878	3,464,447	5,687,325
Kavala	760	2,352	3,112	37,093	221,146	258,239
Corfu	1,964	18,790	20,754	152,519	2,612,040	2,764,559
Kefalonia	540	4,380	4,920	18,566	519,633	538,199
Kos	1,792	13,280	15,072	94,245	1,807,250	1,901,495
Mykonos	906	11,022	11,928	65,787	933,239	999,026
Mytilene/Lesvos	2,388	3,404	5,792	157,702	253,583	411,285
Rhodes	5,044	31,120	36,164	458,004	4,484,382	4,942,386
Samos	1,500	3686	5,186	58,947	287,833	346,780
Santorini	2,092	11,992	14,084	257,197	1,428,498	1,685,695
Skiathos	186	3,644	3,830	4,574	390,427	395,001
Chania/Crete	3,882	15,406	19,288	530,700	2,422,578	2,953,278

4.3. DEA Implementation Factors

To conduct this research, the following assumptions are made:
1. Throughout the year some elements remain stable, such as the airside area, the number and the length of runways, the aircraft parking positions and their area.
2. On the other hand, elements such as gates, baggage collection belts, and check-in counters show seasonal variations. Thus, airport management may choose to use only a part of these resources depending on the period and the occasion.

Seasonal Variation

The majority of the regional airports studied is located in islands. Given the touristic traffic of these areas during the summer months, a significant seasonal variation is observed. Following the example of relative studies for Greek (Psaraki & Kalakou, 2011; Tsekeris, 2011) and Italian airports (Curri et al., 2011), the determinant factor of seasonality is examined. To consider the seasonal variations in demand, data are examined at two periods of the year. The split concerns two sixmonth periods: The Summer (May-October) and the Winter period (November-April).

Model orientation

The model adopted in both designs mentioned above is output-oriented. This suggests that each airport aims to serve as many passengers and aircrafts as possible at a given level of input (i.e. resource) utilization. Although, the results suggested that the model orientation was not crucial.

Returns to scale

The approach adopted includes the estimation of both CRS and VRS as it was considered possible to have some scale effects. As it was already mentioned, the results from the variable returns to scale (VRS) represent pure technical efficiency (PTE), while those from the constant returns to scale (CRS) represent the overall technical efficiency (OTE or TE) as a combination of pure technical efficiency and scale efficiency. The TE/PTE rate provides a measure of scale efficiency (SE).

5. Discussion

Regarding the DEA implementation, in order to assess the airports' efficiency, the use of suitable software is necessary. Especially, the software used were DEAP and DEAFrontier. The efficiency for both terminal and airside operations is presented in Table 6 and Figures 2 and 3 below.

The average overall technical efficiency (TE) is marked on the figures by a horizontal line. Scale efficiency (SE) is given by the O
TE/PTE fraction and marked on the figures by a sideline. These two lines divide the chart into 4 regions, based on which we can derive useful conclusions. The horizontal axis represents PTE values, while the y-axis represents TE values. These values range between 0 and 1. Airports are marked with their codename and indicated as points in the chart.

Table 6. Technical Efficiency for Terminal and Airside Model

Airports	TE(CRS)		PTE(VRS)		Scale Efficiency		Position On Frontier	
	Terminal	Airside	Terminal	Airside	Terminal	Airside	Terminal	Airside
Aktion	0.281	0.347	0.281	0.36	1	0.964	-	irs
Zakynthos	0.498	0.547	0.506	0.602	0.984	0.908	irs	irs
Thessaloniki	1	1	1	1	1	1	-	-
Kavala	0.24	0.095	1	0.1	0.24	0.951	irs	irs
Corfu	0.857	0.866	0.866	1	0.989	0.866	irs	irs
Kefalonia	0.5	0.295	1	0.316	0.5	0.934	irs	irs
Kos	0.79	0.774	0.804	0.814	0.983	0.951	drs	irs
Mykonos	0.474	1	0.484	1	0.98	1	irs	-
Mytilene/Lesvos	0.418	0.591	1	0.615	0.418	0.96	irs	irs
Rhodes	0.869	1	0.869	1	1	1	-	-
Samos	0.243	0.301	0.312	0.355	0.778	0.845	irs	irs
Santorini	1	0.928	1	0.934	1	0.994	-	irs
Skiathos	0.367	0.988	1	1	0.367	0.988	irs	irs
Chania/Crete	1	0.867	1	0.899	1	0.965	-	irs
MEAN	0.61	0.686	0.794	0.714	0.803	0.952		

Regarding Terminal Model, the average PTE value is 0.794 while the average TE value is 0.610. The latter is marked in Figure 2 by the horizontal line. The average SE value is 0.803. The SE value line (TE/PTE) is also presented in Figure 2.
Based on the 4 regions of the chart, the following can be noted:
Observation 1. 4 out of 14 airports are located in point (1,1). This suggests that they operate at the terminal's efficiency barrier. These airports are Thessaloniki, Rhodes, Santorini, and Chania and they are efficient at both CRS and VRS. The airports of Kos and Corfu are in the same region with high PTE and TE, which means that they have exploited their infrastructure efficiently while serving a large number of passengers.
Observation 2. The second region includes airports with a high PTE value and SE value below the average. In the current model, no airport is located in this region.
Observation 3. The third region includes airports with a low TE value and a high SE value. These airports are Mykonos, Zakynthos, and Aktion which serve a large number of passengers but have low efficiency in terms of resource utilization.
Observation 4. The latter region includes airports that serve a small number of passengers with low efficiency in terms of terminal infrastructure. Increasing efficiency depends on attracting more passengers. In this region, the airports of Mytilene, Kefalonia, Kavala, Samos, and Skiathos are located.

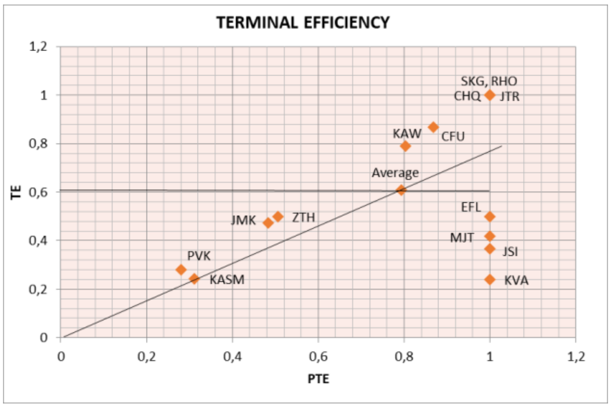

Figure 2. Airports classification in terms of terminal efficiency

Regarding the Airside Model, the average PTE value is 0.714 while the average TE value is 0.686. The average SE value is 0.952. Similar to the Terminal Model, the chart is divided into 4 regions, giving the following conclusions:

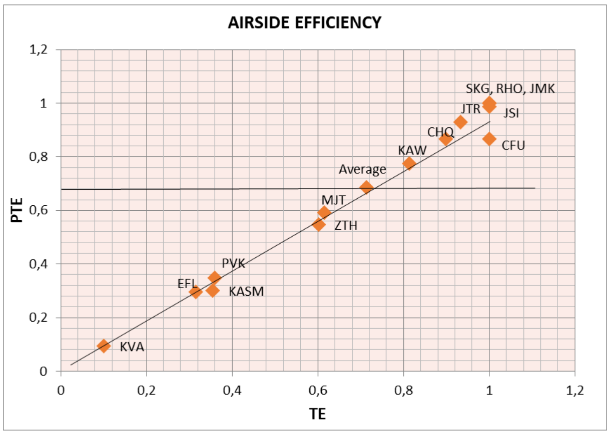

Figure 3. Airports classification in terms of airside efficiency

Observation 1. 3 out of 14 airports are located in point (1,1). This indicated that they operate on the edge of airside infrastructure efficiency. These airports are Thessaloniki, Rhodes, and Mykonos, which are efficient at both constant and variable returns to scale. The airports of Kos, Chania, Santorini, and Skiathos are also located in this region having high PTE and TE values, which means that they have exploited their infrastructure sufficiently while serving a large number of aircrafts. Skiathos is highly efficient as it serves a large number of aircrafts in proportion to its limited infrastructure.

Observation 2. The second region includes airports with high PTE value and SE value lower than the average. In the current model, only Corfu airport is located in this region, which however has a relatively high SE value.

Observation 3. The third region includes airports with low TE value and high SE value. This region includes Mytilene and Aktion airports which serve a large number of aircrafts, having however limited efficiency.

Observation 4. The latter region includes airports serving a small number of passengers with low efficiency regarding their airside infrastructure. Increasing efficiency depends on attracting more passengers/flights. In this region, the airports of Kavala, Samos, Zakynthos, and Kefalonia are located. These airports have sufficient infrastructure (large apron area and runways) to accommodate many more flights. Particularly Kavala airport has the third-largest airside area having though a small number of flights.

5.1. Seasonal Variation

Table 6 presents the efficiency for both models during winter and summer period. Starting from the Terminal model, it can be observed that Thessaloniki airport is on the efficient frontier during the summer period while Santorini Airport and Chania Airport during the summer. In the annual terminal model, the airports operating on the efficient frontier are Thessaloniki, Santorini, and Chania. It is worth to mention that 2 of the airports are located on islands and represent major tourist attractions. Seasonal variation decreases airports' efficiency during the winter. On the contrary, Thessaloniki airport shows less increase in traffic during the summer, a fact that leads to lower efficiency.

During the winter period, PTE is significantly decreased in Aktio, Zakynthos, Corfu, Kos, Mykonos, Rhodes, Chania. Mytilene holds PTE equal to 1. This is due to the lower seasonality because in 2016 the island handled reduced tourism due to refugee flows. In the same period, the number of passengers is lower at all airports. However, the large decrease in SE in Aktio, Kefalonia, Skiathos is due to the extremely small number of passengers at these airports during the winter months.

On the other hand, there is an increase of PTE during the summer period in all tourist destinations: Aktio, Zakynthos, Mykonos, Corfu, Kos, and Rhodes. The last three airports present efficiency equal to 1. The airports of Santorini, Skiathos, Chania and Mykonos also maintain efficiency equal to 1. Additionally, there is an increase in SE at all airports except in Thessaloniki, which as already mentioned has no corresponding seasonal variation.

Regarding the Airside model, it can be observed that Thessaloniki and Mytilene airports operate on the efficient frontier during the winter season while Mykonos, Rhodes, Skiathos, and Thessaloniki operate in summer.

In the annual Airside model, Thessaloniki, Mykonos, and Rhodes are on the efficient frontier. 2 of the airports are located on islands. Therefore, even in this case, the seasonal variation results in these airports having a particularly low efficiency in winter months. Thessaloniki Airport is an Exception. There are a total of 6 airports whose pure technical efficiency and scale efficiency decrease during the winter period and 6 airports which have reduced scale efficiency but maintain their pure technical efficiency at an optimum level. During the summer period, there is increased passenger traffic and therefore an increased efficiency at the majority of airports.

	Winter Period				Summer Period			
Airports	TE(CRS)	PTE(VRS)	Scale Efficiency	Position on Frontier	TE(CRS)	PTE(VRS)	Scale Efficiency	Position on Frontier
Aktion	0.007	0.015	0.448	irs	0.328	0.328	1.000	-
Zakynthos	0.021	0.028	0.767	irs	0.601	0.664	0.905	drs
Thessaloniki	1.000	1.000	1.000	-	0.753	1.000	0.753	drs
Kavala	0.089	1.000	0.089	irs	0.253	1.000	0.253	irs
Corfu	0.122	0.146	0.836	irs	0.997	1.000	0.997	drs
Kefalonia	0.045	1.000	0.045	irs	0.593	1.000	0.593	irs
Kos	0.134	0.145	0.924	irs	0.900	1.000	0.900	drs
Mykonos	0.088	0.131	0.670	irs	0.539	0.541	0.997	drs
Mytilene/Lesvos	0.692	1.000	0.692	irs	0.304	1.000	0.304	irs
Rhodes	0.206	0.206	1.000	-	0.974	1.000	0.974	drs
Samos	0.106	0.296	0.359	irs	0.247	0.295	0.837	irs
Santorini	0.659	1.000	0.659	irs	1.000	1.000	1.000	-
Skiathos	0.011	1.000	0.011	irs	0.447	1.000	0.447	irs
Chania/Crete	0.477	0.605	0.790	irs	1.000	1.000	1.000	-
MEAN	0.261	0.605	0.592		0.638	0.845	0.783	

Table 7. Airports Seasonal Efficiency [Terminal Model]

	Winter Period				Summer Period			
Airports	TE(CRS)	PTE(VRS)	Scale Efficiency	Position on Frontier	TE(CRS)	PTE(VRS)	Scale Efficiency	Position on Frontier
Aktion	0.140	0.179	0.779	irs	0.348	0.361	0.964	irs
Zakynthos	0.119	0.292	0.408	irs	0.593	0.630	0.942	irs
Thessaloniki	1.000	1.000	1.000	-	1.000	1.000	1.000	-
Kavala	0.079	0.178	0.443	irs	0.083	0.087	0.961	irs
Corfu	0.284	0.724	0.392	irs	0.904	1.000	0.904	irs
Kefalonia	0.102	0.203	0.506	irs	0.305	0.321	0.949	irs
Kos	0.291	0.666	0.438	irs	0.793	0.823	0.963	irs
Mykonos	0.356	0.733	0.486	irs	1.000	1.000	1.000	-
Mytilene/Lesvos	1.000	1.000	1.000	-	0.381	0.396	0.961	irs
Rhodes	0.522	1.000	0.522	irs	1.000	1.000	1.000	-
Samos	0.325	0.842	0.386	irs	0.241	0.276	0.874	irs
Santorini	0.552	1.000	0.552	irs	0.879	0.885	0.994	irs
Skiathos	0.216	1.000	0.216	irs	1.000	1.000	1.000	-
Chania/Crete	0.552	1.000	0.552	irs	0.804	0.827	0.973	irs
MEAN	0.396	0.701	0.549		0.667	0.686	0.963	

Table 8. Airports Seasonal Efficiency [Airside Model]

5.2. Airports Upgrades Evaluation

Having studied the upgrades planned by Fraport until 2021 we can conclude that they emphasize on changes related to the airports' terminals. The changes in the airside are related mainly to renovations and reorganizations. This happens due to the fact that airside infrastructures cannot be easily modified (construction of runways, extension of a parking area, etc). Although, Skiathos airport forms an exception, requiring special handling since its location is almost inside the city's urban area (2km away from city center) and surrounded by Mediterranean Sea and road network. In this airport, runway broadening is planned in order to comply with international standards.

According to Psaraki & Kalakou (2011), airports possess sufficient infrastructure to service the predicted demand until 2030. On the other side, there is the fact that recently a higher demand of traffic is observed compared to the expected (Table 9).

Airports	2016	2017	2018	Variation 2016/2017	Variation 2017/2018	Variation 2016/2018
Aktion	472,870	569,082	583,666	20.35%	2.56%	23.43%
Zakynthos	1,415,712	1,659,641	1,801,297	17.23%	8.54%	27.24%
Thessaloniki	5,687,325	6,247,514	6,690,269	9.85%	7.09%	17.63%
Kavala	258,239	337,963	406,949	30.87%	20.41%	57.59%
Corfu	2,764,559	2,917,950	3,364,141	5.55%	15.29%	21.69%
Kefalonia	538,199	629,671	761,656	17.00%	20.96%	41.52%
Kos	1,901,495	2,320,031	2,666,429	22.01%	14.93%	40.23%
Mykonos	999,026	1,207,026	1,395,842	20.82%	15.64%	39.72%
Mytilene/Lesvos	411,285	435,996	477,056	6.01%	9.42%	15.99%
Rhodes	4,942,386	5,301,223	5,567,751	7.26%	5.03%	12.65%
Samos	346,780	410,285	462,749	18.31%	12.79%	33.44%
Santorini	1,685,695	1,931,011	2,255,078	14.55%	16.78%	33.78%
Skiathos	395,001	424,106	437,916	7.37%	3.26%	10.86%
Chania/Crete	2,953,278	3,042,409	3,008,995	3.02%	-1.10%	1.89%

Table 9. Passenger Traffic in years 2016-2018 (source: HCAA)

By using the already mentioned software, the slacks are those suggesting the required changes for the terminal area. The variables are connected to each input and show the capacity surplus for servicing the existing demand. The data related to the variables are compared to the planned upgrades and presented in Table 10.

	Airports	Terminal Area (m^2)	Baggage Collection Belts	Number of Gates	Number of Check-in Counters	Number of Passengers
Aktion	Original Value	6,848	2.00	5.00	8.00	472,870
	Project Value	4,657	1.00	5.00	8.00	1,685,695
	Change (%)	**-31.99**	**-50.00**	**0.00**	**0.00**	**256.48**
	Fraport Upgrade	**9,229**	**2.00**	**8.00**	**14.00**	--
Zakynthos	Original Value	25,356	4.00	8.00	15.00	1,415,712
	Project Value	13,263	2.00	8.00	15.00	2,843,662
	Change (%)	**-47.69**	**-50.00**	**0.00**	**0.00**	**100.86**
	Fraport Upgrade	**Reorganization**	**4.00**	**8.00**	**20.00**	--
Kavala	Original Value	6,614	2.00	3.00	8.00	2,582,39
	Project Value	6,614	0.97	3.00	6.14	1,074,426
	Change (%)	**0.00**	**-51.50**	**0.00**	**-23.29**	**316.06**
	Fraport Upgrade	**8,643**	**2.00**	**3.00**	**10.00**	--
Corfu	Original Value	21,162	3.00	9.00	22.00	2,764,559
	Project Value	20,502	3.00	9.00	18.63	3,226,524
	Change (%)	**-3.12**	**0.00**	**0.00**	**-15.34**	**16.71**
	Fraport Upgrade	**31,456**	**3.00**	**12.00**	**28.00**	--
Kefalonia	Original Value	6,848	2.00	3.00	7.00	538,199
	Project Value	6,848	1.00	3.00	6.21	1,075,575
	Change (%)	**0.00**	**-50.00**	**0.00**	**-11.24**	**99.85**
	Fraport Upgrade	**10,652**	**2.00**	**6.00**	**12.00**	--
Kos	Original Value	8,369	3.00	7.00	16.00	1,901,495
	Project Value	8,369	1.53	7.00	11.90	2,406,598
	Change (%)	**0.00**	**-49.10**	**0.00**	**-25.63**	**26.56**
	Fraport Upgrade	**31,475**	**3.00**	**7.00**	**28.00**	--
Mykonos	Original Value	8,959	2.00	6.00	12.00	999,026
	Project Value	8,959	1.43	6.00	10.88	2,107,820
	Change (%)	**0.00**	**-28.40**	**0.00**	**-9.37**	**110.99**
	Fraport Upgrade	**13,350**	**2.00**	**7.00**	**16.00**	--
Mytilene	Original Value	2,718	2.00	4.00	7.00	411,285
	Project Value	2,718	0.58	2.92	4.67	983,835
	Change (%)	**0.00**	**-70.80**	**-27.05**	**-33.29**	**139.21**
	Fraport Upgrade	**7,185**	**2.00**	**4.00**	**9.00**	--
Rhodes	Original Value	47,291	4.00	16.00	40.00	4,942,386
	Project Value	26,527	4.00	16.00	30.00	5,687,325
	Change (%)	**-43.91**	**0.00**	**0.00**	**-25.00**	**15.07**
	Fraport Upgrade	**Reorganization**	**5.00**	**18.00**	**45.00**	--
Samos	Original Value	8,065	2.00	4.00	10.00	346,780
	Project Value	8,065	1.19	4.00	7.95	1,428,869
	Change (%)	**0.00**	**-40.35**	**0.00**	**-20.51**	**312.04**
	Fraport Upgrade	**15,640**	**2.00**	**5.00**	**14.00**	--
Skiathos	Original Value	6,827	1.00	3.00	9.00	395,001
	Project Value	6,827	1.00	3.00	6.21	1,075,473
	Change (%)	**0.00**	**0.00**	**0.00**	**-31.04**	**172.27**
	Fraport Upgrade	**16,338**	**2.00**	**4.00**	**10.00**	--
Thessaloniki	Original Value	26,527	4.00	16.00	30.00	5,687,325
	Fraport Upgrade	**57,507**	**7.00**	**24.00**	**44.00**	--
Santorini	Original Value	4,657	1.00	5.00	8.00	1,685,695
	Fraport Upgrade	**15,640**	**2.00**	**6.00**	**17.00**	--
Chania	Original Value	35,588	5.00	8.00	22.00	2,953,278
	Fraport Upgrade	**Reorganization**	**5.00**	**10.00**	**22.00**	--

Table 10. Slack variables and planned upgrades

Considering that Data Envelopment Analysis is a benchmarking method, airports lying on the edge of their efficiency supposedly utilize fully their infrastructure, whereas the increase in traffic demands changes in infrastructure. Hence, Thessaloniki, Santorini, and Chania airports have to carry out extensions on the terminal area as well as the gates, check-in counters, and baggage collection belts. In the bottom lines of Table 10, it can be observed that the contractor plans and have already carried out significant improvements at Thessaloniki and Santorini airports, in contrast to Chania airport where the existing infrastructure is maintained. This specific airport forms a particular case because extensions have been carried out recently. At the same time, it's the only airport in which traffic showed a small increase in 2017 and 2018 decreased slightly possibly due to the reduced number of domestic flights because of Ryanair's withdrawal. Therefore, in this case, the development of

infrastructure has to be carried out in parallel with the development of a new business plan to attract new flights and airline companies in order to increase passenger traffic.
Regarding the airports which are not lying on the edge of their efficiency, the proposed actions based on the models created in this research are presented and subsequently a comparison with the upgrades planned by Fraport for the airports until 2021 is carried out. This evaluation is based on Table 10 which summarizes the “slack” variables alongside the planned changes.

According to the models of the current research the following can be observed:
Aktion: The terminal area is much larger than needed. However, due to zero slack variables, the increase in passenger traffic (which is already happening according to Table 9) creates the need for more Check-in counters and gates in order to achieve effective service.
Zakynthos: Possesses a large terminal that can service a higher number of passengers. Increasing traffic demands more check-in counters and gates.
Kavala: Given the current traffic, an extension of the terminal and the construction of new gates are considered significant, while the number of check-in counters and especially baggage collection belts is sufficient.
Corfu: The terminal area is slightly larger than the required for the current passenger traffic. Hence, the airport presents a small margin for increased passenger traffic. Therefore, the upgrade of the entire airport’s infrastructure is crucial since the passenger traffic is increasing rapidly (especially in 2018).
Kefalonia: This airport presents one of the highest increases in passenger traffic (17% in 2017, 21% in 2018). This fact makes the need for expanding the terminal area and generally the infrastructure (except baggage collection belts) apparent.
Kos: Considering the significant increase in passenger traffic, the immediate extension of the terminal is important. The construction of new gates is necessary, while the addition of check-in counters will be needed gradually.
Mytilene: Despite the limited number of passengers, Mytilene airport presents a visible increase in traffic. This specific airport possesses a significantly small terminal which has to be extended considerably. Changes in the rest of the infrastructure are not immediately necessary.
Mykonos: This airport is located on an important tourist attraction, resulting in a significant increase in passenger traffic. Hence, the upgrade of the infrastructure by extending the terming and increasing the number of gates and check-in counters is necessary.
Rhodes: The recently constructed terminal can accommodate many more passengers. The current models are showing the need for more gates and baggage collection belts and in the long-term for more check-in counters.
Samos: In this airport, the traffic has increased considerably (especially in 2017). The extension of its small terminal alongside the addition of gates is crucial. In the long-term, the need for more check-in counters will arise.
Skiathos: As it was already mentioned, this airport needs improvements in the airside because its runway can accommodate only medium-sized aircrafts. Regarding the terminal, its extension alongside with the addition of new gates and baggage collection belt is important. The addition of check-in counters is not immediately necessary.

In summary, it can be observed that all changes indicated by the present research are in a similar direction to the planned upgrades of the contractor.
• Regarding the terminal area, significant differences can be found only at Aktion airport, which is considered able to accommodate many more passengers efficiently.
• Regarding baggage collection belts, differences are found in Corfu. Although no addition is planned, this is considered necessary by current models.
• Gate number differences are found at Zakynthos, Kavala, and Kos airports. Our models indicate that new gates will be needed to accommodate the increasing passenger traffic, which is not included in the planned upgrades.
• Finally, regarding check-in counters, differences are observed at several airports (Kavala, Corfu, Kefalonia, Kos, Mytilene, Mykonos, Rhodes, Samos, Skiathos). The models of the present study consider unnecessary to immediately add check-in counters. However, the increased traffic may make them soon necessary, especially at airports where the “slacks” are relatively small (Corfu, Kefalonia, and Mykonos).

6. Conclusions
Using DEA models, an effort is being made to highlight the changes needed at regional airports. It is noted that there is a great deal of agreement on the proposed changes concerning the planned, but there is no complete match. This is probably due to the lack of knowledge of the contractor’s future business plan, which may lend weight to some airports or set different priorities for each of them.

Given the fact that according to Parker (1999) there are many researchers suggest that privately owned firms can achieve higher levels of operating efficiency (Boardman and Vining, 1989; Megginson et al., 42 1994) while others consider that this may lead to fewer economic benefits (Vickers and Yarrow, 1988; Bishop and Thompson, 1992; Price and Weyman-Jones, 1993; Burns and Weyman-Jones, 1994; Parker and Martin, 1995; Boussofiane et al., 1997), current research can be a tool for future exploitation to explore the impact of privatization on airport efficiency in Greece.

Nowadays, the major lack of efficiency in most of the country's regional airports can be attributed mainly to the relatively low ability to manage their resources in order to increase traffic outputs. Most airports, however, are characterized by increasing returns to scale, which provides incentives for investments to upgrade and/or expand airports, as well as their proper management, in order to limit the inadequate use of their resources. Additionally, the establishment of regional hubs could be examined as a future development plan of the Greek airport system. Furthermore, it is important to develop a plan to improve connectivity between the airports as well as with other airport hubs abroad. This will result in attracting more airlines (some of them low-cost) and thus increasing passenger traffic. Looking at the seasonality factor, unlike the summer season, the winter season leads to a reduced rate of airport efficiency. This phenomenon is more pronounced at regional airports with high tourist traffic (mainly in the islands). This necessitates measures to address the under-utilization of resources at these airports during this period. A key measure is the flexible design of the main terminal area. This planning could include changes in the number of check-in counters, gates, collections belts, information portals, etc. depending on demand in each period, in order to adapt more to the changing needs of airlines. Particularly important for the development of airports with reduced demand in the winter months is the promotion of alternative tourism policies to expand demand during the winter season.

Consequently, the results regarding the airports in our country underline the specificities that exist and highlight the need to develop separate strategic plans for each airport.

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