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THE MEASUREMENT OF AIRPORTS OPERATIONAL EFFECTIVENESS: AN APPLICATION OF THE MAJOR 10 AIRPORTS IN TURKEY

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Abstract:
Nowadays, with the expansion of the Air Transport increased use of airports which is one of the major stakeholders in the air transport industry. Consequently, a number of studies made by airport managers for used more effectively and efficiently of current capacity at airports. As a result of this studies, efficiency and effectiveness measurement of airports just as focused on income and expenses but the main performance has been identified as an imperfect measurement. When examined in this context, with measuring operational efficiency, it is considered to be more reliable measurement of performance. Although various analysis techniques used in the measurement of operational effectiveness, in this study used data envelopment analysis technique. When considered from this point, in this study nine major airports operated by State Airports Authority and Sabiha Gökçen Airport's efficiency and effectiveness were measured by data envelopment analysis techniques in 2014.

Key words:
Productivity, Efficiency, Airport

INTRODUCTION

Air transportation industry is growing with the advancement of the technology and it is one of the most favourite transportation mode. This situation led to the increase in the number of companies in air transportation industry. In addition to this, airport usage level which has an important place in air transportation industry has increased. Because airports cannot meet present demand airport managers and authorities do researches to manage airports more effective and productive. Following the searches, some methods were developed which measures airport efficient and productivity. Through the instrument of these methods, reliable and consistent methods of measurement should be used for determining existing airport capacity and making necessary regulations.

Firstly, data envelopment analysis method was used in non-profit corporation. In the following years, it was used in international corporations and research and development studies [1]. Besides that, data envelopment analysis method is used in manufacture, banking, clothing, medicine, education industries [2]

The aim of this study is to determine efficiency and productivity levels of the busiest in 10 airports in terms of passenger traffic in Turkey. Besides that, subgoals of this study are as followed:

- To measure relative effectiveness of airports,
- To determine efficient level and capacity situation of airports,
- Through the instrument of data envelopment analysis method, to measure effectiveness and productivity of related airports based on 2014 data,
- Through the instrument of data envelopment analysis method, related airports' total, technical and scale effectiveness will be determined.

1 AIRPORT EFFICIENCY MEASURMENT

There are many studies on data envelope analysis method which is used widely in the measurement of airports' productivity and efficiency. Table 1 shows input and output variables used in these studies:

Tab. 1 *Airport Efficiency Studies with DEA*

Author/ Year	Country	Sample	Method	İnput	Output
Gillen & Lall 1997	USA	21 Airports (1989- 93)	Data Development Analysis	Number of Runway Number of Gate Number of Employees Total Runway Length Terminal Area Parking Spotts Total Airport Area Baggage Collection Belts	Total Passenger Number Total Freight
Parker 1999	UK	32 Airports (1979/80-1995/96)	Data Development Analysis	Number of Employees Operating Costs Capital Cost	Total Passenger Number Freight Total
Sarkis 2000	USA	44 Airports (1990-94)	Data Development Analysis	Operating Costs Number of Employees	Total Passenger Number Total Freight Total Aircraft

				Number of Runway Number of Gate	Movements
Martin & Roman 2001	Spain	37 Airports	Data Development Analysis	Capital Cost Employees Cost Other Cost	Total Passenger Number Total Freight Total Aircraft Movements
Fernandes & Pacheco 2002	Brazil	35 Airports (1998)	Data Development Analysis	Apron Area Lounge Area Parking Space Number of Check-in counters	Total Passenger Number
Bazargan and Vasigh 2003	USA	45 Airports (1996-2000)	Data Development Analysis	Operating Cost Non-Operating Cost Number of Employees Number of Runway Number of Gate	Aeronatic and Non-aeronatic Revenues
Sarkis and Talluri 2004	USA	44 Airports (1990-94)	Data Development Analysis	Operating Cost Number of Employees Number of Runway Number of Gate	Operating Revenue Total Aircraft Movements Total Passenger Number
Kıyıldı and Karaşahin 2006	Turkey	32 Airports (1996-2002)	Data Development Analysis	Number of Check-in Contuars Parking Space Terminal Area Total Runway Length Apron Area	Total Aircraft Movements
Barros and Dieke 2007	Italy	31 Airports (2001-2003)	Data Development Analysis	Labor Cost Capital İnvested Operational Cost	Total Passenger Number Total Freight Total Aircraft Movements Aeronatic and Non-aeronatic Revenues
Barros 2008	Arjantin	32 Airports (2003-2006)	Data Development Analysis	Number of Employees Number of Runway	Total Passenger Number Total Freight Total Aircraft

				Apron Area Terminal Area	Movements
Peker and Baki 2009	Turkey	45 Airport (2007)	Data Development Analysis	Parking Space Number of Runway Total Airport Area Number of Employees	Total Passenger Number Total Freight
Barros 2009	Birleşik Krallık	27 tane Havaalanı (2000-2006)	Data Development Analysis	Labor Cost Operational Cost Capital İnvested	Total Passenger Number Total Freight Total Aircraft Movements Total Revenue
Assaf 2010	UK	27 Airports (2007)	Data Development Analysis	Number of Runway Total Airport Area	Total Passenger Number Total Freight Total Aircraft Movements
Koçak 2011	Turkey	40 Airport (2008)	Data Development Analysis	Operational Cost Number of Employees Total Aircraft Number	Total Passenger Number Operasyon gelirleri Total Freight Operational Revenue
Lozano and Gutierrez 2011	Spain	41 Airport (2006)	Data Development Analysis	Total Runway Length Apron Area Terminal Area Number of Check-in Contuars Number of Gate	Total Passenger Number Total Freight Total Aircraft Movements
Karkacıer and Yazgan 2015	Turkey	37 Airports (2008-2011)	Data Development Analysis	Number of Employees Operational Cost Terminal Area Number of Runway	Total Passenger Number Total Freight Total Aircraft Movements
Ülkü 2015	Turkey/Spain	73 Airports (2009-2011)	Data Development Analysis	Labor Cost Number of Runway Total Runway	Total Passenger Number Total Freight Total Aircraft

				Length	Movements Total Revenue

2 DATA DEVELOPMENT ANALYSIS

Data envelopment analysis is used to measure and evaluate efficiency and productivity of similar decision-making units with regard to manufactured product or service. Recently, data envelope analysis has been widely used in operations research and management science fields [3]. According to another defination, data envelope analysis enables efficiency measurement if there are many input and output variables. This diffirentiates it from other non-paramatic measurement methods. As a result of data envelope analysis, it is possible to reach to decision-making units' efficiency situation and which decision-making units they should take as reference to be effective [4].

Basic models used in data envelope analysis are classified according to different criteria. In the beginning, CCR (Charles, Cooper, Rhodes) model which is based on constant returns to scale assumption was used. In the later years, BBC (Banker, Charles, Cooper) model which is based on variable return to scale assumption was used. Nowadays, with the development of data envelope analysis method, many different models are used [5].

2.1. CCR (Charnes, Cooper, Rhodes) model

CCR model is a data envelope analysis method used when companies operate optimum [6]. In addition to this, CCR model measures efficiency of related decision-making units according to constant returns to scale [7].

Output oriented CCR model is as Follows[8]:

$$E_0 = \min\left(\sum_{i=1}^{m} V_i X_{io} \Big/ \sum_{r=1}^{s} u_r y_{ro}\right)$$

Restricts,

$$\sum_{i=1}^{m} V_i X_{ij} \Big/ \sum_{r=1}^{s} u_r y_{rj} \geq 1, \qquad j = 1,2,\ldots n$$

$$V_i, u_r \geq \varepsilon \qquad r = 1,2,\ldots s \qquad i = 1,2,\ldots m$$

n : Decision Make Unıt s : Number of Output m : Number of Input

2.2. BCC (Banker, Charnes, Cooper,) model

Banker, Charles and Cooper developed BCC model in 1984. This model is based on variable return to scale assumption. BCC model is different from CCR model because it

evaluates decision-making units' effectiveness with both input-driven and output-driven based on variable return to scale assumption [9].

Output oriented BCC model is as Follows[10]:

Restricts,

$$\sum_{i=1}^{m} V_i X_{ij} \,/ \sum_{r=1}^{s} u_r y_{rj} \;\geq\; 1, \qquad j = 1,2,\ldots n$$

$$V_i, u_r \;\geq\; \varepsilon \qquad r = 1,2,\ldots s \qquad i = 1,2,\ldots m$$

n : Decision Make Unıt s : Number of Output m : Number of Input

3. Efficiency of Measurement Selected Airports in Turkey

Some steps should be followed for the success of data envelopment analysis. These are [11]:

1. Selection of decision-making units
2. Selection of inputs and outputs
3. Effectivenss measurement
4. Determination of reference groups

The choice of decision-making units: Airports studied represent decision-making units. Therefore, the biggest 10 airports in Turkey in terms of passenger numbers were included in this study. Table 2 shows these airports.

Tab. 2 *Decision Making Unit (DMU) in studies*

1. İstanbul Atatürk Airport
2. Antalya Airport
3. İstanbul Sabiha Gökçen Airport
4. Ankara Esenboğa Airport
5. İzmir Adnan Menderes Airport
6. Adana Airport
7. Muğla Dalaman Airport
8. Muğla Milas Bodrum Airport
9. Trabzon Airport
10. Gaziantep Airport

When examining other studies related to airports, there are two distinct opinions. Some of these studies accept that there is no influence of competent authority on output variables but has influence on input variables. Therefore, these studies used input-oriented data envelope analysis model [12]. Other studies defended the opinion that output quantity should be increased and used output-oriented data envelope analysis model[13]. Therefore, for this study, both CCR and BCC models were utilized to make efficiency measure more detailed.

The Choice of Inputs and Outputs: The choice of inputs and outputs in data envelope analysis are crucial because they affect efficiency measurement directly. In this study, runway number, terminal field size and check-in counter number are used as input variables. As output variables, passenger number and flight number are used. Input and output variables were obtained from General Directorate of State Airports Authority' 2014 annual report.

Efficiency Measurement: To make related airports' efficieny measurement, linear programming-based Deap software was used. As a result of data envelope analysis, if effectiveness of decision-making units is 1, it is accepted as effective. If effectiveness is under 1, it is accepted as non-effective.

Tab. 3 *Results From Output Oriented CCR model Efficiency Scores*

Airports	Output Oriented CCR Efficiency Scores
1. İstanbul Atatürk	1.000
2. Antalya	0.899
3. İstanbul Sabiha Gökçen	1.000
4. Ankara Esenboğa	0.402
5. İzmir Adnan Menderes	0.313
6. Adana	1.000
7. Muğla Dalaman	0.237
8. Muğla Milas Bodrum	0.250
9. Trabzon	0.459
10. Gaziantep	0.589

According to output-oriented CCR model effectiveness measurement, 3 airports were determined as efficient and 7 airports were determined as inefficient.

Tab. 4 *Results From Output Oriented BCC model Efficiency Scores*

Havalimanları	CCR Efficiency Scores	BCC Efficiency Scores	Scale Efficiency Scores
1. İstanbul Atatürk	1.000	1.000	1.000
2. Antalya	0.899	0.935	0.962
3.İstanbul Sabiha Gökçen	1.000	1.000	1.000
4. Ankara Esenboğa	0.402	0.410	0.980
5. İzmir Adnan Menderes	0.313	0.360	0.870
6. Adana	1.000	1.000	1.000
7. Muğla Dalaman	0.237	0.238	0.955
8. Muğla Milas Bodrum	0.250	0.278	0.898
9. Trabzon	0.459	0.471	0.974
10. Gaziantep	0.589	1.000	0.589

According to output-oriented BCC model effectiveness measurement, 4 airports were determined as efficient and 6 airports were determined as inefficient. According to output-oriented CCR model, 3 airports were efficent and 7 airports were inefficient.

Determining Reference Groups: Thanks to data envelope analysis, ineffective decisin-making units might fixate effective decision-making units which they can take as reference. Table 5 shows reference airports which ineffective airports take as a reference for both CCR and BBC models

Tab. 5 *Inefficient Airports and Reference Cluster*

Airports	*Output Oriented CCR model Reference Cluster*	*Output Oriented BCC model Reference Cluster*
Antalya	1(0.248) 3(0.364) 6(1.893)	3(0.043) 1(0.476) 6(0.480)
Ankara Esenboğa	1(0.344) 6(0.682) 3(0.285)	6(0.390) 1(0.392) 3(0.219)
İzmir Adnan Menderes	3(1.490)	3(0.790) 1(0.210)
Muğla Dalaman	1(0.008) 6(0.277) 3(0.698)	6(0.288) 3(0.712)
Muğla Milas Bodrum	1(0.222) 6(0.168) 3(0.166)	6(0.453) 3(0.547)
Trabzon	1(0.015) 3(0.038) 6(0.916)	6(0.936) 3(0.064)
Gaziantep	6(0.235) 3(0.104)	----------

According to output-oriented CCR model as showed in Table 5, Antalya Airport which is one of inefficient airports should take Istanbul Ataturk Airport as a reference at the ratio of 0.248 to be efficient. Similarly, it should take Istanbul Sabiha Gokcen Airport and Adana Airport as references at the ratio of 0.364 and 1.893 respectively. According to output-oriented BCC model, Antalya Airport should take Sabiha Gokcen Airport, Istanbul Ataturk Airport and Adana Airport as references at the ratio of 0.043, 0.476 and 0.480 respectively.

4 CONCLUSION

It is crucial to use airports efficiently and productively. Within this scope, in this study, the biggest 10 airports in terms of passenger numbers were included. According to CCR model, 7 airports are ineffective and 6 airports are ineffective according to BCC model. As a result of analysis, it is revealed that which airports should be taken as a reference for related airports to be efficient. In addition to this, it is revealed that how much input or output variables ineffective airports should increase or decrease to be effective.
The following recommendations are for ineffective airports' managers:

- Before increasing existing airport capacity, they should increase total flight and passenger numbers,
- They should try to decrease charges paid by airlines,
- They should move in concert with ground handling agents to decrease waiting time at airports.

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