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Efficiency analysis of airports in Turkey considering environmental effects

Berna H. ULUTAS

Eskisehir Osmangazi University, Turkey

Abstract:

Aim: This paper aims to attract attention to the “green airport” term that is basically related with environmental legislations.

Design / Research methods: A Data Envelopment Analysis (DEA) model is introduced to assess the efficiency of 22 airports in Turkey with the definition of undesirable output as emission values.

Conclusions / findings: Results illustrate that only two airports are efficient based on the considered outputs and undesirable output.

Originality / value of the article: Up-to-best knowledge, green gas emission data of airports in Turkey are considered in a DEA model for the first time. To minimize the undesirable output, it is considered as a desirable input in the model. Results are expected to support official authorities during decision making.

Limitations of the study: Data for noise levels and the exposed area and/or number of exposed people and buildings were not available for the airports in concern.

Key words: airport efficiency, data envelopment analysis, undesired outputs, environmental factors, noise level, handicap friendly airport, green airport
JEL: L93, L98, O18, O44, Q53, R11, R15

1. Introduction

Air transportation is becoming one of the most popular transportation alternatives due to the changing life style of people. On the other hand, assessing airport performance has several dimensions, therefore the problem is still critical for decision makers. There are several studies in the literature to cope with the issues of

Correspondence address: Berna H. Ulutas, Eskisesehir Osmangazi University, Büyükdere Mahallesi, Meşelik Yerleşkesi, 26040 Odunpazarı/Eskişehir, Turkey. E-mail: bernaulutas@gmail.com.
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airport inefficiency and poor profitability. Managerial efficiency aims to identify the airports that perform better compared to other airports. Recently, Cavaignac and Petiot (2017) analyze 461 articles dealing with the application of Data Envelopment Analysis in the transport sector (1989-2016). It is stated that 40% of the articles deal with the air transportation. Among these articles 63% deal with airport and 36% with airlines. Forsyth (2007) states that it is more difficult to develop satisfactory models for air transport due to the particular problems of ensuring comparability and of defining output which are not encountered in other sectors.

Single European Sky ATM Research (SESAR) state the two main environmental issues associated with aviation are emissions and noise (SESAR, 2017). Global emissions are related to climate change since aircraft emit gases and particles in direct proportion to the quantity of fuel burned directly into the upper troposphere and lower stratosphere; CO_2 is also emitted at airports through various airport operations, such as ground support vehicles and passenger surface transport vehicles. Air Transport Action Group (ATAG) declare that globally, the aviation industry accounts for around 2% of all human-induced CO_2 emissions (ATAG 2017). Local emissions refer to aircraft operations at airports (landing and taking off, taxiing, fuel storage, engine testing and the use of auxiliary power units) that impact on local air quality through pollutants emitted during these operations. Additionally, other airport operations, such as the use of ground support equipment, airport air-conditioning, passenger cars, and many others, also affect local air quality. Generally aircraft noise is influenced by particular factors such as the number of flights, their timing, the type of aircraft, and the flight path.

It is important to consider desirable outputs as passengers and aircraft movements, and undesirable outputs as aircraft noise and pollutants when evaluating the efficiency of airports. On the other hand, it is critical to consider urban development impact factors around the site.

Mahashabde et al. (2011) aim to address shortcomings in current decision-making practices for aviation environmental policies in terms of noise, air quality, and climate impacts of aviation. Püschel and Evangelinos (2012) estimate airport noise annoyance cost around Düsseldorf, Germany. Sari et al. (2013) determine the affected areas around the airports, the topographical information in the study area, the geographical structure and population database were used to create geo database for Antalya airport and Van Ferit Melen airport. Ozkurt et al. (2014) calculate the level of aircraft noise exposure around Istanbul Ataturk Airport, Turkey according to the European Noise Directive. Ozkurt (2014) model noise exposure levels at surrounding areas of Esenboga Airport, Turkey. Ozkurt et al. (2015) calculate noise levels for the day, evening and night time periods around Izmir Adnan Menderes Airport. Hamamci et al. (2017) form noise maps of four international airports in Turkey by using SoundPlan Software and identify the lands affected by noise pollution by overlaying noise maps and CORINE dataset in Geographic Information System (GIS) environment. Layers are typified by four main classes with type codes as; residential, green and agriculture areas, industrial and commercial use, road and railways.

Wolfe et al. (2014) model the net cost and distribution of environmental damages and state that populations living at airport boundaries face damages of $100-400 per person per year from aircraft noise and between $5-16 per person per year from climate damages (in 2006 dollars). Gasco et al. (2017) provide a literature review and shows the increasing importance of communicating noise information from aircraft and the variety of indicators used to communicate with the public. Rodríguez-Díaz et al. (2017) review the literature concerning the noise reduction problem around airports from the Air Traffic Control (ATC) perspective.

Lawton and Fujiwara (2016) state that airport expansion is an issue of intense public debate due to the potential impacts on climate change and the quality of life of affected local communities. This paper is the first study to analyze the relationships between airports and multiple subjective wellbeing measures, by merging national-level population statistics with noise measurement maps for seventeen English airports. Recently, Fujiwara et al. (2017) analyze the association between subjective wellbeing reported in the moment and aviation, in terms of airport location, aircraft noise, and activities within airports and results state that Being within areas of high levels of aircraft noise is associated with lower levels of happiness and relaxation. Grampella et al. (2017) focus on the amounts of different pollutants and the noise annoyance levels generated by an airport in a period of time.

Based on the accessible literature, it can be claimed that there is currently no study to assess the efficiency of airports in Turkey considering airport locations and emissions. Therefore, to fill the gap in the literature, the paper is structured as follows: second section provides basics of DEA and common input and output factors used in the literature. In the third section, the data obtained from General Directorate of State Airports Authority (DHMI, Devlet Hava Meydanları Isletmesi) is evaluated by the defined input and output factors. Results are discussed in the fourth section and the last section of the paper concludes the study and provides directions for future research.

2. Data Envelopment Analysis for airport assessment

DEA, originally proposed by Charnes et al. (1978) is a nonparametric method implemented to measure the productive efficiency of Decision Making Units (DMUs). The envelope of the observed DMUs' input and output levels is calculated by linear programming and can be considered as a best-practice frontier (Cooper et al. 2000). Seiford (1997) reviews DEA studies for 1978-1996, and recently, Emrouznejad and Yang (2017) report an extensive listing of DEA-related articles including theory and methodology developments and "real" applications in diversified scenarios from 1978 to end of 2016. Cavaignac and Petiot (2017) present a comprehensive bibliometric analysis of 461 articles dealing with the application of DEA in the transport sector (1989-2016).

2.1. Determination of decision making units

There is no certain rule for the number of DMUs, inputs and outputs. Golany and Roll (1989) state that the number of DMUs should be greater or equal to twice the product of the number of inputs and the number of outputs and Banker et al., (1989) suggest that the number of DMUs should be at least three times the number of inputs and outputs together

2.2. Defining input and outputs

Several input and output criteria can be defined for performance evaluation in profit and non-profit organizations by means of DEA. Certain factors that can be grouped as physical and technical are considered in literature. However, the determination of specific factors depends on the problem type and also the experience of the researcher. There is no certain input or output factors defined for any problem.

Outputs are considered as the benefits gained from the performance of the decision making units. Inputs for a DEA study are determined as the resources or the factors that may affect the performance of decision making units. Aircraft require airspace, runways, and other terminal capacity such as apron stands. Therefore, staff costs, costs for airport access, runway area, commercial revenues, passenger's air traffic movements and cargo traffic should be optimized. The number of counters, x-ray machines, parking area for cars in an airport, number of boarded and embarked passengers, number of domestic flight passengers, intensity of passengers, and number of flights are defined as outputs in some of the papers. Likewise, apron area, departure lounge area, check-in counter, curb frontage, parking area, baggage claim area, average number of workers, terminal area, runway length, number of gates are defined as inputs.

Gillen and Lall (1997) consider data for 1989-1992 to assess performance of 21 USA airports. Melchor and Carmen (1999) work on the efficiency of Spanish airports by use of Malmquist index. Sarkis (2000) utilized DEA for 44 USA airports. Adler and Berechman (2001) develop a model to evaluate relative efficiency and service quality. Martin and Roman (2001) use DEA to assess efficiency of 37 Spanish airports after privation for 1997 data. Inputs are defined as labor, capital and material cost, outputs are air traffic, number of passengers, and cargo (tons). Pels et al. (2001) assess air cargo and passenger transportation efficiency of European airports for 1995-1997. Pels et al. (2003) utilize physical capacity data of European airport to identify inefficiencies. Oum and Yu (2003) compare efficiencies, unit costs and financial results. Fernandes and Pacheco (2002) consider 35 airports in Brasil. Authors define six input as apron area, departure lounge area, number of check-in counter, curb frontage, number of parking slots, baggage claim area and output as total number of boarded and disembarked passenger

Bazargan and Vasigh (2003) assess 45 airports in USA by CCR method. Pacheco and Fernandes (2003) evaluate 35 airports in Brasil by BCC method by use of 1998 data. Yoshida and Fujimoto (2004) consider 67 airports in Japan and use 2000 data to benchmark with DEA. Sarkis and Talluri (2004), use 5 years data to assess 44 airports in USA. Holvard and Graham (2004) apply DEA for airports in UK. Wang, et al. (2004) analysis the operational performance of 10 major airports in Taiwan. Yu (2004) consider 14 domestic Taiwan airports and focus on environmental effects. Noise (in 1000 New Taiwan dollars) is defined as the undesired output.

Ulutas (2008) assess airports in Turkey by using the data of years 2000-2005 from DHMİ annual statistics. The inputs that effect performance are defined as number of personnel, operating costs, annual passenger capacity, and annual plane capacity and outputs are defined as passenger / area, cargo flow, total plane flow / number of runways, and operating revenue. By taking the airports as a reference set for the inefficient ones, actual and target values for each is calculated and discussed. Further Ulutas and Ulutas (2009) suggest an analytical hierarchy model to prioritize the input and output to be used in the DEA model.

3. Assessing airports in Turkey

Republic of Turkey General Directorate of State Airports Authority (Devlet Hava Meydanları Isletmesi, DHMI) is responsible for operating the airports as well as air navigation services in Turkey. To evaluate efficiency using a DEA framework, data for 55 airports in Turkey are collected for 2017 from the official web site of Airport Authority. However, the airports that are managed by private companies (Zonguldak Caycuma, Gazipasa Alanya, Zafer and Aydın Cildir, Istanbul Sabiha Gokcen) and Eskisehir Anadolu University School of Civil Aviation (Eskisehir Hasan Polatkan) are not considered within the scope of this study. Available data for 49 airports are the population of the city, distance to city, terminal area, parking area, period of service, and total number of flights (passenger and cargo). Currently, 33 airports in Turkey are accredited as "handicap friendly airports" based on meeting the criteria or counter and terminal area interior design, parking area availability etc. 29 airports in Turkey have "green airport" certificate and the amount of emission for these airports are declared on their web site. This study considers 22 homogenous airports that are accredited as "handicap friendly" and "green" airport.

3.1. Defining factors for analysis

Terminal area, terminal aircraft capacity, and total number of flights are considered as outputs in many of the DEA studies in the literature. These factors are known to be related managerial issues. Depending on the demand, there may be a necessity of expansion of the terminal or runways. On the other hand, based on the period of service (year), maintenance may be required for the terminal requiring several new investments. The transportation policies, also marketing strategies of airline companies have attracted attention of the passengers to the airline transport in Turkey, especially for the last decade. Therefore, outputs are considered as Terminal area, m^2 (O1), Terminal airplane capacity (O2), and Total number of air traffic (O3) in this study.

The accreditation for disabled people mainly considers inner design of the terminal and the parking area. On the other hand, the distance to closest city center should be reasonable to enable accessibility (should not be located too far). However, when the terminal is too close to the city center, noise exposure and also total emission can be considered as undesired factors. Distance to the city, *km* (O4) is considered as an output. Considering amount of emission is the undesired output. Emission values stated in the web sites of the airports that are accredited as "green" are utilized in this study. There are possible strategies to deal with undesired factors (as defined in the following section). As suggested by Liu et al. (2010), the undesirable output, emission value, is considered as a desirable input. Tab.1 provides the data for the DMUs considered in this study.

Table 2 presents the correlation matrix for the data in concern. It can be stated that data for emission has a high positive correlation with terminal area, terminal airplane capacity, and total number of air traffic.

Table 1. Data for the DMUs in concern

DMU	O 1	O 2	O 3	O 4	I 1
Adıyaman	23780	5	1711	22	3671.852
Balıkesir Merkez	330	1	156	5.5	129.682
Bursa Yenisehir	12716	6	6856	50	4643.000
Canakkale	12500	5	4595	5	919.002
Denizli Cardak	18739	4	6270	63	5554.000
Diyarbakır	95691	10	14309	10	18818.700
Elazıg	16400	1	7094	12	4740.980
Hatay	43688	6	9606	23	14465.800
Isparta S. Demirel	5400	5	23372	30	3924.020
Kapadokya	3500	5	3726	30	5617.223
Kars Harakani	35946	1	3220	6	5954.610
Kastamonu	3740	2	834	13	1794.475
Kayseri	22000	9	15048	5	21104.231
Konya	23650	8	8727	18	1279.209
Mugla Dalaman	118005	38	33654	6	44165.632
Mus	2490	3	2492	17	3906.121
Samsun Çarşamba	11500	10	17097	25	18740.185
Sivas Nuri Demirag	20047	11	4259	23	6857.360
Sanlıurfa Gap	12000	11	5754	35	10723.442
Tokat	560	1	1177	20	743.238
Trabzon	23745	18	25391	6	36255.097
Usak	1460	1	1800	7	657.000

Source: author’s own elaboration.

Table 2. Correlation matrix for the data

	I 1	O 1	O 2	O 3	O 4
I 1	1	0.705	0.883	0.853	-0.246
O 1	0.705	1	0.736	0.606	-0.238
O 2	0.883	0.736	1	0.807	-0.151
O 3	0.853	0.606	0.807	1	-0.134
O 4	-0.246	-0.238	-0.151	-0.134	1

Source: author’s own elaboration.

3.2. Results for the proposed DEA model

It is known that desirable output should be increased and undesirable output should be reduced to improve the performance. Three main approaches to model undesirable outputs in a DEA are summarized in Dyckhoff and Allen (2001) as follows:

- The undesirable output is modelled as being desirable by using the reciprocal of the undesirable output as DEA output
- The undesirable output is modelled in DEA as input. Both CCR and BCC DEA models can be used, depending on the operational scale of the DMUs.
- Adding to the reciprocal additive transformation of the undesirable output a positive scalar, big enough, so that the final values are positive for each DMU (values translation). This approach is stated to be valid for BCC and additive DEA models.

As a new approach, Gomes and Lins (2008) define the undesirable output emission as input and model undesirable outputs based on the zero sum gains DEA models (ZSG-DEA). In this paper, amount of emission data is considered as an input.

Tab.3 represents the efficiency values obtained by the CCR-I model. Among 22 airports in concern, Balıkesir Merkez and Konya airports (=9.09%) are identified as the most efficient airports. The average efficiency value of the airports is calculated as 0.3852 that is a quite low value. Results illustrate the importance of considering emission values because as the population of the city that is close to the airport increase, the risk for the number of people who are affected by emissions caused by emissions may also increase. However, it should be kept in mind that the efficient/inefficient DMUs may change if the airports that have heavy air traffic (i.e., Istanbul Ataturk, Ankara Esenboga) are considered in the model. Although, operation of airports are influenced by several factors, the results of this study may be considered as a prior information for the official authority in decision making.

Table 3. Results for the DEA

Rank	DMU	Efficiency score	Rank	DMU	Efficiency score
1	Balıkesir Merkez	1	12	Sivas Nuri Demirağ	0.2356
2	Konya	1	13	Kastamonu	0.2333
3	Isparta S. Demirel	0.8731	14	Elazığ	0.2193
4	Çanakkale	0.8414	15	Kapadokya	0.1792
5	Tokat	0.7198	16	Hatay	0.1634
6	Uşak	0.5048	17	Muş	0.1561
7	Bursa Yenişehir	0.3758	18	Şanlıurfa Gap	0.1452
8	Adıyaman	0.3729	19	Muğla Dalaman	0.1445
9	Denizli Çardak	0.3695	20	Samsun Çarşamba	0.1337
10	Kars Harakani	0.3265	21	Kayseri	0.1045
11	Diyarbakır	0.275	22	Trabzon	0.1027

Source: author's own elaboration.

Table 4 represents the projection values for emission values. To minimize the adverse effect of emissions, takeoff and landing (aircraft moves) can be planned accordingly. It is not possible to move an airport to another location. Therefore, these results may aid decision makers to avoid costly investments for the airports that are close to the city center.

Table 4. Projection values for emission values

Rank	Data	Projection	Diff.(%)	Rank	Data	Projection	Diff.(%)
1	129.68	129.68	0	12	6857.36	1615.41	-76.5
2	1279.21	1279.21	0	13	1794.48	418.63	-76.67
3	3924.02	3425.88	-12.69	14	4740.98	1039.84	-78.07
4	919.00	773.26	-15.86	15	5617.22	1006.47	-82.08
5	743.24	535.00	-28.02	16	14465.80	2363.05	-83.66
6	657.00	331.66	-49.52	17	3906.12	609.93	-84.38
7	4643.00	1744.65	-62.42	18	10723.40	1557.03	-85.48
8	3671.85	1369.36	-62.71	19	44165.60	6382.79	-85.55
9	5554.00	2051.99	-63.05	20	18740.20	2506.09	-86.63
10	5954.61	1944.29	-67.35	21	21104.20	2205.75	-89.55
11	18818.70	5175.85	-72.49	22	36255.10	3721.83	-89.73

Source: author's own elaboration.

Environmental impact of airports can also be assessed based on noise. The studies to determine noise level of the airports in Turkey are executed by an accredited organization. Within the scope of the project, measurements are assessed in three noise bands (55 dBA, 65 dBA, and 75 dBA) for different time intervals (overall-Lgag, day-Ld, evening-Le, and night-Ln). Future studies may consider noise exposure area, households, population, number of school, and number of hospital when data are shared with public.

4. Concluding remarks

It is important to measure emission and also consider noise levels constantly to analyze the effect of an airport to the environment. This study aims to attract attention to the importance of this topic and evaluate efficiency of airports in Turkey with relevant available data.

The results are obtained by an input oriented model that assumes the managers cannot influence the traffic level in the short run. It is clear that the location of the airports has a high impact on the operations and environmental effect. Available land may constrain the development of the airport. Once the airport is constructed, the cost of construction or expansion of the airport in future years depends critically on its location. Weather and the proximity of tall buildings or of hills have impact on environmental factors.

Several DEA studies in the accessible literature focus the economic aspects of the airport efficiency problem. However, the factors defined in this study is critical from the environmental point of view. Also, accessibility and “design for everyone” concepts are critical for the social impact. The factors discussed in this paper can also be used to assess the efficiency of airports in other countries by use of related data.

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