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Measuring the Efficiency and Congestion of Iranian Airports in 2008 with Data Envelopment Analysis

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ABSTRACT

Data envelopment analysis (DEA) is a non-parametric method in operations research for measuring the efficiency of a set of decision making units (DMUs) such as firms with multiple inputs and outputs. Efficiency is the ability to produce the outputs with a minimum input required. Congestion is evidenced when the attainment of maximal output requires a reduction in one or more of the input amounts used. This study measures the efficiency and congestion of 45 Iranian airports in 2008 with considering three inputs such as airport area, runway area and terminal area and there outputs such as the number of operational flights, the number of passengers and cargo handle. The results illustrated that most airports were not profitable and require increasing their outputs significantly. In other words, they require increasing the passenger movement, aircraft movements and cargo handle for being more efficient. Moreover, the study demonstrates that most airports have congestion in their airport area and suggests that those airports should decrease their airport area to increase their efficiencies.

KEYWORDS: Data envelopment analysis, Efficiency, Congestion, Airport.

1. INTRODUCTION

It goes without saying that transportation plays a crucial role in the economic development of every country. The aviation industry, as the fastest and the most modern component of the transportation network, is of particular significance in the world trade and tourism. There are many researches in measuring the efficiencies and productivities of airports in some countries which usually were applied on data envelopment analysis (DEA) methods [1-10].

DEA is a nonparametric method in operations research for measuring the efficiency of a set of decision making units (DMUs) such as firms with multiple inputs and outputs. However, a few researches have worked on airports congestion [11]. Congestion is a wasteful phenomenon in the production process where outputs are decreased due to great values of inputs. In the airport industry; for example, congestion can be happened due to the number of movements, particularly in the peak hours.

The first papers on measuring the congestion effect in DEA were developed by Fare and Grosskopf [12] and Fare et al. [13] as a ration of the observed amounts to the expected amounts.

Next, Cooper et al. [14] proposed a slack-based approach that the congestion effect is measured as the difference between the observed amounts and the expected amounts.

Independently, Wei and Yan [15] and Tone and Sahoo [16] developed another type of study on congestion from the output point of view. Moreover, Jahanshahloo and Khodabakhshi [17] proposed another models to estimate the congestion of DMUs. Some other researches on congestion in DEA can be also found in [18-22].

In this paper, the Cooper et al. [14] approach is used to estimate the congestion of Iranian airports in 2008. There are more than 80 airports in Islamic republic of Iran that 45 of them are considered as the scope of this study due to get their information such as the runway area, the airport area and the terminal area for inputs, and the number of passenger, the number of operational flights and cargo for outputs.

2. Preliminary Notes

One of the most important responsibilities of many managers is to improve the performance of an organization. Possible inspections and detailed analysis of DMUs to understand the production process and extract useful information are necessary in order to improve on their efficiency. Data envelopment analysis presents feasible methods for managers and economists in order to high performance in their firms and organizations. In fact, DEA does not require many assumptions, and it provides a number of additional opportunities in many different kinds of entities, activities and contexts. DEA was developed by Charnes et al. [23] based on the earlier work of Farrell [24]. It estimates the relative efficiencies through linear programming and considers continuous multiple inputs and multiple outputs of DMUs. In fact, Charnes et al. [23] described DEA as a mathematical programming model applied to observational

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data by providing a new way of obtaining empirical frontier of the production function which has become the cornerstones of modern economies. Production function is used in order to evaluate the performances of DMUs for producing maximum output for every combination of inputs. The production possibility set is given by $T = \{(x, y): x \text{ can produce } y\}$, where $x \geq 0$ and $y \geq 0$.

On the other hand, congestion is occurred when the output that is maximally possible can be increased (is reduced) by reducing (increasing) one or more inputs without improving any other input or output.

Fare et al. [13] proposed a method to measure congestion comprises two stages whereby each one differentiates the "strong disposal" from "weak disposal" properties given by the inequality and equality in the traditional Charnes, Cooper and Rhodes (CCR) model [23], and calculating two measures of technical efficiency φ^* and $\hat{\beta}^*$ from two following models, where x_{ij} and y_{ij} denote the input i and output r of DMU j and λ denotes the multiplier used for computing a linear combination of DMUs data [13].

Stage 1:

$$
\begin{aligned}
&\varphi^* = \max \varphi \\
&\text{Subject to} \\
&\textstyle\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{io} \quad i = 1,2,\dots,m, \\
&\textstyle\sum_{j=1}^{n} \lambda_j y_{rj} \geq \varphi^* y_{ro} \quad r = 1,2,\dots,s, \\
&\textstyle\sum_{j=1}^{n} \lambda_j = 1, \\
&\lambda_j \geq 0 \quad j = 1,2,\dots,n.
\end{aligned}
$$

Stage 2:

$$
\begin{aligned}
&\hat{\beta}^* = \min \hat{\beta} \\
&\text{Subject to} \\
&\textstyle\sum_{j=1}^{n} \lambda_j x_{ij} = \tau x_{io} \quad i = 1,2,\dots,m, \\
&\textstyle\sum_{j=1}^{n} \lambda_j y_{rj} \geq \hat{\beta} y_{ro} \quad r = 1,2,\dots,s, \\
&\textstyle\sum_{j=1}^{n} \lambda_j = 1, \\
&0 \leq \tau \leq 1, \\
&\lambda_j \geq 0 \quad j = 1,2,\dots,n.
\end{aligned}
$$

Since in the 'weak disposal' model, $0 \leq \hat{\beta}^* \leq \varphi^*$, it allows to measure the congestion by means of $\varphi^*/\hat{\beta}^* \geq 1$. In this case, a DMU shows signs of congestion if and only if $\varphi^*/\hat{\beta}^* > 1$ and congestion is not present if$\varphi^*/\hat{\beta}^* = 1$.

Another approach also is preceded in a two-stage method to calculate the congestion by Cooper et al. which has some differences with the Fare et al. approach. It includes the Banker, Charnes and Cooper (BCC) model [25] and also the incorporation of slacks (s_i^- and s_r^+) into the objective function, being multiplied by the non-Archimedean value ($\varepsilon > 0$). The second stage used as [26] increases even more the differences for the treatment of slacks adopted by Färe et al. The Cooper et al. formulations are as follows [14]:

Stage 1:

$$
\begin{aligned}
&\varphi^* = \max \varphi + \varepsilon \left(\textstyle\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
&\text{Subject to} \\
&\textstyle\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{io} \quad i = 1,2,\dots,m, \\
&\textstyle\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = \varphi^* y_{ro} \quad r = 1,2,\dots,s, \\
&\textstyle\sum_{j=1}^{n} \lambda_j = 1, \\
&\lambda_j \geq 0 \quad j = 1,2,\dots,n, \\
&s_i^- \geq 0 \quad i = 1,2,\dots,m, \\
&s_r^+ \geq 0 \quad r = 1,2,\dots,s.
\end{aligned}
$$

Stage 2:

$$\min \sum_{i=1}^{m} \delta_i^+$$

Subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} - \delta_i^+ = x_{io} - s_i^{-*} = \hat{x}_{io} \quad i = 1,2,\ldots,m,$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} = \varphi^* y_{ro} + s_r^{+*} = \hat{y}_{ro} \quad r = 1,2,\ldots,s,$$

$$\sum_{j=1}^{n} \lambda_j = 1,$$

$$\lambda_j \geq 0 \quad j = 1,2,\ldots,n,$$

$$\delta_i \leq s_i^{-*} \quad i = 1,2,\ldots,m.$$

The values of $s_i^{c*} = s_i^{-*} - \delta_i$ are considered for congestion of each DMU.

3. Airport Efficiency and congestion of Iranian airports

There are a goof number of DEA applications in airports efficiency [1-10]. A recent review on airport efficiency was presented by Lozano and Gutierrez [10]. In almost all studies the outputs are considered as aircraft traffic movement, passenger movement and cargo which illustrates the main transportation services which are supported by airport operations. Little studies have also selected some other outputs such as suitability to airlines, convenience or quality of service [3]. On the other hand, the studies usually considered the variety of inputs such as capital stock and operating costs. Terminal area, aircraft parking positions, number of runways, baggage belts, total runway length, boarding gates and so on can be considered as capital stock input. Moreover, the most common DEA model used in airport efficiency is radial input/output-oriented with either variable returns to scale (VRS) or constant returns to scale (CRS) [10].

On the other side, there are more than 80 airports in Iran. However, a little data of Iranian airports were available. Although, it is approximately impossible to get whole necessary data of each airport to measure their efficiencies, there are some main data for assessing the efficiency of Iranian airports. In other words, three inputs and three outputs are considered in this study from the Statistical Yearbook of Iranian Air Transportation in 2008 to estimate the efficiency and congestion of Iranian airports in 2008 by applying the Cooper et al. method. The airport area the terminal area and the runway area are chosen as the inputs and the number of passengers, the number of operational flights and cargo are selected as the outputs for each airport.

Table 1 illustrates 45 Iranian airports in 2008 with their International Civil Aviation Organization's (ICAO) codes. The second column of Table 1 demonstrates the radial efficiency scores of each airport in output-oriented case in variable returns to scale (VRS) technology.

Table 1: The results of 45 Iranian airports.

Airports	φ^*	$s_{i,A}^{c*}$	$s_{i,T}^{c*}$	$s_{i,R}^{c*}$
OIAA	7.890	0.61	0.00	8.45
OIAH	**1.000**	**0.00**	**0.00**	**0.00**
OIAM	2.450	3.15	0.00	2.57
OIAW	1.588	0.00	61.51	0.00
OIBA	4.616	1.94	0.00	1.99
OIBB	2.081	0.00	0.00	8.06
OIBH	151.000	12.54	0.00	7.98
OIBI	1.938	5.55	0.00	6.09
OIBJ	3.778	1.48	0.00	1.21
OIBL	8.727	1.40	0.00	0.20
OIBQ	**1.000**	**0.00**	**0.00**	**0.00**
OICI	6.901	2.62	0.00	2.18
OICK	14.391	1.14	0.00	3.20
OICS	3.897	1.43	0.00	2.57
OIFM	1.844	6.56	0.00	22.88
OIFS	14.871	2.55	0.00	2.12
OIGG	1.302	0.10	0.00	3.51
OIHH	1.630	5.39	0.00	6.46
OIII	**1.000**	**0.00**	**0.00**	**0.00**
OIKB	1.381	2.74	0.00	14.50
OIKJ	13.525	4.51	0.00	7.26
OIKM	13.190	5.12	0.00	5.46
OIKR	72.695	7.70	0.00	4.20

OIKY	7.665	6.17	0.00	7.63
OIMC	1.828	0.63	0.00	1.27
OIMJ	**1.000**	**0.00**	**0.00**	**0.00**
OIMM	1.003	0.00	92.79	14.70
OIMN	2.654	1.66	0.00	2.50
OIMS	8.160	3.56	0.00	4.94
OINN	6.759	0.37	0.00	0.00
OINR	**1.000**	**0.00**	**0.00**	**0.00**
OISL	2.181	0.97	0.00	4.48
OISR	1.930	6.08	0.00	4.14
OISS	1.423	0.92	0.00	20.89
OISY	6.649	2.44	0.00	1.19
OITK	23.056	6.45	0.00	0.00
OITL	1.676	99.2	0.00	16.47
OITR	3.818	1.32	0.00	3.45
OITT	2.014	5.24	0.00	14.33
OIYY	1.101	3.10	0.00	6.05
OIZB	13.006	1.54	0.00	4.03
OIZH	2.946	7.89	0.00	7.87
OIZI	3.150	2.53	0.00	2.47
OIZN	6.077	0.00	0.00	0.04
OIZS	9.889	4.68	0.00	2.78

There are only 5 efficient airports such as OIAH (Gachsaran airport), OIBQ (Khark airport), OIII (Mehrabad airport), OIMJ (Shahroud airport) and OINR (Ramsar airport); and other airports are inefficient. This result demonstrates that most airports in 2008 did not do the job right and were unprofitable.

The third, fourth and fifth columns of Table 1 represent the congestion amounts of applying Cooper et al. method in the airport area ($s_{i,A}^{c*}$), the terminal area ($s_{i,T}^{c*}$) and the runway area ($s_{i,R}^{c*}$), respectively. As it can be seen in the third column of Table 1, OIBB (Boushehr airport), OIAW (Ahwaz airport), OIZN (Sari airport), OIMM (Mashhad airport) and the efficient airports have the zero congestion in the airport area. Moreover, OIAW and OIMM are only the two airports which do not have the zero amounts of congestion in the terminal area among other airports as depicted in forth column of Table 1.

It is also worth to mention that the runways have the standard widths and lengths according to ICAO's rules and is the uncontrollable input in managing airports.

However, the last column of Table 1 depicts that the most airports have the congestion in runway areas. This is due to little operational flights in the inefficient airports exactly and strongly it is suggested to increase the values of outputs. In addition, there are only three inefficient airports in Table 1 which have the zero amount of congestion in the runway area such as OINN (Nowshahr airport), OITK (Khoy airport) and OIAW.

4. Conclusion

This study discusses the efficiency and congestion of 45 Iranian airports in 2008. The results illustrate that most airports were not efficient and had also congestion in airport areas. Since the airport industry is one of the most efficient sectors in each country that utilizes the resources and infrastructure, the results of this study show there is a need to improve the performance of most Iranian airports. Indeed, only 5 airports were efficient among 45 airports in 2008 and this is necessary to decrease general expenses for maintenance the airports by increasing the outputs values as well as the suggested results of this study. In other words, since the airports have the congestion in airport area (except OIBB, OIAW, OIZN, OIMM, OIAH, OIBQ, OIII, OIMJ and OINR) they should decrease their airport area to increase their efficiency. Moreover, OIAW and OIMM have congestion in the terminal area and they should also reduce its terminal area to raise their efficiency. Furthermore, the passenger movements, aircraft movements and cargo handle should be increased in order to improve the efficiency of those airports.

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