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# Airport Efficiency with Arash Method in Data Envelopment Analysis

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**ABSTRACT**

Airport efficiency with data envelopment analysis (DEA) is one of the common research studies in the last decade. DEA is a nonparametric method in operations research which has been provided some significant tools to estimate the performance evaluation, efficiency and productivity of homogenous decision making units (DMUs) such as firms, factories and organizations. Although, the conventional DEA models (radial or non-radial) have been usually applied in airport efficiency studies, those models are not almost always able to distinguish between efficient DMUs and technical efficient ones. Recently, Arash Method (**AM**) was proposed in DEA to improve the previous DEA techniques and remove their shortcomings to arrange both inefficient and technical efficient DMUs together. In this paper, the importance of using **AM** in DEA to assess the efficiency of airports is illustrated. The method is examined with a numerical example of 17 airports with four inputs (apron, number of baggage belts, check-in-counter and boarding gates) and three outputs (passenger movements, aircraft operations and cargo). The results characterize how the neglect in differences between efficiency and technical efficiency definitions can introduce a weak performer as a strong one which does the jobs right.
**KEYWORDS**: Data envelopment analysis, Technical efficiency, Efficiency, Arash Method, Airport.

## 1. INTRODUCTION

Air transport industry has been experienced a rapid growth worldwide in the recent years. One of the most efficient sectors which utilize the resources and infrastructure in air transport industry is Airports which involve high expenditures such related areas as traffic control, terminals and runways to provide the aircraft operations, cargo handle and passenger movements. Moreover, any attempt to make the airports and other aviation facilities more efficient, by employing appropriate and scientifically approved methods, can be interested for governments and private sectors to decrease general expenses for maintenance the airports. Fortunately, data envelopment analysis (DEA) has been provided a nonparametric technique with multiple inputs and outputs to measure the efficiency of homogeneous decision making units (DMUs) such as airports. It proposed by Charnes et al. [1] based on the earlier work of Farrell [2] and it has dramatically improved in the last three decades. Moreover, there are many researches in airport industry with applying the radial DEA models such as CCR [1] and BCC [3] and a few studies with non-radial models such as SBM [4]. However, those radial and non-radial DEA models are not able to distinguish between efficient DMUs and technical efficient ones. Although, some super-efficiency models [5] such as AP model [6] were proposed to raise the shortcomings of conventional DEA models and characterize the differences between technical efficient DMUs, they are not significantly able to arrange both technical efficient and inefficient DMUs concurrently [7]. Therefore, Khezrimotlagh et al. [7] proposed a significant method called Arash Method (**AM**) to remove those shortcomings and improve the capabilities of DEA to assess the performance evaluation of decision making units. Their proposed method is not only able to distinguish between efficient and technical efficient DMUs, but also it arranges both technical efficient and inefficient DMUs simultaneously. Indeed, **AM** measures the real efficiency scores for DMUs by estimating the instabilities of their scores where a little error happens in those input data. In this study, a numerical example of 17 airports with four inputs and three outputs is considered to characterize the importance of using **AM** to assess the efficiency score of airports in comparison with using the conventional DEA models. The rest of this article is organized in four sections. Section 2 is the background on airports efficiency and the preliminary note on data envelopment

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analysis methods. A numerical example is proposed in Section 3 and the paper is concluded in Section 4. The simulations are also performed with Microsoft Excel Solver due to have the simple linear and nonlinear programming models.

## 2. Airport efficiency and DEA

The conventional DEA models have been used in a number of previous airport efficiency researches in the last decade. The outputs in most of previous studies were usually considered as aircraft movement, passenger movement and cargo handled which characterize the main transportation services supported by airport operations. However, the inputs were selected with variety of physical infrastructure of the airports such as terminal area, number of check-in counters, number of baggage belts, number of boarding gates, apron capacity, number of runways and aircraft parking and so on. Some recent reviews of the airport efficiency literature can be found in [8-10]. On the other hand, most of those studies considered technical efficiency to assess the performance evaluation of airports such as the studies by Gillen and Lall [11], Parker [12], Pets et al. [13], Martin and Roman [14], Fernandes and Pacheco [15], Yoshida et al. [16], Yu [17], Pathomsiri and Haghani [18], Guedes et al. [19], Hong and Kim [20], Barros and Dieke [21], Fung et al [22], Tapiador et al. [23], Tovar and Martin-Cejas [8], Abrate and Erbetta [9] and Lozano and Gutierrez [10].

A DMU is called technical efficient if and only if the performances of other DMUs do not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs. This definition is called Pareto-Koopmans definition in DEA and unfortunately it is wrongly interpreted as efficiency i.e., doing the jobs right, where there is no any units price or costs information for data. Khezrimotlagh et al. [7] recently illustrated that the definition of Pareto-Koopmans in DEA is only able to characterize the technical efficient DMUs and a technical efficient DMU may neither be efficient nor be more efficient than an inefficient one. They proposed a significant method to distinguish between efficient and technical efficient DMUs where the weights, units price or costs information of DMUs are not available and defined that an efficient DMU is a technical efficient DMU which has the best performer in comparison with other technical efficient DMUs, i.e., it has the best combination of inputs and outputs among other DMUs or the ratio of its produced output to its used input (output/input) among other DMUs does not much change where a very little error happens in its data. Their proposed definition does not depend to the weights or units price of data and it is the same as the definition of efficiency in economics where costs information are available. In order to illustrate the models, let us assume that there are $n$ DMUs ($\mathrm{DMU}_i, i = 1,2,\dots,n$) with $m$ nonnegative inputs ($x_{ij}, j = 1,2,\dots,m$) and $p$ nonnegative outputs ($y_{ik}, k = 1,2,\dots,p$) for each DMU which at least one of its inputs and one of its outputs are not zero. The CCR and SBM in constant returns to scale (CRS) are as following where $\mathrm{DMU}_l$ ($l = 1,2,\dots,n$) is evaluated.

**CCR**:

$$\theta^* = \min\ \theta,$$

Subject to

$$\sum_{i=1}^{n} \lambda_i x_{ij} + s_j^- = \theta x_{lj},\ \forall j,$$
$$\sum_{i=1}^{n} \lambda_i y_{ik} - s_k^+ = y_{lk},\ \forall k,$$
$$\lambda_i \geq 0,\ \ \forall i,$$
$$s_j^- \geq 0,\ \ \forall j,$$
$$s_k^+ \geq 0,\ \ \forall k.$$

Targets:

$$\begin{cases} x_{lj}^* = \theta^* x_{lj} - s_j^{-*}, \forall j, \\ y_{lk}^* = y_{lk} + s_k^{+*}, \forall k. \end{cases}$$

**SBM**:

$$\rho^* = \min \frac{1 - (1/m)\ \sum_{j=1}^{m} s_j^- / x_{lj}}{1 + (1/p)\ \sum_{k=1}^{p} s_k^+ / y_{lk}}$$

Subject to

$$\sum_{i=1}^{n} \lambda_i x_{ij} + s_j^- = x_{lj},\ \forall j,$$
$$\sum_{i=1}^{n} \lambda_i y_{ik} - s_k^+ = y_{lk},\ \forall k,$$
$$\lambda_i \geq 0,\ \ \forall i,$$
$$s_j^- \geq 0,\ \ \forall j,$$
$$s_k^+ \geq 0,\ \ \forall k.$$

Targets:

$$\begin{cases} x_{lj}^* = x_{lj} - s_j^{-*}, \forall j, \\ y_{lk}^* = y_{lk} + s_k^{+*}, \forall k. \end{cases}$$

The constant returns to scale means a proportionate increase in inputs results in the same proportionate increase in output. The CCR has two stages, first minimizing $\theta$ and second maximizing the slacks $s_j^-$ (potential reduction of input) and $s_k^+$ (potential increase of output), for $j = 1,2,\dots,m$, and $k = 1,2,\dots,p$. The following notations are also used in the models:

$n$ number of DMUs,
$m$ number of inputs,
$i$ index of DMUs,
$j$ index of inputs,
$k$ index of outputs,
$l$ index of specific DMU whose efficiency is being assessed,
$x_{ij}$ observed amount of input $j$ of $\mathrm{DMU}_i$,
$y_{ik}$ observed amount of output $k$ of $\mathrm{DMU}_i$,
$\lambda_i$ multipliers used for computing linear combinations of DMUs' inputs and outputs,
$s_{ij}^-$ non-negative slack or potential reduction of input $j$ of $\mathrm{DMU}_i$,
$s_{ik}^+$ non-negative slack or potential increase of output $k$ of $\mathrm{DMU}_i$,
$w_{ij}^-$ positive specified weight or price for input $j$ of $\mathrm{DMU}_i$,
$w_{ik}^+$ positive specified weight or price for output $k$ of $\mathrm{DMU}_i$,
$\theta^*$ the optimal efficiency score of a DMU in input-oriented approach of CCR,
$\lambda_i^*$ optimal multipliers to identify the reference sets for a DMU, $i = 1,2,\dots,n$,
$s_{ij}^{-*}$ optimal slack to identify an excess utilization of input $j$ of $\mathrm{DMU}_i$,
$s_{ik}^{+*}$ optimal slack to identify a shortage utilization of output $k$ of $\mathrm{DMU}_i$,
$x_{ij}^*$ target of input $j$ of $\mathrm{DMU}_i$ after evaluation,
$y_{ik}^*$ target of output $k$ of $\mathrm{DMU}_i$ after evaluation.

The CCR and SBM by adding the convexity constraints, i.e., $\sum_{i=1}^{n}\lambda_i = 1$, become BCC and SBM VRS (variable returns to scale). CCR and BCC are radial models which were proposed by Charnes et al. [1] and Banker et al. [3], respectively. Moreover, SBM is a non-radial model which was suggested by Tone [4]. SBM measures a ratio of the average inputs decrease to the average output increase and suggests improving both inputs and outputs simultaneously. Since SBM similar to other conventional DEA models is not able to distinguish between technical efficient DMUs, Khezrimotlagh et al. [7] proposed the flexible method called, Arash Method (**AM**), to identify the efficient DMUs among the technical efficient ones where the weights of data are not available. The **$\boldsymbol{\varepsilon}$-AM** is as following where $\mathrm{DMU}_l$ ($l = 1,2,\dots,n$) is evaluated and $\boldsymbol{\varepsilon} = (\varepsilon_1,\varepsilon_2,\dots,\varepsilon_m)$, $\varepsilon_j \geq 0$.

**$\boldsymbol{\varepsilon}$-AM**:

$$\max \sum_{j=1}^{m} w_j^- s_j^- + \sum_{k=1}^{p} w_k^+ s_k^+,$$

Subject to

$$\sum_{i=1}^{n}\lambda_i x_{ij} + s_j^- = x_{lj} + \varepsilon_j / w_j^-, \forall j,$$
$$\sum_{i=1}^{n}\lambda_i y_{ik} - s_k^+ = y_{lk}, \ \forall k,$$
$$\lambda_i \geq 0, \ \forall i,$$
$$s_j^- \geq 0, \ \forall j,$$
$$s_k^+ \geq 0, \ \forall k.$$

Targets:

$$\begin{cases} x_{lj}^* = x_{lj} + \varepsilon_j / w_j^- - s_j^{-*}, \forall j, \\ y_{lk}^* = y_{lk} + s_k^{+*}, \forall k, \end{cases}$$

Score:

$$A^* = \frac{\sum_{k=1}^{p} w_k^+ y_{lk} \,/\, \sum_{j=1}^{m} w_j^- x_{lj}}{\sum_{k=1}^{p} w_k^+ y_{lk}^* \,/\, \sum_{j=1}^{m} w_j^- x_{lj}^*}.$$

In **AM** when the weights $w_j^-$ and $w_k^+$ are not available they defined as following, where $N_j$ and $M_k$ can be selected in positive real numbers set or even zero through the goals of each DMU for its resources and productions.

$$w_j^- = \begin{cases} N_j & x_j = 0 \\ 1/x_j & x_j \neq 0 \end{cases} \quad \text{and} \quad w_k^+ = \begin{cases} M_k & y_k = 0 \\ 1/y_k & y_k \neq 0 \end{cases}.$$

Moreover, it is usually defined that $\boldsymbol{\varepsilon} = (\varepsilon,\varepsilon,\dots,\varepsilon)$, and when $\varepsilon > 0$ and $A_\varepsilon^* < 1$ for a DMU, the linear **$\boldsymbol{\varepsilon}$-AM** suggests it to change its input and output values to the new **$\boldsymbol{\varepsilon}$-AM** target and otherwise i.e., when $A_\varepsilon^* \geq 1$, **$\boldsymbol{\varepsilon}$-AM** warns that the DMU should not accept the new targets of **$\boldsymbol{\varepsilon}$-AM**, because it may decrease its efficiency score. Khezrimotlagh et al. [24] also proposed the following definition

**Definition:** A technical efficient DMU is efficient with $\varepsilon$-degree of freedom in inputs if $A_0^* - A_\varepsilon^* \leq \delta$. Otherwise, it is inefficient with $\varepsilon$-degree of freedom in inputs. The proposed amount for $\delta$ is $10^{-1}\varepsilon$ or $\varepsilon/m$.

## 3. Discussion with a numerical example

Let us consider the DMUs in Table 1 which represent 17 airports labelled A01 to A17 with four inputs such as apron capacity, number of baggage belts, check-in-counter and boarding gates and three outputs such as passenger movements, aircraft operations and cargo.

**Table 1: The example of 17 airports with four inputs and three outputs.**

| DMU | Input1 | Input2 | Input3 | Input4 | Output1 | Output2 | Output3 |
|---|---|---|---|---|---|---|---|
| **A01** | 31 | 9 | 42 | 16 | 8893749 | 76816 | 4930928 |
| **A02** | 121 | 19 | 143 | 65 | 30008152 | 327636 | 93397869 |
| **A03** | 17 | 3 | 18 | 7 | 3614223 | 33436 | 502407 |
| **A04** | 9 | 3 | 13 | 5 | 1381560 | 46534 | 309873 |
| **A05** | 43 | 16 | 85 | 30 | 13076252 | 127769 | 5125898 |
| **A06** | 5 | 4 | 18 | 5 | 1645886 | 18136 | 6921 |
| **A07** | 86 | 16 | 204 | 68 | 22408302 | 190280 | 22442448 |
| **A08** | 5 | 3 | 8 | 5 | 1385157 | 24894 | 5931 |
| **A09** | 16 | 5 | 37 | 16 | 4025601 | 65295 | 23180961 |
| **A10** | 18 | 2 | 7 | 3 | 173607 | 12348 | 30343616 |
| **A11** | 23 | 1 | 1 | 1 | 19568 | 9212 | 12 |
| **A12** | 5 | 2 | 13 | 5 | 1175328 | 21362 | 1382556 |
| **A13** | 5 | 1 | 4 | 2 | 308313 | 10696 | 430375 |
| **A14** | 23 | 6 | 42 | 10 | 3870600 | 58565 | 11530230 |
| **A15** | 35 | 8 | 42 | 18 | 4969113 | 87906 | 13067720 |
| **A16** | 21 | 7 | 36 | 12 | 3876062 | 58573 | 3417746 |
| **A17** | 34 | 8 | 34 | 10 | 4424880 | 44044 | 3197021 |

Table 2 depicts the scores of CCR, SBM, **0-AM**, **0.0001-AM**, **0.001-AM** and **0.01-AM** in constant returns to scale (CRS). There are 11 technical efficient DMUs (A01 to A11) which characterized by applying CCR, SBM and **0-AM**, and other DMUs are inefficient. There are no any differences between the scores of SBM and **0-AM** for the inefficient DMUs in this example and **0-AM** similar to other conventional DEA models is not able to identify the differences between technical efficient DMUs. However, **0.0001-AM** clearly shows that only one ten thousandth errors in each input are enough to characterize the instability of the efficiency of technical efficient DMUs as the fifth column of Table 2 illustrates it. In fact, A02 and A09 are two technical efficient DMUs which have the best combination of their data in comparison with other technical efficient DMUs.

Moreover, **0.0001-AM** identifies that the technical efficient DMU A11 can be more inefficient than all inefficient DMUs, because only 0.0001 errors in its input values fail its efficiency score to 0.0629 which is the worst score among all DMUs' scores. This outcome clearly represents the differences between technical efficiency and efficiency definition in DEA and identifies the advantages and capabilities of **AM** in comparison with other conventional DEA models to characterize those distinctions. Moreover, it warns that the Pareto-Koopmans definition in DEA should not wrongly interpreted as the definition of efficiency or doing the jobs right where there are no any weights or costs information.

**Table 2: The score of conventional DEA models and Arash Method in CRS.**

| DMU | CCR | SBM | 0-AM | 0.0001-AM | 0.001-AM | 0.01-AM |
|---|---|---|---|---|---|---|
| **A01** | 1.0000 | 1.0000 | 1.0000 | 0.9992 | 0.9918 | 0.9240 |
| **A02** | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9998 | 0.9975 |
| **A03** | 1.0000 | 1.0000 | 1.0000 | 0.9735 | 0.7852 | 0.2605 |
| **A04** | 1.0000 | 1.0000 | 1.0000 | 0.9974 | 0.9743 | 0.7927 |
| **A05** | 1.0000 | 1.0000 | 1.0000 | 0.9985 | 0.9850 | 0.8680 |
| **A06** | 1.0000 | 1.0000 | 1.0000 | 0.8711 | 0.4032 | 0.0633 |
| **A07** | 1.0000 | 1.0000 | 1.0000 | 0.9953 | 0.9541 | 0.6493 |
| **A08** | 1.0000 | 1.0000 | 1.0000 | 0.9087 | 0.4989 | 0.0909 |
| **A09** | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9998 | 0.9979 |
| **A10** | 1.0000 | 1.0000 | 1.0000 | 0.9997 | 0.9972 | 0.9725 |
| **A11** | 1.0000 | 1.0000 | 1.0000 | 0.0629 | 0.0067 | 0.0007 |
| **A12** | 0.9529 | 0.4203 | 0.4203 | 0.4202 | 0.4184 | 0.4094 |
| **A13** | 0.7360 | 0.1739 | 0.1739 | 0.1738 | 0.1737 | 0.1723 |
| **A14** | 0.9399 | 0.6475 | 0.6475 | 0.6474 | 0.6463 | 0.6360 |
| **A15** | 0.7316 | 0.5411 | 0.5411 | 0.5411 | 0.5408 | 0.5378 |
| **A16** | 0.7791 | 0.2875 | 0.2875 | 0.2875 | 0.2871 | 0.2838 |
| **A17** | 0.8435 | 0.2495 | 0.2495 | 0.2494 | 0.2489 | 0.2440 |

In addition, **0.0001-AM** strongly arranges both technical efficient and inefficient DMUs together. The sixth and seventh columns of Table 2 depict the **0.001-AM** and **0.01-AM** scores for DMUs which demonstrate the differences between other technical efficient DMUs obviously. For instance, only one thousandth errors in input values of technical efficient DMU A08 fail its rank to $13^{th}$ level after the rank of inefficient DMUs A14, A15 and A12.

**Table 3: The score of conventional DEA models and Arash Method in VRS.**

| DMU | BCC | SBM | 0-AM | 0.0001-AM | 0.001-AM | 0.01-AM |
|---|---|---|---|---|---|---|
| A01 | 1.0000 | 1.0000 | 1.0000 | 0.9993 | 0.9935 | 0.9386 |
| A02 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| A03 | 1.0000 | 1.0000 | 1.0000 | 0.9957 | 0.9583 | 0.6983 |
| A04 | 1.0000 | 1.0000 | 1.0000 | 0.9975 | 0.9757 | 0.8018 |
| A05 | 1.0000 | 1.0000 | 1.0000 | 0.9987 | 0.9872 | 0.8850 |
| A06 | 1.0000 | 1.0000 | 1.0000 | 0.9381 | 0.6025 | 0.1318 |
| A07 | 1.0000 | 1.0000 | 1.0000 | 0.9957 | 0.9578 | 0.6742 |
| A08 | 1.0000 | 1.0000 | 1.0000 | 0.9359 | 0.5936 | 0.1280 |
| A09 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 0.9992 |
| A10 | 1.0000 | 1.0000 | 1.0000 | 0.9997 | 0.9972 | 0.9726 |
| A11 | 1.0000 | 1.0000 | 1.0000 | 0.0665 | 0.0071 | 0.0007 |
| A12 | 1.0000 | 1.0000 | 1.0000 | 0.9998 | 0.9977 | 0.9774 |
| A13 | 1.0000 | 1.0000 | 1.0000 | 0.9991 | 0.9914 | 0.9209 |
| A14 | 0.9453 | 0.6759 | 0.6759 | 0.6758 | 0.6747 | 0.6636 |
| A15 | 0.7684 | 0.5431 | 0.5431 | 0.5431 | 0.5428 | 0.5398 |
| A16 | 0.7795 | 0.2967 | 0.2967 | 0.2967 | 0.2962 | 0.2916 |
| A17 | 0.8568 | 0.2497 | 0.2497 | 0.2496 | 0.2491 | 0.2438 |

The above discussions can be similarly examined in variable returns to scale by adding the convexity constraint, i.e., $\sum_{i=1}^{n} \lambda_i = 1$, to the constraints of those models. For example, Table 3 depicts the scores of BCC, SBM, **0-AM**, **0.0001-AM**, **0.001-AM** and **0.01-AM** in variable returns to scale (VRS). From the table, only four DMUs A14, A15, A16 and A17 are inefficient and other DMUs are technical efficient. Likewise, A11 has the worst combination of its input and output data in comparison with all other DMUs due to this fact that just 0.0001 errors in its input data fail its efficiency score to 0.0665.

Furthermore, from the columns six and seven, A02 in variable returns to scale technology has the best combination of its data among other DMUs even if 0.01 errors happened in its input values and it is absolutely efficient.

## 4. Conclusion

This study clearly illustrates that the technical efficient DMUs may not do the jobs right and they should be exactly examined to find the efficient ones. Although, there are many researchers in airport efficiency with using DEA, they did not almost always characterize the differences between technical efficient DMUs and their performances in comparison with inefficient ones. In other words, there may be some inefficient DMUs which are more efficient than some technical efficient ones, but the conventional DEA models are not almost always able to identify those differences. Therefore, this study illustrates the importance of using the new method in DEA called Arash method (**AM**) to characterize the efficient DMUs among the technical efficient ones. The study examines the Arash Method for 17 airports with four inputs and three outputs. The outcomes clearly demonstrate how the neglect in differences between efficiency and technical efficiency definitions can introduce a weak performer as a strong one which does the jobs right. Moreover, the study suggests using **AM** to assess the performance evaluation of airports and concurrently arrange both technical efficient and inefficient airports together.

## REFERENCES

[1] A. Charnes, W.W. Cooper and E. Rhodes, Measuring the efficiency of decision making units, European Journal Operational Research, 2 (1978), 429–444.

[2] M.J. Farrell, The measurement of productive efficiency, Journal of Royal Statistical Society, 120 (1957), 253-281.

[3] R.D. Banker, A. Charnes and W.W. Cooper, Some Models for Estimating Technical and scale Inefficiencies in Data Envelopment Analysis, Management Science, 30 (1984), 1078-1092.

[4] K. Tone, Several algorithms to determine multipliers for use in cone-ratio envelopment approaches to efficiency evaluations in DEA. In: Amman, H., Rustem, B., Whinston, A.B. (Eds.), Computational Approaches to Economic Problems. Kluwer Academic Publishers, Dordrecht, The Netherlands, (1997) 91-109.

[5] G.R. Jahanshahloo, F. Hosseinzadeh Lotfi, M. Sanaei and M. Fallah Jelodar, Review of ranking models in data envelopment analysis, Applied Mathematical Sciences, 2 (2008), 1431-1448.

[6] P. Anderson and N.C. Petersen,. A procedure for ranking efficient units in data envelopment analysis. Management science, 39 (1993), 1261-1264.

[7] D. Khezrimotlagh, S. Salleh and Z. Mohsenpour, A new method in data envelopment analysis to find efficient decision making units and rank both technical efficient and inefficient DMUs together, Applied Mathematical Sciences, 6 (2012), 93:4609 – 4615.

[8] B. Tovar and R.R. Martin-Cejas, Technical efficiency and productivity changes in Spanish airports: A parametric distance functions approach, Transportation Research Part E, 46 (2010), 249–260.

[9] G. Abrate and F. Erbetta, Efficiency and patterns of service mix in airport companies: An input distance function approach, Transportation Research Part E, 46 (2010), 693–708.

[10] S. Lozano and E. Gutierrez, Efficiency Analysis and Target Setting of Spanish Airports, Networks and Spatial Economics, 11 (2011), 139–157.

[11] D. Gillen and A. Lall, Developing measures of airport productivity and performance: An application of data envelopment analysis, Transportation Research Part E, 33(1997), 261–273.

[12] D. Parker, The performance of BAA before and after privatization, Journal of Transport Economics and Policy, 33 (1999), 133–146.

[13] E. Pels, P. Nijkamp and P. Rietveld, Relative efficiency of European airports, Transport Policy, 8 (2001), 183–192.

[14] J.C. Martin and C. Roman, An application of DEA to measure the efficiency of Spanish airport prior to privatization, Journal of Air Transport Management, 7 (2001), 149–157.

[15] E. Fernandes and R. Pacheco, Efficient use of airport capacity. Transportation Research Part A, 36 (2002), 225–238.

[16] Y. Yoshida and H. Fujimoto, Japanese-airport benchmarking with the DEA and endogenous-weight TFP methods: testing the criticism of overinvestment in Japanese regional airport, Transportation Research Part E, 40 (2004), 533–546.

[17] M. Yu, Measuring physical efficiency of domestic airports in Taiwan with undesirable outputs and environment factors, Journal of Air Transport Management, 10 (2004), 295–303.

[18] S. Pathomsiri and A. Haghani, Benchmarking efficiency of airports in the competitive multiple-airport systems: the international perspective. In: Proceedings of the 19th Transport Chicago Conference. CD-ROM, Chicago, IL, 2004.

[19] E.C. Guedes, R.P.D. Santos and A.R. Correia, Airport efficiency: a comparative approach with data envelopment analysis and inverted Frontier. In: Proceedings of 10th Annual World Conference of Air Transport Research Society, Nagoya, Japan, 2006.

[20] S. Hong and T. Kim, A Performance analysis of the airports in Korea-super-efficiency and DEA approach using WLU. In: Proceedings of 10th Annual World Conference of Air Transport Research Society, Nagoya, Japan, 2006.

[21] C. Barros and P. Dieke, Performance evaluation of Italian airports: a data envelopment analysis, Journal of Air Transport Management, 13 (2007), 184–191.

[22] M.K.Y. Fung, K.K.H. Wan, Y.V. Hui and J.S. Law, Productivity changes in Chinese airports 1995–2004, Transport Research Part E, 44 (2008), 521–542.

[23] F.J. Tapiador, A. Mateos and J. Marti-Henneberg, The geographical efficiency of Spain's regional airports. a quantitative analysis, Journal of Air Transport Management, 14 (2008), 205–212.

[24] Khezrimotlagh, D., S. Salleh and Z. Mohsenpour, 2012. Arash Method and Uncontrollable Data in DEA. Applied Mathematical Sciences. 6(116):5763-5768.

[25] Khezrimotlagh, D., Z. Mohsenpour and S. Salleh, 2012. Cost-Efficiency by Arash Method in DEA. Applied Mathematical Sciences. 6(104):5179-5184.

[26] Khezrimotlagh, D., Z. Mohsenpour and S. Salleh, 2012. Comparing Arash Model with SBM in DEA. Applied Mathematical Sciences. 6(104):5185-5190.