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(Research Article)

Analyzing the efficiency and performance of Indian airlines through data envelopment analysis

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Abstract

The aim of this study is to use data envelope analysis to examine the performance efficiency of India's airline industry. The researcher considers two output variables and four input variables for this study. According to this model, there are two categories for the airline industry: efficient and inefficient. Based on the results, it is possible to identify which Indian airlines are the most and least efficient.

Keywords: Decision Making Units; Data Envelopment Analysis; Input variable; Output variable; Efficiency analysis.

1. Introduction

The Indian aviation industry is one of the fastest-growing in the world. Improving customer service is the main objective of the airline sector. Although cost control has always been a crucial aspect of airline management, in the recent past it has also been a critical component of an airline's survival strategy. While the financial condition of most international airlines has improved since the recent global financial crisis, it is much too early to assume that more airlines do not face financial difficulties or are compelled to participate in any sort of merger or acquisition operation. The current cost pressure is a result of margins for premium goods in particular declining in several airline markets throughout the world as economic circumstances and competition rise. In this context, the author addressed the efficiency level of Indian airlines, taking the cost measures as output such as operating revenue per kilometre & operating revenue per employee using data envelopment approach.

1.1. Data Envelopment Analysis

A non-parametric method called Analysis of Data Envelopment (DEA) is focused on an interesting application in linear programming. In the beginning, it was created for measuring performance. It has been effectively used to evaluate the relative performance of a group of companies that generate a range of identical outputs using a variety of identical inputs. DEA was first put forward by Charnes, Cooper and Rhodes in 1978 [2]. It is a performance measurement technique which, as we shall see, can be used for evaluating the relative efficiency of decision-making units [DMU's] in organisations. DMU is a distinct unit within an organisation that has flexibility with respect to some of the decisions it makes, but not necessarily complete freedom with respect to these decisions. one advantage of DEA is that it can be applied to non-profit making organisations. Since the technique was first proposed much theoretical and empirical work has been done. Many studies have been published dealing with applying DEA in real-world situations. The framework has been adapted for multi-input, multi-output production functions and applied in many industries. DEA develops a function whose form is determined by the most efficient producers. Compared to the Ordinary Least Squares (OLS)

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statistical technique, which bases comparisons against an average producer, this method is different. Similar to Stochastic Frontier Analysis (SFA), DEA assesses companies exclusively against the top producers, thereby identifying a "frontier" on which the relative performance of other utilities in the sample may be compared. It can be described as an extreme point method that makes the assumption that another firm of equal scale should be able to create a given level of output using a given level of input. The most efficient producers can form a 'composite producer', allowing the computation of an efficient solution for every level of input or output. Where there is no actual corresponding firm, 'virtual producers' are identified to make comparisons.

This technique aims to measure how efficiently a DMU uses the resources available to generate a set of outputs (Charnes et al 1978). Decision-Making Units can include manufacturing units, departments of big organizations such as universities, schools, bank branches, hospitals, power plants, police stations, tax offices, prisons, and defence bases, a set of firms or even practicing individuals such as medical practitioners. DEA has been successfully applied to measure the performance efficiency of all these kinds of DMUs. The performance of DMUs is assessed in DEA using the concept of efficiency or productivity, which is the ratio of total outputs to total inputs. Efficiencies estimated using DEA are relative, that is, relative to the best performing DMU (or DMUs if there is more than one best-performing DMUs). The best performing DMU is assigned an efficiency score of unity or 100 per cent, and the performance of other DMUs varies, between 0 and 100 percent relative to this best performance [4].

Mariappan, Jenifer Christinal, and Dave (2020) analyzed the efficiency of selected countries worldwide using DEA, highlighting disparities and identifying benchmarks for performance improvement [5]. In another study, Mariappan, Jenifer Christinal, and Dave (2020) focused on the agricultural sector, assessing the production efficiency of principal crops in India through DEA [6]. This work emphasizes the importance of resource optimization and productivity enhancement in the Indian agricultural landscape. Expanding on the application of DEA, Mariappan, Jenifer Christinal, et.al., (2021) evaluated the operational efficiency of public district hospitals in Tamil Nadu. This research underscores the relevance of DEA in the healthcare sector, providing actionable insights for improving hospital performance [7].

This paper differs entirely from all other previous works by investigating and examining the current performance of the Airline Industries in India individually, in terms of their efficiency for the period [2020 – 2023] using the Data Envelopment Analysis. Based on the study, it also classifies the Airline Industries into two categories as efficient and inefficient.

1.2. Mathematical Modelling

The DEA model developed by Charnes, Cooper, and Rhodes (Charnes et al., 1978) has the following general structure:

1.2.1. Fractional DEA Program

Let's compare N DMUs' efficiency and consider one of the DMUs as being m^{th}.DMU [Refer 2, 4 & 8].

The mathematical problem is,

Max $E_m = \frac{\sum_{j=1}^{J} v_{jm} y_{jm}}{\sum_{i=1}^{I} u_{im} x_{im}}$

Subject to the Constraints

$0 \leq \frac{\sum_{j=1}^{J} v_{jm} y_{jm}}{\sum_{i=1}^{I} u_{im} x_{im}} \leq 1, n = 1,2, \dots j$

$v_{jm}, u_{im} \geq 0; \;\; i = 1,2, \dots I; \;\; j = 1,2, \dots J$

Where,

E_m is the efficiency of the m^{th}DMU,

Y_{ij} is the j^{th} output of the m^{th} DMU,

V_{jm} is the weight of that output,

X_{im} is i^{th} the input of the m^{th} DMU,

U_{jm} is the weight of that input, and

Y_{jn} is the j^{th}output and X_{in} is the i^{th} input, respectively, of the n^{th} DMU, n = 1, 2, …, N.

Note that here n includes m. [2, 4 & 8]

1.3. Constant Returns to Scale Model

1.3.1. General Form of Output-Oriented CRS Model

The structure of the Output Maximization DEA [CRS] model can be viewed in the form of Fractional Programming problem as follows [Refer 2 & 8]:

Here the general model is constructed to maximize the efficiency of the q^{th} output variable:

$v_{jq} - j^{th}$ output value of the q^{th} DMU

$y_{jq} - j^{th}$ output variable of the q^{th} DMU

$u_{iq} - i^{th}$ input valueof the q^{th} DMU

$x_{iq} - i^{th}$ input valueof the q^{th} DMU

$E_q -$ Efficiency of the q^{th} DMU

$$Max\ \ E_q = \frac{\sum_{j=1}^{m} v_{jq} y_{jq}}{\sum_{i=1}^{s} u_{iq} x_{iq}}$$

Subject to the constraints

$$\frac{\sum_{j=1}^{m} v_{jq} y_{jq}}{\sum_{i=1}^{s} u_{iq} x_{iq}} \leq 1; q = 1,2, \dots, n$$

$$v_{jq}, y_{jq}, u_{iq}, x_{iq} \geq 0\ for\ all\ i = 1,2,..s; j = 1,2,..m, q = 1,2, \dots n$$

For the fractional model mentioned above, the equivalent linear programming problem is described as follows [2][4][8]:

$Max\ \ E_q = \sum_{j=1}^{m} v_{jq} y_{jq}$

Subject to the constraints

$\sum_{i=1}^{s} u_{iq} x_{iq} = 1$

$\sum_{j=1}^{m} v_{jq} y_{jq} - \sum_{i=1}^{s} u_{iq} x_{iq} \leq 0 ; \quad q = 1,2, \dots n$

$$v_{jq}, y_{jq}, u_{iq}, x_{iq} \geq 0\ for\ all\ i = 1,2,..s; j = 1,2,..m, q = 1,2, \dots n$$

1.4. Variable Returns to Scale Model

1.4.1. General Form of the Input-Oriented VRS Model

The Input-Oriented DEA envelopment program for considering variables return to scale referred by Banker et al. (1984) [1][4][8] is as follows:

$$Min\ \theta_m$$

Subject to the Constraints

$$Y\lambda \ \geq \ Y_m; \quad X\lambda \ \leq \ \theta X_m$$

$\sum_{n=1}^{N} \lambda_n = 1;` \lambda \geq 0; \quad \theta_m\ free\ variable$

2. Research Methodology

2.1. Data Collection

For this study, the required data of selected Airlines in India based on the availability of reputed data have been taken from the Official Website www.dgca.com for the financial years 2020–2023 [9].

When reviewing the literature on the usage of DEA, it is evident that many research have employed various combinations of inputs and outputs. In order to perform a study, the researcher considers two output variables and four input variables for the current study.

The variables under the study are listed below:

Key variables for Analysis

Input Variables	**Output Variables**
Number of Employees	Operating Revenue Per Kilometre
Number of Aircrafts	Operating Revenue per Employee
Operating Expense	

2.2. Problem Formulation

CCR Model-Fractional Programming Problem: (Air India 2020 -2021)

$$Max\ E_{Air\ India} = \frac{199923.30x_1 + 16100000x_2}{12880x_3 + 107x_4 + 198873.30x_5}$$

subject to constraints

$$\frac{199923.30x_1 + 16100000x_2}{12880x_3 + 107x_4 + 198873.30x_5} \leq 1$$

$$\frac{29179.57x_1 + 16100000x_2}{988x_3 + 18x_4 + 22283.43x_5} \leq 1$$

$$\frac{2738.58x_1 + 16100000x_2}{507x_3 + 11x_4 + 3241.62x_5} \leq 1$$

$$\frac{50880.72x_1 + 9500000x_2}{5365x_3 + 43x_4 + 47735.05x_5} \leq 1$$

$$\frac{211117.71x_1 + 14300000x_2}{14756x_3 + 108x_4 + 199085.39x_5} \leq 1$$

$$\frac{161399.09x_1 + 13100000x_2}{12362x_3 + 107x_4 + 136370.73x_5} \leq 1$$

$$\frac{28816.96x_1 + 11900000x_2}{2417x_3 + 19x_4 + 26704.43x_5} \leq 1$$

$$\frac{11136.46x_1 + 8700000x_2}{740x_3 + 8x_4 + 11154.11x_5} \leq 1$$

$$\frac{6588.42x_1 + 8700000x_2}{757x_3 + 6x_4 + 8405.43x_5} \leq 1$$

$$\frac{3191.13x_1 + 3700000x_2}{855x_3 + 3x_4 + 3904.73x_5} \leq 1$$

$$\frac{6913.73x_1 + 7300000x_2}{948x_3 + 9x_4 + 11154.68x_5} \leq 1$$

$$\frac{649.24x_1 + 2400000x_2}{269x_3 + x_4 + 1151.54x_5} \leq 1$$

$$\frac{539.63x_1 + 3100000x_2}{174x_3 + 2x_4 + 558.32x_5} \leq 1$$

$$x_1, x_2, x_3, x_4, x_5 \geq 0$$

CCR Model – Linear Programming Problem (Air India 2020-21)

$Max\ E_{Air\ India} = 199923.30x_1 + 16100000x_2$

subject to constraints,

$199923.30x_1 + 16100000x_2 - 12880x_3 - 107x_4 - 198873.30x_5 \leq 0$

$29179.57x_1 + 16100000x_2 - 988x_3 - 18x_4 - 22283.43x_5 \leq 0$

$2738.58x_1 + 16100000x_2 - 507x_3 - 11x_4 - 3241.62x_5 \leq 0$

$50880.72x_1 + 9500000x_2 - 5365x_3 - 43x_4 - 47735.05x_5 \leq 0$

$211117.71x_1 + 14300000x_2 - 14756x_3 - 108x_4 - 199085.39x_5 \leq 0$

$161399.09x_1 + 13100000x_2 - 12362x_3 - 107x_4 - 136370.73x_5 \leq 0$

$28816.96x_1 + 11900000x_2 - 2417x_3 - 19x_4 - 26704.43x_5 \leq 0$

$11136.46x_1 + 8700000x_2 - 740x_3 - 8x_4 - 11154.11x_5 \leq 0$

$6588.42x_1 + 8700000x_2 - 757x_3 - 6x_4 - 8405.43x_5 \leq 0$

$3191.13x_1 + 3700000x_2 - 855x_3 - 3x_4 - 3904.73x_5 \leq 0$

$6913.73x_1 + 7300000x_2 - 948x_3 - 9x_4 - 11154.68x_5 \leq 0$

$649.24x_1 + 2400000x_2 - 269x_3 - x_4 - 1151.54x_5 \leq 0$

$539.63x_1 + 3100000x_2 - 174x_3 + 2x_4 + 558.32x_5 \leq 0$

$x_1, x_2, x_3, x_4, x_5 \geq 0$

BCC Model Linear Programming Problem: (Air India 2020-2021)

$Min\ Z_{Air\ India} = x_{14} - x_{15}$

Subject to constraints

$199923.30\ x_1 + 29179.57x_2 + 2738.58x_3 + 50880.72x_4 + 211117.7x_5 + 161399.09x_6 + 28816.96x_7 + 11136.46x_8 + 6588.42x_9 + 3191.13x_{10} + 6913.73x_{11} + 649.24x_{12} + 539.63x_{13} \geq 199923.30$

$16100000x_1 + 16100000x_2 + 16100000x_3 + 9500000x_4 + 14300000x_5 + 13100000x_6 + 11900000x_7 + 8700000x_8 + 8700000x_9 + 3700000x_{10} + 7300000x_{11} + 2400000x_{12} + 3100000x_{13} \geq 16100000$

$12880x_1 + 988x_2 + 507x_3 + 5365x_4 + 14756x_5 + 12362x_6 + 2417x_7 + 740x_8 + 757x_9 + 855x_{10} + 948x_{11} + 269x_{12} + 174x_{13} - 12880x_{14} + 12880x_{15} \leq 0$

$107x_1 + 18x_2 + 11x_3 + 43x_4 + 108x_5 + 107x_6 + 19x_7 + 8x_8 + 6x_9 + 3x_{10} + 9x_{11} + 1x_{12} + 2x_{13} - 107x_{14} + 107x_{15} \leq 0$

$198873.30x_1 + 22283.43x_2 + 3241.62x_3 + 47735.05x_4 + 199085.39x_5 + 136370.73x_6 + 26704.43x_7 + 11154.11x_8 + 8405.43x_9 + 3904.73x_{10} + 11154.68x_{11} + 1151.54x_{12} + 558.32x_{13} - 198873.30x_{14} + 198873.30x_{15} \leq 0$

$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} = 1$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, x_{15} = 1$$

All Such 78 mathematical problems were generated and solved by using the software TORA.

3. Empirical Results

- Efficiency Results [CRS Model]
- Constant Return to Scale [CCR Model]

The DEA efficiency score under the CCR Model is communicated in Table 1 and is based on Technical Efficiency [Constant return to scale]. The Analysis report strongly communicates Airline Industries attained maximum efficiency score 1 for efficient based on CRS Model for the year 2020 – 2023. It is observed that there is a varying trend in their mean of Technical Efficiency of Airline Industries from 2020 to 2023, the score lies in the interval [0.635, 1.000].

Table 1 Constant Return to Scale – Efficiency Table

Name of the Airlines	2020-2021	2021-2022	2022-2023	Mean
Air India	0.989	0.975	1	0.988
Air India Express	1	1	1	1
Alliance Air	1	1	0.782	0.927333
Spice jet	0.814	0.879	0.903	0.865333
Jet Airways	1	1	1	1
Indigo	0.919	0.913	0.949	0.927
Go Air	0.89	0.936	0.948	0.924667
Jetlite	0.953	1	1	0.984333
Air Asia	0.982	0.724	0.781	0.829
Air Costa	0.846	1	1	0.948667
Vistara	0.617	0.595	0.693	0.635
Trujet	1	0.762	0.601	0.787667
Air Pegasus	1	0.578	1	0.859333

- Efficiency Results [VRS Model]
- Variable Return to Scale [BCC Model]

According to the BCC Model, Table 2 presents the DEA efficiency score that is determined by Technical Efficiency [Variable Return to Scale]. In BCC Model there is an increase in number of Airline Industries, which shows the consistency in their performance. The Analysis report clearly states that all Thirteen Airline Industries, six airlines attained maximum efficiency score 1 for the year 2020–2023.

Table 2 Variable Return to Scale – Efficiency Table

Name of the Airline	2020-2021	2021-2022	2022-2023	Mean
Air India	1	1	1	1
Air India Express	1	1	1	1
Alliance Air	1	1	1	1
Spice jet	0.859	0.926	0.936	0.907
Jet Airways	1	1	1	1
Indigo	1	1	1	1
Go Air	0.893	0.945	0.971	0.936333
Jetlite	0.973	1	1	0.991
Air Asia	1	0.724	0.785	0.836333
Air Costa	0.849	1	1	0.949667
Vistara	0.628	0.595	0.707	0.643333
Trujet	1	1	0.703	0.901
Air Pegasus	1	1	1	1

3.1. Overall Mean Efficiency

There are only two airline industries that are highly consistent, ranking first with an efficiency score of 1, out of the thirteen airline industries that were examined for this study. Table 3 shows the rankings for the airline industry.

3.1.1. Mean of Mean Efficiency

Table 3 Overall Mean Efficiency

Name of the Airlines	Mean – CRS	Mean - VRS	Ranking
Air India	0.988	1	0.994
Air India Express	1	1	1
Alliance Air	0.927333	1	0.963667
Spice jet	0.865333	0.907	0.886167
Jet Airways	1	1	1
Indigo	0.927	1	0.9635
Go Air	0.924667	0.936333	0.9305
Jetlite	0.984333	0.991	0.987667
Air Asia	0.829	0.836333	0.832667
Air Costa	0.948667	0.949667	0.949167

Vistara	0.635	0.643333	0.639167
Trujet	0.787667	0.901	0.844333
Air Pegasus	0.859333	1	0.929667

4. Conclusion

Among the thirteen Airlines only Air India Express and JET Airways attained the maximum efficiency score 1. The remaining Airlines should take the necessary measure to improve their performance.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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