A NDEA MODEL TO EVALUATE AIRPORT EFFICIENCY TO GENERATE NON-AVIATION REVENUES: A CASE STUDY OF GUARULHOS INTERNATIONAL AIRPORT

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ABSTRACT

This paper aims to evaluate the airport performance in generating financial gains provided by non-aviation revenues. Financial results have been highlighted in the structuring of an airport as a business, considering that the airport administrator is looking for alternatives to maximize its revenues and to improve the commercial function of the airport. Also, this theme is aligned to the fact that non-aviation revenues have a prominent place in the financial health of modern airports. The identified technical-scientific challenge is to estimate the airport efficiency using a 2-Step Network Data Envelopment Analysis model. As a result, the airport manager has a better understanding of the airport performance which allows faster and more consistent decisions. An example of these decisions is the readjustment of the layout of a terminal to promote consumption since the literature indicates a strong relationship between passenger experience at the terminal and the willingness-to-spend. To test the proposed method in this paper the model was be applied considering the Guarulhos International Airport. The model results indicated that maximum efficiency was achieved during periods when the airport had a higher proportion of international passenger movements. As an example, we can mention the quarters when Brazil hosted the FIFA World Cup in 2014.

Keywords: Non-aviation revenues, Airport, Efficiency, Performance, Privatization.

2. INTRODUCTION

Zenglein and Müller (2007) defend the hypothesis that the performance of an airport should be associated with the ability of its manager to leverage financial gains in each provided service. Thus, airport operators were forced to diversify its revenues sources (Figure 1). Currently, assessing an airport for its efficiency to generate revenues gains implies analyzing both aviation and non-aviation revenues. Aviation revenues is a result of every aeronautical operation such as airplane movement, cargo storage, and luggage handling. In contrast, non-aviation revenues are classified as all those coming from elements non-related to the end operation of an airport, such as parking lots, shops, restaurants, duty-free, and stores in general.



Figure 1 - Types of revenues. Source: IATA, 2019 and GRAHAM, 2008. Prepared by the author.

A notorious fact is that the taxation of aeronautical operations is also under less regulation than it was observed in the past. As consequence, the sector faces an increasing market power of low-cost carriers which correlates to the decreasing of aviation revenues (Yokomi, Wheat and Mizutani, 2017; Fuerst and Gross, 2018). Thereby, non-aviation revenues are positioning itself as potential sources to promote the sustainable financial development of airports (Torres et al., 2005; Wu and Chen, 2019).

The main objective of this paper is to evaluate the airport efficiency to generate non-aviation revenues considering a cost-revenue production cycle. Based on airport main infrastructure, traffic data and passenger experience at terminals, this paper intends to fill a literature gap of a method that indicates efficiency financial targets to the airport management body.

After this introduction, the paper is divided as follows:

- Literature Review
- NDEA Model Application
- Results
- Final Considerations

3. LITERATURE REVIEW

In this section we investigate academic and technical contribution published in high impact journals that brings fundamentals concepts for the development of this thesis. The relevant issues can be classified according to the following elements: (i) passenger satisfaction, (ii) privatization and airport financial performance, (iii) challenges on aviation revenues generation (iv) airport efficiency.

Before addressing these four elements, Table 1 reviews recent studies that demonstrates factors that can impact non-aviation revenues generation.

Table 1 - Overview of studies on airport financial performance

Authors	Methodology	Collected Data	Main Conclusions
Fasone, Kofler and Scuderi (2016)	Econometrics	60 observations (15 airports during the years of 2009 to 2012)	- Increasing number of Low-Cost-Companies has a negative impact on passenger expenditures - More passenger in the terminal discourages the willingness to spend - Total m² of commercial areas is not significant to explain the levels of non-aviation revenues
Yokomi, Wheat and Mizutani (2017)	Log-Log Regression	238 observations (26 airports during the years 1999 to 2008)	- Increasing number of Low-Cost-Companies has a negative impact on passenger expenditures - Low-Cost-Companies' passengers spend less time in terminal than non-Low-Cost-Companies
Fuerst and Gross (2018)	Log-Log Regression	75 Airports	- Share of international passengers and the size of the commercial area have significant positive effect on airport commercial performance
Nascimento et al. (2022)	Linear Regression	Quarter time series data from 2013 to 2019	- Higher satisfaction with products price has negative impact on nonaviation revenues. - New international terminal operation generates quarterly growth of 56.6 million R$ in non-aviation revenues. - International passengers have a positive impact on non-aviation revenues generation

As seen on Table 1, some papers indicate that the operation of non LCC has a positive influence on passengers' expenditures when comparing with the airports with more LCC (Fasone, Kofler and Scuderi, 2016, and Yokomi, Wheat and Mizutani, 2017).

Also, some studies indicated that the share of international passengers also contributes to non-aviation revenues generation (Fuerst and Gross, 2018, and Nascimento et al., 2022).

These results can be associated with the fact that LCC passengers and domestic passengers spend less time in the terminal than non LCC passenger and international passengers. Castillo-Manzano et al (2010) observed a positive correlation between the time spend at terminals and the propension to consume.

3.1. PASSENGER SATISFACTION

Airport service quality is not an issue that has just started to be addressed. In the 1970s, published papers like Brink and Madison (1975) started the discussion about the level of service based on how much time a passenger spends at a terminal. At the time, the authors discussed that for both travelers who seeks to minimize the processing time on the landside and travelers which travel experiences are enhanced by time spent at the terminal, the experience perception is affected by architectural objective attributes such as open space, ceiling heights, lighting, and terminal design features. Although, all these attributes are subjectively evaluated by passengers. Also, the paper addresses the role of the cost of using services provided at the terminal. These services include parking lot, restaurants, commercial facilities etc. The authors conclude that all these services may affect the overall impression of level of service.

Several new studies aiming to understand the relations between how well and how much time a passenger stays at a terminal and the effects of the dwell time on non-aviation revenues. Castillo-Manzano (2010), for example, suggests that the expenditure levels increase as the waiting time increases.

In these cases, it is essential to know how the passenger perceives the terminal environment (e.g., signaling quality, comfortable seats etc.) and how these

perceptions stimulate the willingness-to-spend. It is impossible to dissociate the concept of passenger experience to service quality, and new research indicates some terminal attributes which are positively evaluated by passengers.

Kiliç and Çadirci (2020) identified leisure activities, ambient conditions, and terminal facilities as three of the top 10 attributes that have positive impact on passenger experience. Also, the study found out that operational readiness is another way to promote a quality perception at terminal.

Nascimento et al. (2022) presented that the positive passenger evaluation of products price on commercial establishments has a negative impact on nonaviation revenues. The authors conclude that a better passenger satisfaction level with price should indicate lower prices for groceries and products. At the same time, it is possible that the price reduction is not accompanied by a growth in sales volume. This result demonstrates a possibility that the commercial environment inside the airport terminal has a different concept of supply and demand balance that should be investigated in future works.

3.2. PRIVATIZATION AND AIRPORT FINANCIAL PERFORMANCE

Airports are fundamental part of the air transport value chain since they correspond to the system's basic operational infrastructure. The competitive market and the novel business perspective for airports put a lot more pressure for profit margins gains (Merkert and Assaf, 2015; Cruz and Sarmento, 2017).

Thus, due to the increasing necessity to relieve the public sector of the financial burden of providing large investments, airport's privatization become a worldwide practice (Horonjeff et al. 2010). In these scenario, Cruz (2017) considers that airports are structures susceptible to the financial claw back strategy of governments, particularly those that are recovering from global and financial crisis.

With the privatization trend, the new airport managers have been facing a challenging scenario to be more financially self-sufficient and to improve the airport performance as an oriented business structure (Fasone et al., 2014; Fragoudaki and Giokas, 2020). This challenging scenario fosters the development of novel strategies to promote airport's profitability and financial performance such as the role of commercial infrastructures at passenger terminals (Zuidberg, 2017).

3.3. CHALLENGES ON NON-AVIATION REVENUES GENERATION

As seen on Kazda and Caves (2015) many airport administrations obtain higher revenues from non-aviation services than from aviation services. In Brazil, for example, the airports privatization has started in 2012. Since then, the concessionaires financial report indicates an average growth of almost 65% in the participation of non-aviation revenues on airport revenues distribution after the first year of privatization.

Since commercial areas become the main sources of non-aviation revenues, IATA (2014) recommends that passengers should have a set of high-quality services available while waiting at the terminal. In this case, it is essential that the commercial section of the terminal become an integrated part of the design planning. For the design of these spaces, IATA (2014) recommends a proportion between the area used by each commercial facility type and the whole terminal area (Table 2**Error! Reference source not found.**).

Table 2 - Estimated area by commercial facility types

Commercial Facility	Percent of whole terminal area
Duty-free	5% - 15%
Personal or business services	5% - 10%
Convenience retail	10% - 20%
Specialty retail	25% - 40%
Food and Beverage	40% - 60%

(Source: IATA, 2014)

3.4. AIRPORT EFFICIENCY

A wide variety of studies uses data envelopment analysis (DEA) to evidenciate the individual performance of airports (Graham et al., 2005; Lai et al., 2012; Merkert et al., 2012; Vogel and Graham, 2013, lo Storto, 2018, Fragoudaki and Giokas, 2020).

Although, the main airport performance studies rely mainly on operational efficiency analysis and there is a literature gap to evaluate financial performance, including airport´s performance considering non-aviation revenues generation (Psaraki-Kalouptsidi and Kalakou, 2011; Fernandes and Pacheco 2018; Olariaga and Moreno, 2019).

Lo Storto (2018) is one interesting publication that proposes a relationship between operational and revenues generation using a NDEA model. Since traditional DEA models was developed to evaluate the efficiency of a DMU as a black box, NDEA models consider the internal structure of the DMU's and become a common application in problems that requires a sequence of production stages. Lo Storto (2018) paper provides an insight of airport cost-revenue production cycle that allows a comprehensive view of how different types of resources (inputs) are sequentially utilized and transformed to produce necessary outputs in an airport. In this case, the author specified two stages for airports cost-revenue cycle, creating a relationship between operational costs with passenger and aircraft movement, and airport revenues (both, aviation and non-aviation revenues).

4. NDEA MODEL APPLICATION

Based on the literature presented on Item 3 (Maghbouli et al., 2014, Lo Storto, 2018 and Nascimento et. al, 2022), Table 3 indicates suggested variables to compose the NDEA model. Also, Table 3 presents the function of each variable on the NDEA model.

Table 3 - NDEA variable's description

Variable	Measurement	Explanation	Variable function Stage 1	Variable function Stage 2
Operational Costs	R$MM	Represents the main necessary operational costs to maintain the airport operation	Input	-
Personal Costs	R$MM	Represents the main necessary personal costs to maintain the airport operation	Input	-
Quality of commercial establishments	Number	Passenger satisfaction regarding the quality of commercial establishments	Output	Input
Quality of food & beverages establishments	Number	Passenger satisfaction regarding the quality of food & beverages establishments	Output	Input
Price of commercial establishments	Number	Passenger satisfaction regarding the price of commercial establishments	Output	Input
Price of food & beverages establishments	Number	Price of food & beverages establishments	Output	Input
Non-Aviation revenues	Value of non-aviation revenues x1000000	Non-Aviation revenue during a specific period	-	Output

The NDEA model can be mathematically expressed by the sequence of Equations (1). Note that the proposed mathematical formulation is a 2-Stage NDEA model that is a standard mathematical structure in the literature (Chen et al., 2009, Kao, 2009 and Meza et al., 2018).

$$E_0 = \max \sum_{r=1}^{s} u_r . y_{r0} \quad (1)$$

$$\sum_{i=1}^{m} v_i . x_{i0} = 1$$

$$\sum_{d=1}^{q} w_d . z_{dj} - \sum_{i=1}^{m} v_i . x_{ij} \leq 0, \; j = 1,2,\ldots,n.$$

$$\sum_{r=1}^{s} u_r . y_{rj} - \sum_{d=1}^{q} w_d . z_{dj} \leq 0, \; j = 1,2,\ldots,n.$$

$$u_r, v_i, w_d \geq \varepsilon, \; i = 1,2,\ldots,m; \; r = 1,2,\ldots,s; \; d = 1,2,\ldots,D.$$

Where:

ur = non-negative weights determined for the outputs of the second stage

vi = non-negative weights determined for the inputs of the first stage

wd = non-negative weights determined for the outputs of the first stage (that become the weights for the inputs of the second stage)

yr0 = outputs values of the analyzed DMU

xi0 = inputs values of the analyzed DMU

xij = inputs values of the first stage for all DMUs

zdj = outputs values of the first stage for all DMUs (that become the input for the second stage)

yrj = outputs values of the second stage for all DMUs

4.1. GUARULHOS INTERNATIONAL AIRPORT AND DATA COLLECTION

Guarulhos International Airport is the main Brazilian airport in passenger and airplanes movement. Considering the year 2019, it reported a movement of 43 million passengers.

In comparison to the whole Brazilian airport infrastructure during the years 2013 to 2018, the airport represents itself around 35% of the country's passenger movement. These results place Guarulhos International Airport as the second busiest airport in Latin America. Mexico City International Airport is the largest airport in the Latin American region as measured by passengers handled and by aircraft movements (Nascimento, 2022).

All data for the Guarulhos International Airport has been collected since 2013 until 2020. These data were acquired through the airport financial reports. Table 4 presents the collected data. The Guarulhos International Airport administration body deliver a quarter report about the airport performance. The Service_Costs and Personal_Costs columns represents the respective costs in Brazilian Reais (BRL) and need to be multiplied by 1000. Thus, the observation for the first quarter of 2013 indicates that the airport had 182.89 millions of Brazilian Reais of total cost to provide its services (both aviation and non-aviation services). Columns QUAL_EST, QUAL_FB, PRICE_EST and PRICE_FB indicate the average passenger satisfaction regarding the commercial and food & beverage services. In this case, 1 is equal to total dissatisfaction and 5 is equal to total satisfaction. Finally, the column NA_Revenue represents the amount of non-aviation revenues in the specific quarter. This value also needs to be multiplied by 1000.

Table 4 – Collected data

Obs	Airport	YEAR	QUARTER	Service_Costs	Personal_Costs	N_EST	PAX_DOM	PAX_INT	NA_REVENUE
1	**GRU**	2013	1	182898	42299	102	5379.0	3081.0	128.0
2	**GRU**	2013	2	235652	51600	102	5528.0	2938.0	157.4
3	**GRU**	2013	3	225039	46941	144	6027.0	3289.0	154.3
4	**GRU**	2013	4	217892	47880	144	6504.0	3216.0	186.0
5	**GRU**	2014	1	233932	50953	144	6505.0	3212.0	176.1
6	**GRU**	2014	2	265820	33529	144	6095.0	3246.0	241.6
7	**GRU**	2014	3	316512	19456	235	6493.0	3653.0	251.9
8	**GRU**	2014	4	278571	75789	227	6863.0	3470.0	245.6
9	**GRU**	2015	1	301482	40048	223	6491.0	3409.0	240.5
10	**GRU**	2015	2	499752	42460	234	5956.0	3231.0	239.6
11	**GRU**	2015	3	323297	31973	231	6488.0	3594.0	229.4
12	**GRU**	2015	4	119831	56564	238	6430.0	3386.0	228.6
13	**GRU**	2016	1	318175	38603	230	6200.8	3394.5	221.6
14	**GRU**	2016	2	317679	39440	223	5308.0	3239.0	227.4
15	**GRU**	2016	3	326850	42105	229	5841.0	3506.0	234.7
16	**GRU**	2016	4	321442	41084	241	5781.4	3357.2	227.6
17	**GRU**	2017	1	317664	37805	260	5820.7	3454.5	213.4
18	**GRU**	2017	2	314055	34049	259	5372.9	3297.2	223.5
19	**GRU**	2017	3	323063	34624	268	6193.6	3678.9	241.4
20	**GRU**	2017	4	318198	35202	292	6398.8	3549.3	242.5
21	**GRU**	2018	1	335237	35488	301	6485.1	3728.0	232.2
22	**GRU**	2018	2	332804	27480	264	6456.7	3524.7	243.9
23	**GRU**	2018	3	334033	30394	313	7106.6	3899.9	257.2
24	**GRU**	2018	4	338481	41176	323	7294.0	3735.3	257.0
25	**GRU**	2019	1	353173	25636	333	7105.8	3823.9	259.9
26	**GRU**	2019	2	353377	25589	310	6085.8	3593.4	258.4
27	**GRU**	2019	3	366730	32249	310	7198.6	3805.8	271.2
28	**GRU**	2019	4	366586	39826	350	7848.2	3540.5	275.0

4.2. NDEA MODEL

The NDEA application for the Guarulhos International Airport resulted in the following efficiency levels (Table 5).

Table 5 – NDEA results

YEAR	QUARTER	Global_Efficiency(%)
2013	1	0.47
2013	2	0.45
2013	3	0.42
2013	4	0.52
2014	1	0.44
2014	2	0.83
2014	3	1.00
2014	4	0.54
2015	1	0.66
2015	2	0.51
2015	3	0.72
2015	4	0.81
2016	1	0.65
2016	2	0.66
2016	3	0.65
2016	4	0.63
2017	1	0.63
2017	2	0.68
2017	3	0.73
2017	4	0.74
2018	1	0.68
2018	2	0.79
2018	3	0.80
2018	4	0.71
2019	1	0.83
2019	2	0.83
2019	3	0.78
2019	4	0.73

The NDEA model was implemented through the DJL package in the R language. The DJL is a complete library that implements various decision support tools related to the Econometrics and Thecnometrics (CRAN, 2023).

The efficiency results presented on Table 5 indicate that the Guarulhos International Airport reached the highest efficiency level in the third quarter of 2014. Coincidently, this is the quarter that Brazil held the FIFA 2014 World Cup.

In this period, the country received a significant number of international passengers. The efficiency results can be in accordance with recent studies which indicate that international passengers are more likely to spend at the commercial areas of airport terminals (Castillo-Manzano, Valpuesta, and Braza, 2018; Fuerst and Gross, 2018).

Also, since the first quarter of 2014 the airport started a new terminal operation. Known as Terminal 3, this new infrastructure is totally dedicated to international flights.

5. FINAL CONSIDERATIONS

This article presented an NDEA modeling to assess the efficiency of an airport in generating non-aviation revenues. The proposed model is based on a 2-step production cycle in which operating costs impact passenger perception of quality, which in turn affects the airport's ability to generate revenues.

As an application, the context of Guarulhos International Airport was chosen, the largest airport in terms of aircraft and passenger movement in Brazil and the second largest in Latin America. The data was compiled in conjunction with the airport administration from their quarterly reports to shareholders. Data on costs, revenues, and movement were obtained. In addition to the data collected from the airport, passenger perception of quality was obtained through the Quality Survey developed by ANAC.

The application results indicated that Guarulhos International Airport achieved a higher efficiency index during periods of specific passenger movement, namely the 2014 FIFA World Cup in Brazil. Interestingly, this was a period of high volume of international passengers. This result was aligned with specific literature pointing to a trend of increased consumption from passengers on long-distance flights, especially continental ones.

As future work, the application of Machine Learning tools is suggested to

observe other variables that may affect airport efficiency, including seasonality and specific passenger profiles (e.g. gender, age, and travel frequency).

It is also understood that this work is limited to its application context. Results may vary depending on the chosen airport's context and specific events to which the airport's location is subject.

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