Identification and Analysis of Efficiency Drivers: Evidences from Brazilian Airports

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Abstract

The aim of this study is to identify and analyze efficiency drivers in international airports. To this end, a research was designed in three parts. The first part is an exploratory study of the literature, which supports a proposal for a representative structure of the typical operations of an international airport and allows the identification of 27 efficiency drivers implemented at airports in order to obtain the study objectives. The second part is a quantitative analysis of 33 Brazilian international airports, which allows them to be classified into different levels of efficiency. For that, two analysis techniques were used: a Two-Stage Data Envelopment Analysis (Two-Stage DEA), which allowed the comparison of efficiency levels between airports; and the Malmquist Index (mi), which allows comparing levels of comparison over time. A third part of the research was a multiple case study that investigated the degree of implementation of the 27 practices at three airports selected for different levels of efficiency. Evidence was found that confirms 16 out of 27 efficiency drivers.

Keywords
Airport operations, Efficiency drivers, Data Envelopment Analysis, Malmquist Index.

1. Introduction
Airports are structures for boarding, disembarking and supporting air operations immersed in complex and dynamic environments where political, economic and social interests converge (ANAC, 2016).

According to Assaf and Gillen (2012), airports are important strategic assets for a country, airports facilitate the approximate territorial integration of distant communities and promote the commercial, business and tourism development of the surrounding regions. Perelman and Serebrisky (2012) also highlighted that airports exercise the role of distribution platforms and distribution of loads for supply chains of local and multinational companies.

Globally, an aviation industry employs approximately 10 million people, 35% of the total value of imported and exported goods is transported by air, and in 2015, more than 3.5 billion passengers were transported by this mode (ATAG, 2016). However, airports are considered internal and external factors that influence the scenarios in which they operate and are constantly changing, requiring increasingly robust and flexible management models (Fernandes et al., 2015).

Despite the recent drop in economic activity in Brazil, the demand for air transport has grown significantly over the past decade. In the early 2000s, policies to facilitate access to credit and the entry of low-cost operators opened the market for low-income consumers, and the years 2010 were marked by international events (World Youth Day (2013), World Cup (2014) and Olympics (2016) - which tested the capacity limits of the national air infrastructure.This demand has exerted enormous pressure on the country's air structure, which has not been able to keep up with its growth, generating overcrowded terminals and constant flight delays (Wanke, 2012)

The increasing pressure on airport infrastructure has led the market to focus its efforts on the improvement of efficiency and in the use of installed capacity. Zhang et al. (2012) warn that the increase in air demand causes two immediate effects: pressure on the infrastructure to increase installed capacity and urgency in the efficient use of available resources in order to ease the pressure in the short term. However, investing in capacity is not a trivial decision, especially for airports in large urban centers where there is little or no space for new facilities and runways. Therefore, increasing efficiency becomes a crucial alternative to relieve pressure and reduce air strangulation.

However, the application of operations management practices can increase the operational efficiency of an organization, reducing the distance between the current level of performance and the maximum performance that can be achieved (Schmenner and Swink, 1998). Thus, the application of these practices in airports can enable a better use of available resources and installed capacity, reducing the need for investments to increase performance.

Although efficiency is a topic widely explored in airport management, there is still a need for studies based on the Brazilian reality (Fernandes and Pacheco, 2002; Yoshimoto et al., 2018). The present study aims to identify and analyze efficiency drivers on Brazilian international airports.

This article is organized into five sessions including this introduction. Section 2 presents a literature review followed by the research methods in section 3. The quantitative and qualitative results are presented in section 4. Conclusions are presented in section 5 and section 6 presents the acknowledgements.

2. Literature review

This section presents a discussion of the first stage of the research, which aimed to identify efficiency drivers implemented at airports and identified in empirical studies in scientific literature. First, section 2.1. presents two taxonomies that were proposed to understand the main processes of airport operations and to serve as a reference for the search of airport efficiency drivers. Section 2.2 shows the efficiency drivers identified and a proposal of its categorization.

2.1. Airside and Landside taxonomies

A search for operations management practices implemented at airports was conducted based on typical operations at international airports. Although there are academic studies that describe airport operations, as a rule, studies presented as operations in general (Fayez et al., 2008) or address topics and practices of use such as, for example, risk management (Wilke et al., 2014), recovery operations (Wu, 2008) and boarding terminal processes (Guizzi et al., 2009). No academic studies were found that relate or set of operations satisfactorily to the objectives of this research. Therefore, we choose to create a framework capable of using the main operations existing at international airports in a comprehensive manner, in order to provide a reference for the search of efficiency drivers

The framework design started with the Total Airport Management (TAM) manual prepared by Günther et al. (2006), which relate several airport operations based on EUROCONTROL and DLR guidelines. Other sources, such as academic articles, books and official pages of airports, regulators and similar entities were researched identify other operations and complementing the TAM structure. Each new source included were validated and adjusted in order to create a common understanding of all the references used.

Günther et al. (2006) and Schmidt (2017) adopted the division of airport operations in two perspectives: Airside, which performs operations such as operations centered on aircraft and in the processes supporting the air operation as a whole; and Landside, which groups together as operations centered on passengers and on support processes related to departure and arrival terminals. Landside operations have been identified in Günther et al. (2006) and ACRP (2010) and complemented by others described in Babu et al. (2006), De Barros et al. (2017), Kalakou et al. (2015), ACI (2016), Airsight (2016), Changi Airport (2016), Kotopouleas and Nokolopoulou (2016) and Miami Airport (2016). Figure 1 shows the operations organized in five categories applied by the authors of this study: Terminal, Infrastructure, Information and Landside Security. There are already seven groups of Airside operations shown in Figure 2 following categories displayed in the sources surveyed. At IATA (2016) there were five groups of five groups: Turnaround, Under the Wing, Aircraft Protection and Airside Safety. The Control Tower group was identified in Hu and Di Paolo (2009), Airsight (2016) and Miami Airport (2016); and the group Passengers in Kazda and Caves (2010).

The proposed model represents the consensus granted by the research group and reflects as resources common to all the sources consulted in relation to the operations and the categories displayed, organizing them in the two taxonomies applied below.

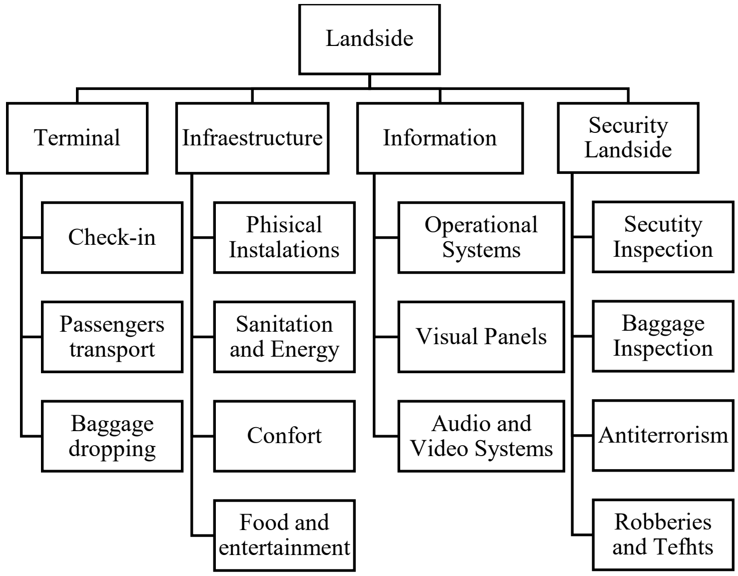

Figure 1. Landside taxonomy

Figure 1 presents operations focused on processes that involve the reception of passengers and cargo until they enter the planes, divided into "Terminal", related to check-in, reception of luggage and transportation of passengers, "Infrastructure", which involves the physical facilities of the airport, "Information", related to the processing and dissemination of information to passengers, airlines and other stakeholders. Finally, "Security Lanside", is related to the prevention of robberies, theft, accidents and terrorism. Figure 2 presents the Airside taxonomy.

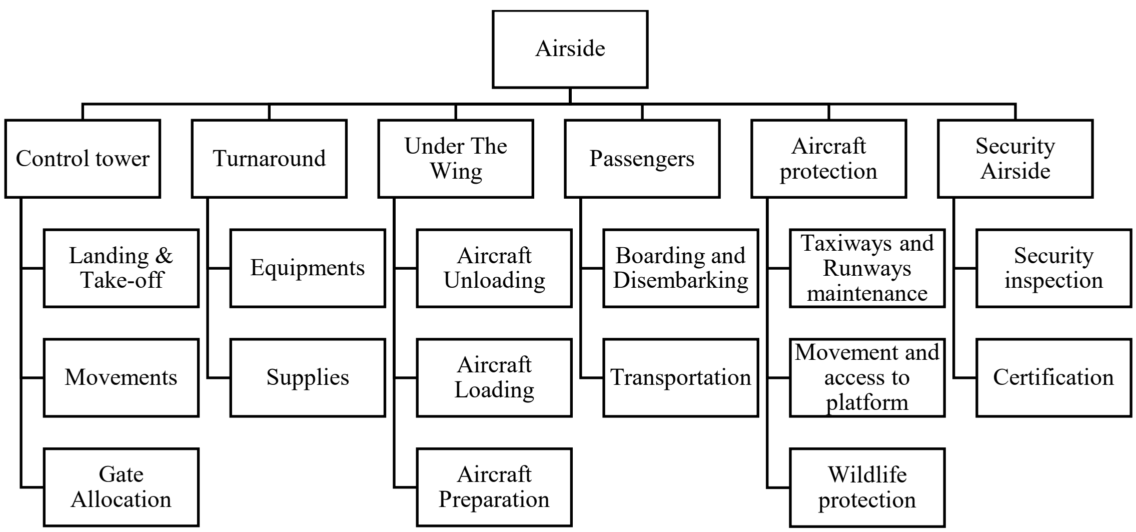

Figure 2. Airside taxonomy

Figure 2 shows the division of Airside operations into six categories. The first is the "Control tower", which involves the control of approach, landing and takeoff of the aircraft as well their movements on the ground and the allocation to the gates. "Turnaround" is related to the work of all equipment and supplies on the ground from landing to aircraft takeoff. "Under the wing" contains the job of unloading and loading supplies onto aircraft in addition to preparing for flight. "Passengers" involves boarding and disembarking the aircraft in addition to transporting passengers on the aprons (when occurs). "Aircraft protection" is related to all the protection work, such as the maintenance and cleaning of the runways, the access control to the platforms and the monitoring of wildlife that can cause accidents, either on the runway or in the air.

2.2. Efficiency drivers

Based on the taxonomies included in the previous section 27 efficiency drivers were identified in the scientific literature. Table 1 presents the efficiency drivers selected for this study, organized into the six groups. Within each group, the practices were listed in alphabetical order, with no meaning of relative importance or priority to each other.

Table 1. Efficiency drivers

Category	*Practices*	*Publications*
Airport Management	Use of Key Performance Indicators (KPI)	Eshtaiwi et al. (2017)
	Integrated decision support systems	Zografos and Madas (2006)
	Optimization of resources allocation	Mirkovic et al. (2016)
	Total Quality Management (TQM) principles	Francis et al. (2002)
	Just in Time (JIT) principles	Sui Pheng et al. (2011)
	Knowledge management programs	Gamo-Sanchez and Cegarra-Navarro (2015)
	Benchmarking	Chen (2002)
	Passenger satisfaction surveys	Bogicevic et al. (2013)
	Demand management practices	Gillen et al. (2016)
Turnaround	Boarding infrastructure sharing	Wu and Lee (2014)
	Optimization models for towing equip. allocation	Du et al. (2014)
	Integrated cargo management system	Chung et al. (2015)
	Baggage tracking by RFID	Zane and Reyes (2010)
Control tower	Optimization of runways allocation to aircrafts	Lieder and Stolletz (2016)
	Minimization of gates blockage	Castaing et al. (2016)
	Decision models for aircraft ground movement	Behrends and Usher (2016)
Check-in/Boarding	Queue management strategies	Kiyildi and Karasahin (2008)
	Automated check-in equipments	Lu et al. (2009)
	Signaling and information systems	De Barros et al. (2007)
	Passengers boarding optimization	Jaehn and Neumann (2015)
Safety operations	Surface Safety Management Systems	Wilke et al. (2014)
	Risk-based inspection baggage selection	Da Cunha et al. (2017)
	Aircraft risk mitigation methods	Ning and Chen (2014)
External factors	Location	Fernandes and Pacheco
	Hub	Sarkis (2000)
	Airport layout	Simić and Babić (2015)
	Integration with logistical system	Wessel (2019)

Table 1 shows six categories of efficiency drivers: “Airport Management” related to organizational management practices such as benchmarking, Total Quality Management (TQM) and Just in time (JIT) principles or the use of Key Performance Indicators (KPIs), “ Turnaround ”, with the use of RFID and integrated cargo management systems,“ Control tower ”, which involves, for example, the optimization of runways allocation to aircrafts,“ Check-in / Boarding ”, which involves queue management strategies and others,“ Safety operations ”with Risk-based inspection baggage selection and Aircraft risk mitigation methods and the“ External factors ”like the location of the airport or the integration with logistical system.

3. Materials and methods

To achieve the research objective presented in the first section, this research was structured in two stages, the first being quantitative and the second qualitative. The first stage sought to analyze the operational efficiency of Brazilian international airports, using secondary data from the ACI ANNUAL World Airport Traffic Report and primary data collected at the sample participating airports.

From these data sources, the Data Envelopment Analysis (DEA) technique was used to assess efficiency. It is a non-parametric boundary estimation technique that assesses the relative efficiency of decision-making units (or DMU’s) that use multiple resources (inputs) and generate multiple products (outputs).

In this particular study, for the definition of the inputs and outputs used in the technique, the model proposed by Wanke (2013) was adopted, who also carried out a study on airports, reaching very consistent results. The approach used by the author considers a two-stage model, where the first assesses the efficiency of the airport's infrastructure and the second the efficiency of cargo and passenger consolidation as shown in the following figure 3:

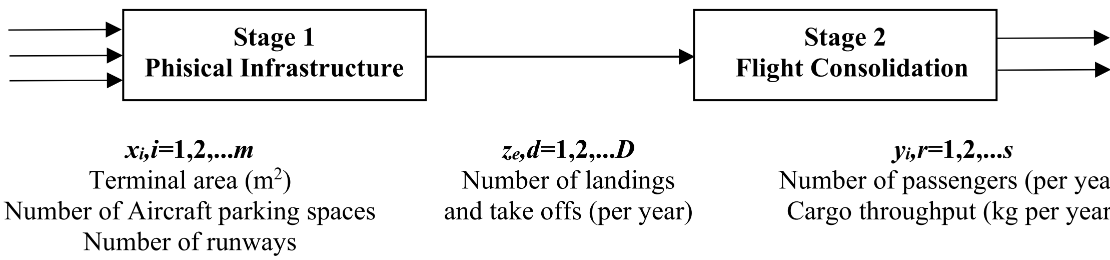

Figure 3. Stages of airport efficiency by Wanke (2013)

In the first stage, concerning the use of physical infrastructure, the terminal area, the number of spaces for aircraft and the number of runways are inputs and the number of landings and takeoffs are outputs. In the second stage, related to the consolidation of landings and takeoffs per year, the number of landings and takeoffs are the inputs and the number of passengers and cargo transit are the outputs. The justification for the inclusion of these variables is the positive correlation presented between inputs and outputs (Wang and Hong, 2011).

In this work, to expand the efficiency analysis, it was decided to analyze the performance of DMUs (Airports) in different periods of time. However, it is not reasonable to just compare the absolute results numerically because the efficiency shown by the DEA in each DMU is in relation to all the others, and, in two different moments of time, it is likely that the values of the inputs and outputs indicators will change in all decision units.

Thus, it is necessary to make use of some tool that makes it possible to compare these units at different times in time. Within the literature, the most consolidated form is through the Malmquist Index (MI). This index was initially developed by Caves et al. (1982) and, according to them, allows comparisons to be made under very general circumstances, as long as the data has inputs, outputs and comparability, in addition to adapting to arbitrary returns to scale. Therefore, it is possible to use the IM to compare the same DMU at different times.

After the quantitative stage and based on the airport efficiency ranking obtained with the DEA technique, it was possible to start the qualitative stage, which allows the identification of efficiency drivers in the airports selected for the study.

For that, multiple and exploratory case studies were carried out, carried out at three airports, with data collection through interviews with managers and on-site observations. The selection of cases was made based on the results of the quantitative stage and on their availability to receive researchers for the application of the data collection instrument. The selected airports were Guarulhos (GRU), Viracopos (VCP) and Manaus (MAO). The next section presents the results obtained in the two stages of the study

4. Results and discussion

The Data Envelopment Analysis technique, considering the model used in this work, allows the calculation of three types of efficiency, use of infrastructure, flight consolidation and global (which is the product of the first two). The years selected for the analysis were 2014 and 2015 because in this period a decrease in the Brazilian economy occurred, going from stagnation (2014) to recession (2015). This choice provides another dimension for the analysis, that is, how the efficiency behaves when economic performance regresses.

The values obtained in the quantitative phase of the research are summarized in Table 2.

Table 2. DEA and MI results

Airport	*Two-Stage* DEA 2014 Infraestructure (%)	*Two-Stage* DEA 2014 Consolidation (%)	*Two-Stage* DEA 2014 Global (%)	*Two-Stage* DEA 2015 Infraestructure (%)	*Two-Stage* DEA 2015 Consolidation (%)	*Two-Stage* DEA 2015 Global (%)	Malmquist Index Infraestructure 14 para 15	Malmquist Index Consolidation 14 para 15
Belém	81,10	60,89	47,48	77,98	59,87	28,43	0,94	1,00
Belo Horizonte	100,00	77,73	77,73	100,00	77,04	59,88	1,03	1,01
Boa Vista	9,97	55,77	7,75	13,89	35,09	2,72	1,37	0,70
Brasília	100,00	75,82	75,82	100,00	78,94	59,85	1,00	1,06
Campinas	100,00	82,98	82,98	100,00	74,74	62,02	0,97	0,92
Campo Grande	19,69	55,86	10,33	18,49	56,80	5,87	0,92	1,03
Campos	100,00	6,42	6,42	100,00	7,45	0,48	1,00	1,18
Corumbá	5,28	100,00	5,08	5,08	100,00	5,08	0,96	1,02
Cruzeiro do Sul	7,86	13,47	0,91	6,73	16,40	0,15	0,86	1,19
Cuiabá	92,61	41,01	36,54	89,11	41,80	15,28	0,96	1,04
Curitiba	100,00	76,41	76,41	100,00	75,58	57,75	0,97	1,01
Florianópolis	65,61	57,71	34,73	60,18	61,28	21,28	0,93	1,08
Fortaleza	68,81	78,47	50,46	64,31	83,29	42,03	0,90	1,08
Foz do Iguaçu	34,10	82,05	31,16	37,98	82,27	25,64	1,06	1,03
Guarulhos	100,00	100,00	100,00	100,00	100,00	100,00	1,00	1,00
João Pessoa	23,41	86,30	23,05	26,71	84,79	19,54	1,10	1,02
Macapá	15,21	47,07	5,50	11,69	54,76	3,01	0,77	1,15
Maceió	25,40	76,94	19,40	25,21	82,44	15,99	0,95	1,09
Manaus	48,33	100,00	41,37	41,37	100,00	41,37	0,88	1,00
Navegantes	100,00	53,82	53,82	100,00	55,86	30,06	1,00	1,06
Parnaíba	5,77	18,45	0,91	4,91	33,07	0,30	0,82	1,26
Pelotas	5,13	44,08	2,04	4,63	51,30	1,05	0,86	0,99
Petrolina	11,98	67,00	6,34	9,47	83,94	5,33	0,76	1,19
Porto Alegre	100,00	70,43	70,43	100,00	72,04	50,74	1,00	1,04
Porto Velho	21,74	45,44	8,88	19,55	51,54	4,58	0,92	1,15
Recife	100,00	76,49	76,49	100,00	73,23	56,01	0,96	0,97
Rio de Janeiro	64,88	94,66	59,09	62,42	96,56	57,05	0,95	1,04
Salvador	81,38	68,99	52,65	76,32	73,41	38,65	0,91	1,08
Santarém	18,37	34,06	5,96	17,51	35,64	2,13	0,92	1,06
São Luis	19,59	65,34	12,05	18,44	63,97	7,71	0,91	0,99
SJ dos Campos	54,87	2,99	1,49	49,74	2,04	0,03	0,87	0,69
Tabatinga	6,89	18,87	0,97	5,16	27,15	0,26	0,74	1,25
Vitória	100,00	45,93	45,93	100,00	46,78	21,49	1,00	1,04

Table 2 shows that 100% efficiency values calculated by the DEA model indicates an airport to be at the efficiency frontier in relation to the analyzed group. This means that there is no other airport in this group capable of presenting a superior performance that is located at the frontier. In relation to Physical Infrastructure (Stage 1), there are 10 airports on the efficiency frontier, in the two years analyzed. They are: Belo Horizonte, Brasília, Campinas, Campos, Curitiba, Guarulhos, Navegantes, Porto Alegre, Recife and Vitória. Regarding Flight Consolidation (Stage 2), there are only three airports 100% efficient in the two years analyzed: Corumbá, Guarulhos and Manaus. Only Guarulhos airport has the maximum value for Global Efficiency in two years, occupying the position of the most efficient international airport in Brazil in the years 2014 and 2015. There is no other extreme at the airports of Cruzeiro do Sul, Parnaíba and Tabatinga, which had Global Efficiency below 1% in both years.

The Malmquist Index indicates an evolution of efficiency between two periods, in the case of 2014 to 2015. Values equal to 1 stability, values less than 1 denote a reduction in efficiency and values greater than 1 pointed to an increase in efficiency. Only four airports had increased efficiency in Physical Infrastructure from 2014 to 2015 (Belo Horizonte, Boa Vista, Foz do Iguaçu and João Pessoa). Regarding Flight Consolidation, most airports have increased efficiency, with only six reductions (Boa Vista, Campinas, Pelotas, Recife, São Luís and São José dos Campos). This is a very interesting result when considering the economic recession in the country, because its much harder to improve the use of infrastructure when demand (correlated with economic activity) are reduced, however, most the airports adapted its capacity to improve cargo and passengers processing, consequently, increasing its flight consolidation efficiency. The results presented in Table 2 supported the choice of the airport to be subjects in the next stage of the research. It was selected one airport that was considered efficient only in the use of physical infrastructure, one that was efficient only in flight consolidation and one efficient globally (all of them in both years). In addition, all the airports that was eligible within this criterion was contacted and three of them agreed to participate in the case studies: Guarulhos (GRU), Viracopos (VCP) and Manaus (MAO). Composed in this way, the sample is sufficient to confirm or counter all the phenomena under investigation and for this reason it was considered sufficient for the purposes of this research. Thus, by comparing these airports:

- GRU x VCP: Maximizes similarities in Physical infrastructure and differences in Flight Consolidation;
- GRU x MAO: Maximizes similarities in Flight consolidation and differences in Physical infrastructure.

4.1 São Paulo-Guarulhos International Airport (GRU)

The São Paulo-Guarulhos International Airport, identified by IATA using the GRU code, is located in the city of Guarulhos in the state of São Paulo. Founded in 1985 and granted to the private sector in 2012, it is managed by the Concessionaire of Aeroporto Internacional de Guarulhos S.A., under the brand GRU Airport. The airport contains three passenger terminals and a cargo terminal that, served by two highways and a line of metropolitan trains, operate domestic and international flights 24 hours a day, (GRU Airport, 2019).

The Guarulhos airport land has a total area of 13,774,086 m^2 where two landing and takeoff runways positioned in parallel connect the aircraft to 108 operational spaces. In 2014, the airport operated 304,559 landings and takeoffs, through which 39,765,714 passengers and 554,663 tons of cargo were transported; and in 2015, 295,030 landings and takeoffs were operated, transporting 39,213,865 passengers and 526,012 tons of cargo (data extracted from the ACI bases).

Among the 33 Brazilian international airports analyzed in this research, Guarulhos is the only one with 100% efficiency in the two stages in the two years investigated, positioning itself on the two efficiency frontiers and standing out as the main reference for the other airports. The study at Guarulhos airport was carried out on November 30, 2019, when two researchers from the group were received by the Safety and Operations Coordinator and by a representative from the Institutional Relations area for an interview and guided technical visit. Of the 27 efficiency drivers 20 were identified in full, five partially and two were not identified, either because the airport does not implement the practice or because respondents were unable to report on its implementation.

4.2 Viracopos-Campinas International Airport (VCP)

Viracopos-Campinas international airport, identified by IATA by the VCP code, is located in the city of Campinas in the state of São Paulo. With direct access along the 66 km of Rodovia Santos Dumont (SP 75), passengers can arrive and leave using their own vehicle or one of the more than 10 bus lines serving the airport. Founded in 1930 and approved for international flights in 1960, since 2012 the airport has been managed by the Concessionaire Aeroportos Brasil Viracopos, composed of Triunfo Participações e Investimentos, UTC Participações, Egis Airport Operation and Infraero. Currently, the airport contains two passenger terminals and a cargo terminal that operate domestic and international flights 24 hours a day (Viracopos, 2019). Occupying an airport site with a total area of 8,348,943 m^2, Campinas has a runway for takeoffs and landings and 71 operational spaces. In 2014, 131,531 landings and takeoffs were carried out, in which 9,846,853 passengers and 223,280 tons of cargo were transported. In the following year, 2015, there were 127,395 landings and takeoffs, transporting 10,324,658 passengers and 182,967 tons of cargo (data extracted from the ACI bases).

Positioned in 2nd place in the ranking determined by Global Efficiency in 2015, just below Guarulhos with 100% efficiency in the two years in the first stage of the Two-Stage DEA (Physical Infrastructure) and 82.98% in 2014 and 74.74% in 2015 in the second stage (Flight Consolidation), the airport is one of the 10 that delimit the frontier of efficiency in Physical Infrastructure, thus being an important reference for other airports in this dimension. Its Malmquist Indexes indicate stability for stage 1 and efficiency reduction for stage 2. The study at Viracopos-Campinas airport was carried out on August 24 and 31, 2017, when three researchers from the group were received by the Planning Director. Of the 27 efficiency drivers investigated, 19 were fully identified, four were partially identified and four were not identified, either because the airport does not implement the practice or because the respondent was unable to report on its implementation.

4.3. Manaus International Airport (MAO)

Inaugurated in 1976 and modernized in 2011, the international airport of Manaus, identified by IATA through the MAO code, is considered one of the main integration portals of the Amazon region with Brazil and the world. Located 15 km from the center of Manaus, in the State of Amazonas, the airport can be accessed by the BR 174 highway and by streets in the adjacent neighborhoods, where common and executive buses travel. Administered by Infraero, the airport complex contains two passenger terminals and a cargo terminal that operate domestic and international flights 24 hours a day (Infraero, 2019). Manaus airport is located on a land with a total area of 14,050,529 m^2 where a landing and take-off runway is connected to the 39 operational spaces through two access loops. In 2014, the airport operated 54,862 landings and takeoffs, through which 3,555,835 passengers and 142,532 tons of cargo were transported; and in 2015, 48,433 landings and take-offs were carried out, transporting 3,409,725 passengers and 112,331 tons of cargo (data extracted from the ACI bases).

Positioned in 10th place in the ranking determined by Global Efficiency in 2015, Manaus airport had an efficiency of 48.33% in 2014 and 41.37% in 2015 in the first stage (Physical Infrastructure) and 100% in both years in the second stage (Flight Consolidation), Manaus showed stability bias in the Malmquist Index for stage 2 and efficiency reduction bias for stage 1. Among the 33 Brazilian international airports analyzed in this research, Manaus is one of three that delimit the efficiency frontier in Flight Consolidation, standing out as an important reference at this stage for other airports. The study in Manaus was carried out on December 12, 2019, when one of the authors of this article was received by four airport employees for interviews and guided technical visit - Operational Management Manager, Passenger Terminal Representative, Logistics Manager of Cargo and Coordinator of the Call Center of the Cargo Terminal. Of the 27 efficiency drivers, 11 were identified in full, 10 partially and six were not identified, either because the airport does not implement the practice or because respondents were unable to report on its implementation.

Table 3 consolidates the presence of efficiency drivers in each investigated airport, according to the symbology: "●" for drivers fully identified, "⭘" for drivers partially identified, and "⃠" for drivers whose was not possible to identify.

Table 3. Efficiency drivers of GRU, VCP and MAO

Efficiency drivers	Guarulhos (GRU)	Campinas (VCP)	Manaus (MAO)
Use of Key Performance Indicators (KPI)	●	●	●
Integrated decision support systems	●	●	●
Optimization of resources allocation	●	●	●
Total Quality Management (TQM) principles	⭘	●	●
Just in Time (JIT) principles	●	⃠	●
Knowledge management programs	⭘	●	⭘
Benchmarking	●	●	⭘
Passenger satisfaction surveys	●	●	●
Demand management practices	●	●	⭘
Boarding infrastructure sharing	●	●	●
Optimization models for towing equip. allocation	●	●	⭘
Integrated cargo management system	●	●	●
Baggage tracking by RFID	⭘	⃠	⃠
Optimization of runways allocation to aircrafts	●	⭘	⃠
Minimization of gates blockage	⭘	⭘	⭘
Decision models for aircraft ground movement	●	⭘	⭘
Queue management strategies	⃠	●	⃠
Automated check-in equipments	⭘	●	⭘
Signaling and information systems	●	●	●
Passengers boarding optimization	⃠	⃠	⃠
Risk-based inspection baggage selection	●	⃠	⭘
Surface Safety Management Systems	●	●	●
Aircraft risk mitigation methods	●	●	●
Location	●	⭘	⃠
Hub	●	●	⃠
Airport layout	●	●	⭘
Integration with logistical system	●	●	⭘

The degree of efficiency drivers presence ("fully identified" and "partially identified") was used to assign different levels of intensity to the its confirmation. Whitin the results it is possible to highlight those that was fully identified in the three airports (9 of 27), and so can be associated to both physical infrastructure and flight consolidation efficiencies: Use of Key Performance Indicators (KPI), Integrated decision support systems, Optimization of resources allocation, Passenger satisfaction surveys, Boarding infrastructure sharing, Integrated cargo management system, Signaling and information systems, Surface Safety Management Systems and Aircraft risk mitigation methods.

In addition, Benchmarking, Demand management practices, Optimization models for towing resources allocation, Hub, Airport layout and Integration with logistical system (6 of 27) seems to be associated to infrastructure efficiency because they were fully identified in GRU and VCP, but not in MAO. The only driver fully identified in GRU and MAO, but not in VPC, was the use of Just in Time (JIT) principles, so it seems to be associated to flight consolidation efficiency.

In total, 16 of the 27 efficiency drivers investigated were identified as associated to at least one efficiency dimension (infrastructure and/or flight consolidation). When comparing the results to Table 1 it is possible to verify that seven of them are from "Airport management" category, three from "Turnaround", 1 from "Check-in/Boarding", 2 from "Safety operations" and 3 from external factors.

5. Conclusions

This work sought to identify and analyze efficiency drivers in Brazilian international airports. For this purpose, a two-step research was conducted, the first quantitative, using a two-stage DEA model: and the second qualitative, with three case studies.

The first conclusion that can be obtained with the study is that there is a large number of elements cited in the literature that can be considered as efficiency drivers at airports. These elements, for purposes of understanding and analysis, can be classified into different categories. The proposed categorization in this article was Airport management, Turnaround, Control tower, Check-inn / Boarding, Safety operations and External factors.

From the results of the quantitative stage it is possible to conclude that in the period considered (2014-2015) only one airport can be considered efficient in the two stages of the DEA model (Physical Infraestructure and Flight Consolidation), Guarulhos International Airport. However, nine other airports were considered efficient in the period: Belo Horizonte, Brasília, Campinas, Campos, Curitiba, Navegantes, Porto Alegre, Recife and Vitória. Regarding flight consolidation, two more airports were considered efficient: Corumbá and Manaus.

The results of the DEA scores allowed to select three cases to identify the efficiency drivers: Guarulhos (GRU), Viracopos (VC) and Manaus (MAO). The case studies allowed us to conclude that not all drivers identified in the literature are present in airports considered efficient, either in one or both stages of the DEA model.

In total, 16 of the 27 efficiency drivers presented in Table 1 were identified, with most of them being in the Airport Management category. This result seems to indicate that airport efficiency is more linked to management practices than to technical or infrastructural aspects. Another point worth mentioning is the "External factors" category where the airport will be a "Hub", have a layout that allows a smoother flow and have integration with the existing logistics system were identified drivers. These elements are more difficult to obtain as they depend on public investments and strategies of the airlines that use the airport and therefore airports that have them tend to have advantages in terms of efficiency.

As the main limitation of this study, it is possible to highlight the impossibility of investigating efficiency drivers at all airports considered in the first stage. If this were possible, the relevance of each element to airport efficiency would probably be better understood.

It is suggested in future works to increase the sample (if possible global) and to conduct a survey to obtain a wider range of responses and enable the use of statistical techniques such as regression or structural equations modelling in order to explain the efficiency of these airports as a function of their eficiency drivers.

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