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Analysis of layout flexibility on the efficiency of airport passenger terminals

Análise da flexibilidade do layout na eficiência dos terminais de passageiros aeroportuários

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ABSTRACT
The usage of concepts that add flexibility to built spaces by generating the capacity to adapt to new demands is an economically viable and operationally attractive alternative to deal with demand fluctuation. This study aims to analyze the influence of those concepts on the Airport Passenger Terminal's layout by evaluating the performance of the 13 busiest Brazilian airports' check-in areas. It carries out a comparative assessment to establish the main flexibility parameters within the Airport Passenger Terminals. Moreover, it identifies the most efficient characteristics used in the built spaces at the airports. For that, this examination applies the DEA-BCC model oriented to input, analyzing as input data the relation between the check-in area and the total area of the Airport Passenger Terminal building, the number of check-in counters and the waiting time at the queue, and output data the installed capacity of the airports. The results indicate that change in the percentage of check-in area used is the criteria that best reflects the efficiency of an Airport Passenger Terminal.

RESUMO
Alguns estudos mostram que a utilização de conceitos que agreguem flexibilidade na construção de espaços gerando capacidade de adaptação a novas demandas são alternativas economicamente viáveis e operacionalmente interessantes para lidar com situações de flutuação de demanda. O objetivo deste estudo é analisar a influência da utilização desses conceitos no layout do Terminal de Passageiros do Aeroporto (TPS), avaliando o desempenho da área de check in dos 13 aeroportos brasileiros mais movimentados. Com a identificação das características mais eficientes utilizadas nos espaços construídos nos aeroportos em questão, é realizada uma avaliação comparativa para estabelecer os principais parâmetros de flexibilidade dentro dos Terminais de Passageiros do Aeroporto. Para isso, é utilizado o modelo DEA-BCC orientado a entrada, analisando como dados de entrada a relação entre a área de check in e a área total do edifício do TPS, o número de balcões de check in e o tempo de espera na fila; e para dados de saída a capacidade instalada dos aeroportos. Os resultados indicam que a variação do percentual de área de check in utilizada é o critério que melhor reflete a eficiência do espaço construído de um Terminal Aeroportuário de Passageiros.

1. INTRODUCTION

Some analysis indicates that using flexibility concepts in built spaces is an alternative to deal with lack of space capacity issues. It is also economically attractive and operationally viable. The economic advantage relies on adapting the existing space to new needs without carrying out significant physical changes. Furthermore, the operational advantage comes through the gain in the capacity to serve and process passengers.

The concept of flexibility used in airports' spatial planning is recent. There is much discussion in the existing literature about the possibilities of this concept of practical applications and characteristics that enable physical adaptations to the Airport Passenger Terminals' building according to demand oscillations (Edwards, 2005; Graham, 2009; Kwakkel et al., 2010; Shuchi and Drogemuller, 2012; Solak et al., 2009). Despite this, there still needs to be an academic gap to evaluate the efficiency of using flexibility principles at the airport layout and the results generated.

In practice, the development of a master plan happens during the preparation of a project to implement an airport site. It will establish the main development guidelines, such as setting the size and capacity of buildings (e.g., Airport Passenger Terminal) to be built and a certain period for this construction to reach its total operational capability by the initial assumptions.

However, Edwards (2005) assumes that the forecast of demand for operational activities related to the airport is intricate as many interferences impact the airline industry market, such as: (i) technological changes, (ii) economic changes, and (iii) changes in the political scenario.

In this sense, several studies in the literature discuss the most efficient or appropriate way to plan the infrastructure of the airport sector, especially Airport Passenger Terminals, which is also considered one of the major bottlenecks in this sector (Neufville, 2007; Pasin and Lacerda, 2003; Saffarzadeh and Braaksma, 2000).

This work analyzes the influence of flexibility on the Airport Passenger Terminal's layout on the performance of the check-in area at the busiest Brazilian Airports by evaluating the relative efficiency of the physical characteristics adopted through the application of the Data Envelopment Analysis (DEA) technique.

2. MATERIALS AND METHOD

2.1. Characteristics of flexibility

The present analysis carried out literature research in the existing bibliographic with the keywords: airport terminal; design flexibility; flexible design; airport flexibility; airport planning; and airport terminal development. An investigation that better defines the main flexibility criteria used at the Airport Passenger Terminals' layout spatial distribution.

There is a convergence of opinions that demonstrate that a layout with flexible characteristics is a space capable of quickly absorbing the needs of changes in its physical spatial distributions and economical and without harming the level and quality of service offered to users (Além, 2015). Even though there is no definite consensus on the concept of space flexibility.

The subject became recurrent at the beginning of the 21st century, according to Pasin and Lacerda (2003). The topic was initially addressed in 1995 by Neufville nonetheless, a time when there was a significant oscillation in the aeronautical market worldwide and a change in airport management, seeking to increase the sector's profitability in an increasingly competitive scenario.

Figure 1 presents the leading research on the topic. On the left, an image identifies the methods applied to the flexibility characteristics in each article. And on the right, an image shows the use of the attributes for the airport passenger terminals.

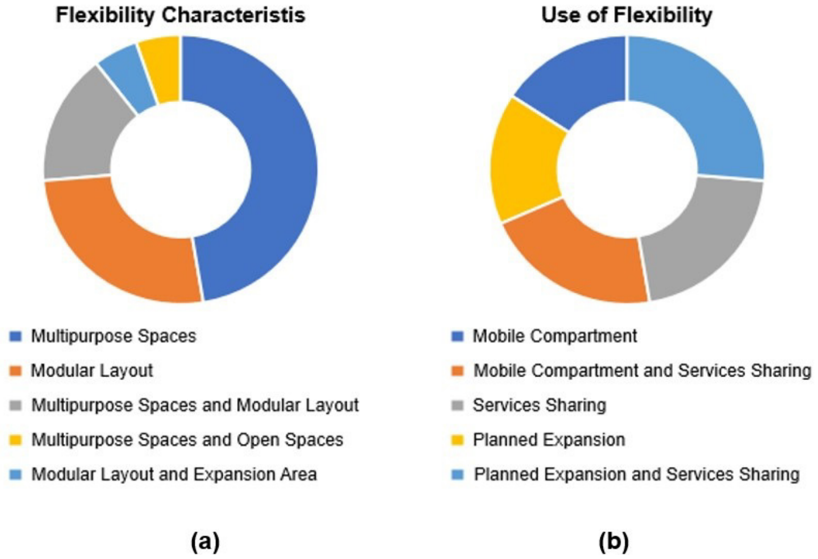

Figure 1. (a) Flexibility characteristics and (b) use of flexibility.

Edwards (2005), on the one hand, argues that architects or engineers should solve problems related to Airport Passenger Terminal building space adaptation by implementing functional built spaces. On the other hand, Chambers (2007) suggests that the planning of these sites should not be carried out based on static and long-term forecasts and should always seek the possibility of different scenarios. Solak et al. (2009) mention that solutions to adapt existing spaces to new demands are costly, so, interestingly, the area is designed with adaptability or flexibility, avoiding future and unnecessary costs.

Saffarzadeh and Braaksma (2000) also reinforce the efficient use of space according to the operation, since changes in the terminal structure are costly, planners and managers must design areas that favor the flexibility of use of their spaces. Shuchi et al. (2012) and Martins et al. (2014) argue that flexibility is the primary success vector of a project with the characteristics of the Airport Passenger Terminal. They also indicate that, despite being a relatively new concept, the use of these characteristics at the conception time and planning of Airport Terminal projects endows them with a greater capacity to accommodate layout changes, which makes the passenger experience more straightforward and faster.

It is possible to observe that the research converges to a definition of Airport Passenger Terminal's flexibility characteristics as the use of multipurpose and modular spaces that allow the expansion of the used area in a programmed and sequenced manner (Gil and Tether, 2011; Kwakkel et al., 2010; Martins et al., 2014; Shuchi et al., 2012; Shuchi and Drogemuller, 2012).

Regarding flexible layout implementation, studies show that spaces with efficient processing of passengers and the quick possibility of switching uses give a more remarkable ability to adapt the system to market fluctuations (Além, 2015; Neufville and Belin, 2002; Graham, 2009; Shuchi and Drogemuller, 2012; Shuchi et al., 2017b; Shuchi et al., 2012).

Some authors such as Além (2015), Magalhães et al. (2010), and Shuchi et al. (2017a) still argue that actions to achieve flexibility in the Airport Passenger Terminal flexibility fit into three groups according to their planning level: operational, tactical, and strategic.

Quick actions reflected in a short period are operational planning level and usually only need a little planning. The actions classified as tactics are the ones that most significantly affect the dynamics of the functioning of these terminal spaces and, therefore, take longer to be effective. And those that require more accurate planning are those of a strategic nature, as they will significantly affect the terminal's operation, which features long-term applications and responses.

2.2. Passenger terminal layout efficiency analysis

The present study conducted a literature review using keywords such as data envelopment analysis, airport performance, airport efficiency, airport planning, and benchmarking, from academically relevant journals published between 2003 and 2019. It aimed to define the best methodology to evaluate the performance of the Airport Passenger Terminal's built space.

Iyer and Jain (2019) suggest that the possibility of measuring the performance of any industry sector is significant from a managerial point of view, especially for the aeronautical sector. It is an example of a market that groups several different sectors because - despite being heavily influenced by external economic issues - the commercial aviation sector is a significant point of interest for private and public investments.

Moreover, the sector needs constant monitoring for improvements. Iyer and Jain (2019) still argue that although the literature presents several methods to monitor the efficiencies of the air sector, the use of Data Envelopment Analysis is in place due to the possibility that this tool has to investigate relatively.

Among the analyzed material, it is possible to observe the preference for using the DEA BCC model, with variable returns to scale. The authors assumed the use of this model in their analysis, considering that they were dealing with organizations of different scales. This type of analysis is present in most works that evaluate efficiency in similar scenarios.

Another relevant data observed is the basis for analyzing inputs and outputs. Authors as Abreu et al. (2016), Barros (2008), Bazargan and Vasigh (2003), Castro et al. (2017), Iyer and Jain (2019), and Negri and Borille (2019) used as input data operational information infrastructure built or installed, such as the Passenger Terminal area, runways, and the number of airlines. The output data references also have more operational aspects, most of which are related to the movement of the set as a whole, such as the movement of passengers, aircraft, and cargo. It is also possible to find elements with financial aspects in the studies by Bazargan and Vasigh (2003); Curi et al. (2010); Iyer and Jain (2019); and Pacheco and Fernandes (2003).

Regarding the orientation of the models proposed in the selected articles, it is possible to observe that the choice of the product or output-oriented analysis model stands out, a fact confirmed by the studies presented by Bazargan and Vasigh (2003), Schaar and Sherry (2008), Barros (2008), Curi et al. (2010), Castro et al. (2017), and Negri and Borille (2019).

3. ANALYSIS MODEL: DATA ENVELOPMENT ANALYSIS

3.1. General context

The data analysis tool known as DEA, Data Envelopment Analysis, is a technique that evaluates the relative efficiency of the units of a given set, comparing the efficiency of one or more units considered with the other units in question. As a result, it establishes an indicator for comparing the efficiency of the units considered efficient (Charnes et al., 1978).

A multivariate mathematical model of non-parametric linear programming is its base. It evaluates the relative efficiency of the Decision-Making Unit, DMU, through the analysis of the relationship between consumed materials, the inputs, and generated products, the outputs. It is a widely used tool in operational research, economics, and operations management for estimating production frontiers by establishing a comparative assessment between the analyzed units (Charnes et al., 1978; Mariano, 2012)

In this way, the data obtained helps monitor the productivity or efficiency of the units under analysis, providing quantitative information that optimizes the performance of inefficient units (Mariano, 2012). Initially proposed by Charnes et al. (1978) but based on work done by Farrell (1957), its use became more comprehensive in the 1980s when the first authors generalized the initial model by proposing the analysis of efficiency through multiple inputs and outputs.

The use of this tool to measure the performance of airports is supported by several authors, as mentioned above. Iyer and Jain (2019) point out that, given the different scenarios of operation and implementation of each airport complex, this analysis technique allows for a comparison between a predetermined group of airports and therefore measured by similar characteristics.

3.2. Data analyzed

The present study chose the variables for analysis according to each planning level. As input data, the following are considered: (i) the relationship between the area used for check-in and total built area, with a long-term characteristic of realization and observation of general results; (ii) queue time to check in, medium-term time for implementation and response; and (iii) number of check-in counters, an option that presents as results a short-term period of implementation. As a product analyzed to verify the system's performance, (iv) the installed capacity of each airport will be used.

Table 1 shows the aspects considered as input and output data for each airport, the level of planning and the corresponding response time, and the information sources captured for each.

The information collected is restricted to the land side, specifically in the check-in area, that is, the area for use and public access, comprised of passenger access at the terminal and admission to the departure area.

Table 1: Input and output data

Input	Planning Level/Response Time	Source
(i) % check-in area/passenger terminal´s area	Strategic/Long	- Airports’ websites - Airport Exploration Plan* - Declaration of Airport Infrastructure Capacity of each airport*
(ii) check-in queue time	Tactic/Median	- Airport Operational Performance Report (Data from the 4th quarter of 2019)*
(iii) check-in counters	Operational/Short	- Airport Infrastructure Capacity Statement (Season: S19 - Summer 2019)*
Output	**Planning Level/Response Time**	**Source**
nominal capacity (passengers/year)	Strategic/Long	- Airports’ websites - Capacity declaration*

*Informations provided by ANAC (2020).
Source: adapted from Além (2015); Magalhães et al. (2010); Shuchi et al. (2017a).

3.3. Data validation

3.3.1. Numbers of DMU

Regarding the number of units in the study group, Cooper et al. (2007) suggest that if the number of analyzed units (n) is smaller than the number of considered inputs and products summed $(i + p)$, the result may present units whose efficiency is questionable. The authors still argue that the number of units analyzed must be greater than or equal to the most considerable value between the product of inputs and products or their sum multiplied by three, $n \geq max\{i \times p, 3\,(i+p)\}$.

It is possible to find several guidelines on the subject, continuously varying because the units must sometimes exceed the number of inputs and products in the literature. Pedraja-Chaparro et al. (1999) indicate that the units analyzed should not be smaller than the sum of products and inputs $(n \geq i + p)$. Dyson and Shale (2010) argue that the number of units in the analysis must be greater than twice the sum of the amount of input and product data considered in the analysis $(n > 2(i + p))$.

The present work considers three inputs and one output, a minimum of 12 units, or airports, to correct process modeling, as Cooper et al. (2007) recommended. Table 2 shows the data referring to each airport investigated in descending order of passenger movement in 2019, indicating the input and output data used for the proposed study.

3.3.2. Correlation

Wagner and Shimshak (2007) propose using correlation analysis between input and output data as a methodology for research validation. High correlation indices between input or output variables with each other, generally greater than 0.9, represent redundancy between the data. The correlation indices between input and output data should not be low, less than 0.1, as they mean that they are not explanatory variables, that is, that they are not related to the production function.

Thus, the data initially considered, presented in Table 2, are analyzed to investigate the existence of a correlation between the variables to avoid repeated information or data that do not show significant results to the proposed research.

Table 2: Data used for research

	Input			Output
Airport (ICAO Code)	**% Check-in Area/Airport Passenger Terminal Area[1]**	**Check-in Counter (Unit)[2]**	**Check-in Wait Time (Minutes)**	**Installed Capacity (Millions Passenger/Year)**
SBGR	12%	380	10	50
SBGL	7%	174	8	37
SBKP	7%	61	4.5	25
SBCF	15%	104	7.5	22
SBBR	7%	120	11.5	21
SBSP	8%	120	12	17
SBRF	13%	98	4	17
SBPA	8%	91	5.5	15
SBSV	6%	112	6	15
SBCT	9%	90	4.5	15
SBFZ	6%	101	4.5	12
SBRJ	7%	83	8	10
SBFL	9%	60	6	8

[1]The analysis used the areas of the lobby and check-in counters, considering waiting areas, circulation, and restrooms.
[2]The total number of check-in counters was used for the analysis, considering face-to-face and self-service counters.
ICAO Code: International Civil Aviation Organization Code.

The variables used as input and output are mutually explanatory, as they present correlation indices more significant than 0.1. Regarding the correlation analysis between the input groups' data with each other, the correlation values are below 0.9, meaning that they are not redundant data, and that the data serves the proposed model.

Table 3 shows the correlation matrix calculated for the inputs and products used initially to research the efficiency of using flexibility criteria in the layout of a Passenger Terminal.

Table 3: Input and output correlation analysis

		Output	Input		
		Installed Capacity (Millions Passenger/Year)	**% Check-in Area/Airport Passenger Terminal Area**	**Check-in Counter (Unit)**	**Check-in Wait Time (Minutes)**
Output	**Installed Capacity** (Millions Passenger/Year)	1.00			
Input	**% Check-in Area/Airport Passenger Terminal Area**	0.2311	1.00		
	Check-in Counter (Unit)	0.8712	0.2407	1.00	
	Check-in Wait Time (Minutes)	0.3719	-0.0098	0.4588	1.00

3.3.3. Analysis model definition

Périco et al. (2017) argue that due to the differences between the two models, a system that presents a constant return to scale consumes inputs in the same proportion as the production of products. They also state that a system with a variable return to scale consumes the inputs disproportionately to the outputs produced, so the type of return to scale that the data in question will operate on may reflect the results obtained.

They still advocate using the hypothesis test of returns to scale presented by Banker (1996) to help define the most appropriate methodology for the study. The test verifies which return to scale (constant or variable) is the most suitable for the data set by applying the non-parametric Kolmogorov-Smirnov test, based on the maximum accumulated distribution distance of the efficiency indicators of the two models, CRS and VRS. It evaluates the null hypothesis of constant returns to scale against the alternative hypothesis of variable returns to scale, where p-value results close to zero provide more robust evidence against the null hypothesis and, therefore, acceptance of the alternative hypothesis.

The results of applying the Kolmogorov-Smirnov test, the KS test, considering the constant returns to scale model, presented results for the KS test = 0.202 and p-value more significant than 15%. The same procedure was performed considering the variable returns to scale model, obtained results such as KS = 0.269 and a p-value of 1%.

The results also showed that although the values obtained for the test in the two models are close (KS = 0.202 for constant returns to scale and KS = 0.269 for the hypothesis of variable returns to scale), the result of the p-value for the alternative of variable returns to scale is closer to zero (1%), so one should reject the null hypothesis of constant returns to scale and accept the alternative hypothesis of variable returns to scale.

Therefore, the DEA analysis model of variable returns to scale, DEA BCC, will be used to investigate the efficiency of using options that provide flexibility to the layout of the studied Airport Passenger Terminals.

3.3.4. Analysis model orientation

Cooper et al. (2007) indicate as the main feature of the analysis of the results obtained by the DEA technique the identification of the projection of the inefficiency of the units in the efficiency frontier, making it possible to direct the decision maker in the best way so that the system under study achieves adequate efficiency.

This projection can heed three directions, according to the authors: (i) product orientation, when the efficiency frontier is reached in a vertical direction, increasing the products generated with the same amount of input consumed; (ii) input orientation occurs when producing the same quantity of products, decreasing the number of inputs in the horizontal direction, thus increasing efficiency; and (iii) simultaneous orientation to inputs and products - which occurs in additive models and models based on slacks, SBM, which uses the minimum capacity of the inputs to generate the maximum amount of products, thus reaching the efficiency frontier in a way radial, and not orthogonal as the two previous ones.

Most authors such as Barros (2008), Bazargan and Vasigh (2003), Castro et al. (2017), Curi et al. (2010), Negri and Borille (2019), and Schaar and Sherry (2008) developed their research using the product-oriented model. According to Castro et al. (2017) and Iyer and

Jain (2019), changes involving inputs in the commercial aviation scenario involve the interaction of many different areas, a very costly and delicate situation. However, despite the arguments mentioned, Iyer and Jain (2019) assume that service industry benchmarks are generally carried out with an input orientation, as external factors often control activities with product-related orientations.

That said, given that the variable input data used are easier to accept proposals for quick interventions, the analysis with a lower level of physical changes is put in place considering the Data Envelopment Analysis model with input direction.

The expectation is that when proposing changes related to the helpful area used for check-in, the number of counters, or waiting time in line for check-in, the airport considered inefficient will achieve adequate performance.

4. RESULTS

For that, the SIAD software processed the data Integrated Decision Support System, developed by the Fluminense Federal University (Meza et al., 2003), notably for the application of the DEA analysis technique.

The use of the software to analyze the previously defined data makes it possible to generate results that demonstrate the behavior of each unit with the others, so the study is divided according to the results obtained, namely: (i) index of the relative efficiency of the studied units; (ii) weight attributed to each variable; (iii) goals of each data and how much charge for the unit in question to reach the efficiency frontier; and (iv) airports as a benchmark (BCMK).

Table 4 summarizes the results obtained for analyzing efficiency in the layout of Airport Passenger Terminals considered relatively inefficient.

4.1. Relative efficiency

The results obtained by analyzing the data through the input-oriented DEA BCC model are in Table 4, which shows only the Airport Passenger Terminals considered relatively inefficient. Considering the entire group of airports as shown in Table 2, the airports fit into four distinct groups according to the annual passenger processing capacity: (i) above 25 million passengers/year, (ii) between 15 and 25 million passengers/year, (iii) between 10 and 15 million passengers/year, and (iv) airports with installed capacity below 10 million passengers/year.

The first group of airports, with a capacity of more than 25 million passengers/year, all have a relative efficiency index equal to 1; that is, they are all considered efficient compared to the others, namely, SBGR, SBGL, and SBKP. Among airports with a capacity between 15 and 25 million passengers/year, SBRF is the only one considered efficient. The other airports SBCF, SBSP, and SBBR have respective relative efficiency indexes of 0.5979, 0.7857, and 0.9149.

SBBR still needs to be considered more efficient, despite having a high-efficiency index value, reflecting the long waiting time at check-in and many check-in counters. This airport takes 11.5 minutes to process passengers carrying out check-in procedures at its 120 counter units.

Table 4: Summary of the main results for the inefficient units

SBCT (*eff*: 0.963)					**SBRJ (*eff:* 0.9394)**				
Variable	**Actual**	**Target**	**Weight**	**BCMK**	**Variable**	**Actual**	**Target**	**Weight**	**BCMK**
Check-in Area/Airport Passenger Terminal Area (%)	9	8.60	1.36		Check-in Area/Airport Passenger Terminal Area (%)	7	6.60	11.019	
Check-in Counter (Unit)	90	86	0.0003		Check-in Counter (Unit)	83	78	0.0027	
Check-in Wait Time (Minutes)	4.5	4.3	0.1882		Check-in Wait Time (Minutes)	8	4.5	0	
Installed Capacity (Millions Passenger/Year)	15	18	0	SBKP SBRF SBFZ	Installed Capacity (Millions Passenger/Year)	10	19.5	0	SBKP SBFZ
SBBR (*eff*: 0.9149)					SBPA (*eff*: 0.8297)				
Variable	Actual	Target	Weight	BCMK	Variable	Actual	Target	Weight	BCMK
Check-in Area/Airport Passenger Terminal Area (%)	7	6.40	12.776		Check-in Area/Airport Passenger Terminal Area (%)	8	6.60	9.732	
Check-in Counter (Unit)	120	109	0.0009		Check-in Counter (Unit)	91	75	0.0024	
Check-in Wait Time (Minutes)	11.5	6	0		Check-in Wait Time (Minutes)	5.5	4.5	0	
Installed Capacity (Millions Passenger/Year)	21	21	0.0083	SBGL SBKP SBSV	Installed Capacity (Millions Passenger/Year)	15	20.2	0	SBKP SBFZ
SBSP (*eff*: 0.7857)					SBCF (*eff*: 0.5979)				
Variable	Actual	Target	Weight	BCMK	Variable	Actual	Target	Weight	BCMK
Check-in Area/Airport Passenger Terminal Area (%)	8	6.30	10.674		Check-in Area/Airport Passenger Terminal Area (%)	15	7	0	SBKP SBRF
Check-in Counter (Unit)	120	94	0.0012		Check-in Counter (Unit)	104	62	0.0015	
Check-in Wait Time (Minutes)	12	5	0		Check-in Wait Time (Minutes)	7.5	4.5	0.112	
Installed Capacity (Millions Passenger/Year)	17	17	0.0045	SBKP SBSV SBFZ	Installed Capacity (Millions Passenger/Year)	22	24.7	0	

eff: Relative efficiency. BCMK: Benchmark.

This investigation deemed SBCF one of the least efficient of all the airports analyzed; despite having the number of check-in counters and check-in waiting time within the sample standards, respectively 104 units and 7.5 minutes. It is possible to verify that it exhibits the highest percentage of check-in area regarding the total area of the terminal, 15%.

The airports of the third group, whose annual handling capacity is between 10 and 15 million passengers, have two efficient units, SBSV and SBFZ, and two inefficient units, SBCT, and SCPA, with relevant relative efficiency indices of 0.963 and 0.8297. SBCT, even if not considered efficient, also presents a relative efficiency index value close to the maximum, 0.963. Unlike SBSP, this high value must result from its waiting time at check-in (4.5 minutes) being one of the lowest in the analyzed set.

The last group of airports refers to those whose handling capacity is less than 10 million passengers/year: SBFL, efficient, and SBRJ, inefficient. Notwithstanding the difference, it is possible to observe that, even considered inefficient, the SBRJ has a high relative efficiency index value, 0.9394, and is out of step with the SBFL due to the waiting time of 8 minutes and the number of check-in counters.

4.2. Variable's weight

By investigating the weights provided for each variable, the percentage of the ratio of the check-in area and the entire building of the Airport Passenger Terminal area was the set of data that received the highest weights, varying between approximately 1.36 for the airport in SBCT and 13.74 to SBSV. The value of waiting time at check-in was the second variable that showed the most significant impact on the efficiency of the airports in question, ranging between 0.014 for SBGL and 0.1954 for SBFZ. The data referring to the number of counters is below 0.01 for all analyzed units and, therefore, exert an inexpressive reflection on the efficiency indices of the studied airports.

Regarding the weights of the output data, the products must remain unchanged, as the orientation of the chosen model for analysis is directed to the inputs or the input data. However, as the software used for the study provides such information, it is possible to observe that the values of the weights assigned to the output data exert little effect on the final efficiency of each unit.

4.3. Benchmarks

By analyzing the results, all efficient airports (eff =1) are benchmarks for some other inefficient airports. It means that the units that presented a relative efficiency index equal to 1 must serve as a model for the inefficient ones so that they can maximize their performance. Thus, the SBCF airport should have as reference the SBKP and SBRF airports but should focus its efforts on matching the SBKP, whose benchmark value weight is 97% against 3% for SBRF.

SBSP airport has three airports as models, SBKP and SBFZ, with an equal weight of 28.5%, and SBSV airport, with a weight of 43%. SBPA airport grounds SBKP, with a weight of 64%, and SBFZ, with 36%. SBBR has as benchmarks the SBGL and SBKP airports, with respective weights of 16% and 24%, and the SBSV airport, serving as a model with a weight of 60%.

The SBKP and SBFZ airports support SBRJ, with weights close to each other of 58% and 42%, respectively. Finally, the SBCT airport, which should also consider the SBKP, SBRF, and SBFZ airports as models, each showing a weight of 33.33%, while the SBGR and SBFL airports do not serve as a reference to any of the other airports despite being considered efficient.

5. CONCLUSIONS

It is possible to identify the efficient units with the other airports analyzed: (i) SBGR, (ii) SBGL, (iii) SBKP, airports with an installed capacity exceeding 25 million passengers per year; and (iv) SBRF, (v) SBSV, (vi) SBFZ, and (vii) SBFL, airports with variable installed capacities.

The inefficient airports concerning the others analyzed: (viii) SBCT, (ix) SBRJ, (x) SBBR, (xi) SBPA, (xii) SBSP, and (xiii) SBCF, are among the groups of airports with annual capacity installed below 25 million passengers.

Regarding the weight values assigned to each variable, the data related to the proportion between the check-in area and the total area of the Passenger Terminal is the variable that gives greater importance to the performance of airports compared to the others.

The other airports SBCT, SBPA, SBRJ, and SBBR, have a percentage of check-in area relating to the building ranging between 7% and 9%. It references the results generated for the relationship variable between the check-in area and the total area of the Airport Passenger Terminal concerning relatively inefficient airports, except for SBCF airport, which has a 15% check-in area for the entire terminal.

The target values of the percentage of check-in area per total area of the Airport Passenger Terminal for all inefficient airports to reach efficiency, according to the results obtained by the analysis, must remain between 6% and 8%. The research also showed that the percentage of the number of check-in counters used by an airport to carry out the relative procedure should change. There is a reduction need to increase airports' performance as the relative efficiency index decreases.

The variable related to waiting time at check-in demonstrates that relatively efficient airports operate with a waiting time for check-in between 4 and 6 minutes, while airports with a low-efficiency rate process passengers in this area with a time of up to 11.5 minutes, as in the case of SBBR.

Concerning airports considered benchmarks, SBGL, SBKP, SBRF, SBSV, and SBFZ airports obtained a relative efficiency index of 1, serving as models for other airports to become more efficient. SBGR and SBFL were not considered benchmarks for any of the inefficient units despite being efficient compared to the others.

However, it is essential to emphasize that the model used to investigate the physical performance of the airports in question has limitations regarding the parameters assigned to the airports considered benchmarks. These limitations converge in that the observed results must be interpreted within the set of investigated units, therefore, restricted to the variables considered in the analysis model.

This set of data can complement traditional research, adding new perspectives regarding the interpretation of the link between the installed capacity of airports and the efficiency of the spatial distribution of their buildings.

The advantages lie in: (i) the possibility of optimizing the built space through the use of shared services; (ii) implementing new technologies that allow for greater efficiency in passenger processing, such as the implementation of online check-in or remote baggage dispatch; and (iii) directing managers' efforts regarding the effectiveness of carrying out physical changes within the check-in areas of the Passenger Terminals by allocating a higher percentage of occupancy to commercial areas.

Information with this content can guide managers in situations of need for physical expansion or in cases in which it is essential to prioritize the sectorization of operational occupations within the construction that houses the Passenger Terminal.

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