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ALTERNATIVE POLICY FOR GATE ALLOCATION AT HUB AIRPORTS: A CASE STUDY AT GRU AIRPORT

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ABSTRACT

Efficient allocation of gates at hub airports is necessary for optimizing air operations, improving the passenger experience and reducing operating costs. This study uses a heuristic model to solve the problem of gate allocation, considering the number of passengers connecting between flights. Using real data, such as the Electronic Stamp File Transfer (SELO2D), and big data processing techniques, the study analyzes passenger connectivity patterns and flight flows during different IATA seasons. Through a case study of the São Paulo International Airport, the largest in Brazilian Airport in number of passengers, flights and volume of cargo transported, a model is proposed that takes into account the quantity of passengers in connection in each flight. The results show a reduction in the walking distance for connecting passengers of approximately 4 minutes, using a method that is straightforward and allows for a quick analysis, primarily applicable to operational sectors where rapid decision-making is essential.

Keywords: Gate Allocation, Hub Airports, Passenger Connectivity

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1. INTRODUCTION

The allocation of airport gates, particularly within air transport hubs, presents a significant challenge for airport administrations. This challenge stems from the necessity to optimize both airside and landside operations while enhancing the passenger experience and minimizing operational costs for airlines. Previous studies, such as those by Yan and Huo (2001) and Malighetti et al. (2008), have highlighted the complexities involved in gate allocation, particularly concerning passenger connectivity and flight scheduling. Building on this body of work, the present study aims to develop and implement a heuristic model that strategically allocates gates with a focus on improving passenger connectivity and operational efficiency. This approach is designed to optimize both airside and landside operations, improve the passenger experience, and reduce airline operating costs. The complexity of this problem lies in the need to make rapid and accurate decisions that not only meet immediate operational demands but also anticipate future needs and optimize resource utilization. Furthermore, there is a necessity to provide an efficient and scalable solution for Airport Operations Control Centers (AOCC), which face ongoing challenges in managing the increasing volume of flights and passengers.

Short-term solutions to streamline airport operations have been the focus of research, particularly in areas such as airspace management, air traffic control, and terminal and apron operations. Yan and Huo (2001) suggest optimizing the allocation of flights to parking positions or gates as one such solution. Flight allocation considers factors such as flight scheduling, gate availability, and both airline and airport restrictions, including equipment needs and aircraft characteristics. Frequent flight schedule changes, often due to delays and cancellations, make aircraft relocation a dynamic process. This process is especially challenging when performed manually and involves a large number of aircraft.

São Paulo International Airport (IATA code GRU), as the main South American hub for a major airline, requires a specialized resource allocation policy. This policy, applicable to similar airports, focuses on enhancing passenger comfort by reducing missed connections. The development of an efficient allocation model allows the airport to better meet these demands by increasing passenger connectivity between flights, thereby reducing walking distances and time spent inside the terminal. Additionally, it can increase gate capacity utilization and optimize the use of stand positions.

2. GATE AND SLOT ALLOCATION

The literature contains several proposals to optimize aircraft allocations at gates. Hagspihl et al. (2024) developed a methodology that aims to minimize the use of remote positions by introducing a decomposition structure that addresses the problem's inherent complexity and employs computational time acceleration techniques. Another advantage of an efficient allocation policy is the reduction of passenger connection losses, which is the primary objective of this paper.

Airport operations require attention to key performance indicators such as punctuality and connectivity, especially in hub-and-spoke airports. The "hub" structure is an operational model where a central airport serves as the main connection point for flights from various origins and destinations. These flights feed into the hub, allowing passengers to change aircraft and continue their journeys to their final destinations. For passengers, this model offers greater connectivity, providing access to a variety of destinations with fewer layovers, as analyzed by Malighetti et al. (2008). However, the "hub" model also has disadvantages, such as the potential for delays in connecting flights and dependence on a single airline or alliance at a specific airport.

Connectivity significantly influences flight punctuality, one of the most important Key Performance Indicators (KPIs) for airports, as addressed by Guépet et al. (2016). Their study proposes a new approach to critical indicators such as punctuality and taxiing time, making them more relevant

for stakeholders. When passengers have connecting flights, delays in the initial flight can lead to cascading effects, impacting the punctuality of subsequent flights. Therefore, airlines and airports must consider connection times when scheduling flights and managing operations.

Strategies such as creating adequate intervals between connecting flights and efficiently coordinating arrival and departure times can minimize the impact of delays on overall flight punctuality. Additionally, understanding the systematic allocation of aircraft to positions is crucial, particularly at airports with limited capacity where flight schedules are managed through slot control. According to Mendes et al. (2020), slot control is a strategic option for managing flight schedules in the context of limited capacity, addressing the problems of congestion and delays.

An airport slot is a designated time for an aircraft to take off or land on a specific day. It ensures the orderly and efficient conduct of air operations, especially at busy airports where demand for airspace and ground infrastructure is high. Airport slots are typically allocated in 15- or 30-minute windows and are assigned to airlines so they can schedule their flights (Wang et al., 2023). Allocation is regulated by the Worldwide Airport Slot Guidelines (WASG), administered by the Airports Council International (ACI), which defines the rules and procedures for slot distribution among airlines.

As part of managing airport operations, where absorbing the planned seasonal slots satisfactorily is essential, a capacity declaration is issued, establishing the airport's maximum capacity to handle takeoffs and landings within specific time slots (Wang et al., 2023). This capacity is determined based on runway infrastructure, apron space, air traffic, and passenger and baggage processing capacity. In the following section, a method for allocating aircraft to gates is described, taking into account the number of connecting passengers on various routes. This method is particularly applicable to hub airports, aiming to reduce walking distances and times, thereby increasing connection rates.

3. METHODS

Heuristic methods are algorithms, techniques, or procedures specifically designed to address the problem under study. Alves (1987) employed these methods to tackle the problem of aircraft gate allocation, considering different strategies, including those that prioritize the order of flight arrivals, turnaround times, aircraft size, and the number of passengers. Consequently, the heuristic model proved efficient for operational use by delivering a solution with a short computational processing time.

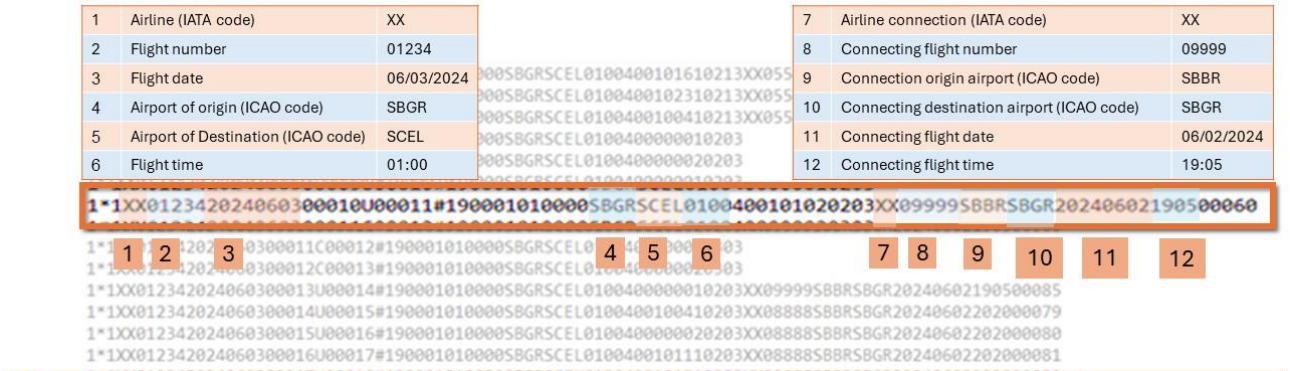
In this study, a heuristic model was utilized to address the complex problem of gate allocation, particularly in the context of optimizing passenger connectivity at hub airports. The model comprises several stages: initially, the connectivity of key airline routes was analyzed, considering the number of connecting passengers within a specific timeframe during the IATA Summer season. This analysis was followed by the application of optimization techniques to determine the most efficient gate allocation strategy. The model employs specific algorithms, including those that prioritize flight nature and passenger connectivity, to dynamically optimize gate allocations. Additionally, it integrates a Python-based data processing system that handles SELO2D data, accounts for incomplete data, and applies necessary assumptions for robust output generation. The final allocation decisions are made through an iterative process, ensuring that the best possible configuration is achieved within the given constraints.

The model's effectiveness depends on its ability to process and utilize connectivity data provided by airlines, as well as slot timings published by Civil Aviation regulatory agencies. These data are processed by a Python code that generates information on the number of passengers on "feeder" and "feeded" flights, i.e., flights that land and subsequently connect to departing flights. Data from flights that are delayed, canceled, or diverted due to Meteorological Aerodrome Reports (METAR), technical issues, or other external factors are excluded from the analysis as they are not covered by routine operations.

The data processed in this model are extracted from the Electronic Stamp File Transfer (SELO2D), a document standardized by INFRAERO (2017), a national public company applicable to airports. SELO2D, issued by domestic air carriers, includes the number of passengers boarded on each flight, as well as data on cargo, baggage, and connecting passengers. SELO2D must be delivered to airport administration after the flight, and it serves as the basis for billing and reporting related to airport operations.

To analyze the number of passengers connecting on each flight and identify routes with higher connectivity, it is necessary to extract data from this report. The raw data are delivered by airlines to airport administrators in a simple file with a ".txt" extension. The SELO2D file consists of a standardized string of characters that are referenced for analysis.

Figure 1 illustrates the interpretation scheme of a SELO2D file, where each file represents a flight and each line represents a passenger. The most relevant data for the model's analysis are highlighted in the diagram below.



Field	Meaning	Subtitle
1	Record type	Record type. Fixed = 1
3	Nature of flight	0 = Domestic 1 = International
4	Airline	IATA code of the airline
6	Flight number	Flight number (with zeros to the left)
11	Flight date	YYYYMMDD
19	Check-in sequence	Passenger check-in sequence (with zeros to the left)
24	Type of downtown	U = Used C = Canceled T = Transferred
25	Line sequence	Line sequence within the file, starting with 00002 (with zeros to the left)
31	Report printing date	YYYYMMDD
39	Report printing time	HHMM
43	Airport of origin	ICAO acronym of the airport of origin
47	Airport of destination	ICAO acronym of the destination airport
51	Flight time	HHMM
55	Check-in type	1 = Web 2 = Mobile 3 = Kiosk 4 = Counter 5 = Others

Field	Meaning	Subtitle
56	Baggage volume	Total baggage volume (with zeros to the left)
59	Luggage weight	Total weight of luggage (with zeros to the left)
62	Passenger's gender	1 = Male 2 = Female 3 = Not informed
63	Passenger type	O = Adult 3 = Child 4 = Lap (infant) 5 = Extra crew member 6 = INSPAC - Civil Aviation Inspector 7 = Free pass 8 = Diplomat 9 = Others
64	Passenger's nationality	1 = Brazilian 2 = Foreigner 3 = Not informed
65	Boarding type	O = Location 1 = Connection 2 = Transit 3 = Reboarded 4 = Others
66	Type of charge	2 Paying Domestic Section 3 = Paying International Section 4 = Exempt Domestic Section 5 = Exempt International Section
67	Airline connection	IATA code
69	Connecting flight number	Flight number (with zeros to the left)
74	Connection origin airport	Acronym ICAO
78	Connecting destination airport	Acronym ICAO
82	Connecting flight date	YYYYMMDD
90	Connecting flight time	HHMM
94	Connection check-in sequence	Passenger check-in sequence

Figure 1: Representation of a SELO2D file. Source: Author, 2024

The data were analyzed using a Python code that processes all the files and generates a spreadsheet compiling all the passenger information. Figure 2 illustrates the routine created for data processing. For example, the code was applied to Guarulhos Airport, which handles an average of 750 landings and takeoffs daily (GRU Airport, 2024). The code initially reads all the files, extracts the number of passengers on each flight, the number of passengers making connections, and their final destinations. As input data, it was necessary to provide the period to be analyzed and the airline's IATA code.

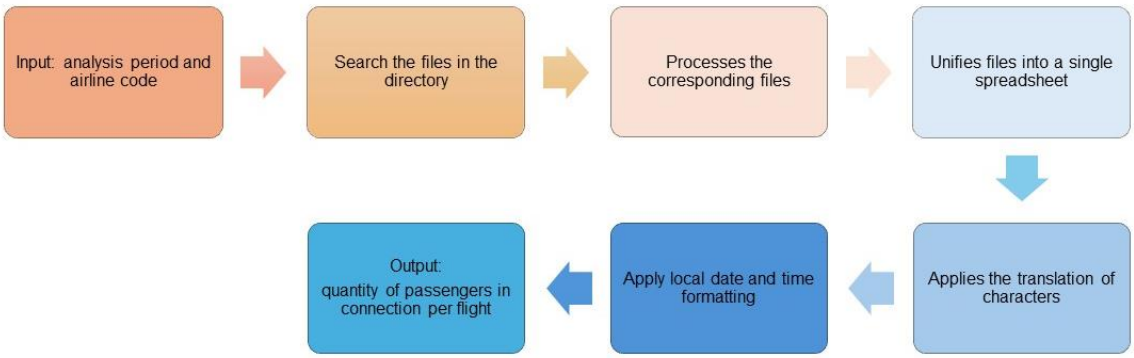


Figure 2: Code routine for data extraction. Source: Author, 2024

According to the approach used by Hagspihl et al. (2024), the model considers various factors in the configuration of aircraft parking positions, including the number of remote positions, the distance between the position and the terminal, the terminal configuration, the number of gates, the nature of operations (domestic or international), and the aircraft mix. The model applied in this study considered the West and East piers located at Terminal 2 of São Paulo International Airport – Guarulhos, which has three terminals:

- Terminal 1: Domestic flights for a single airline;
- Terminal 2: Domestic and international flights. Currently, the "east pier" (left of Figure 3) operates flights of both types, while the "west pier" (right of Figure 3) handles only domestic flights;
- Terminal 3: International flights for twenty-one airlines.

There is a corridor connecting both piers of Terminal 2 and Terminal 3, allowing passengers to make connections between the two terminals without having to leave the airside (post-inspection control).

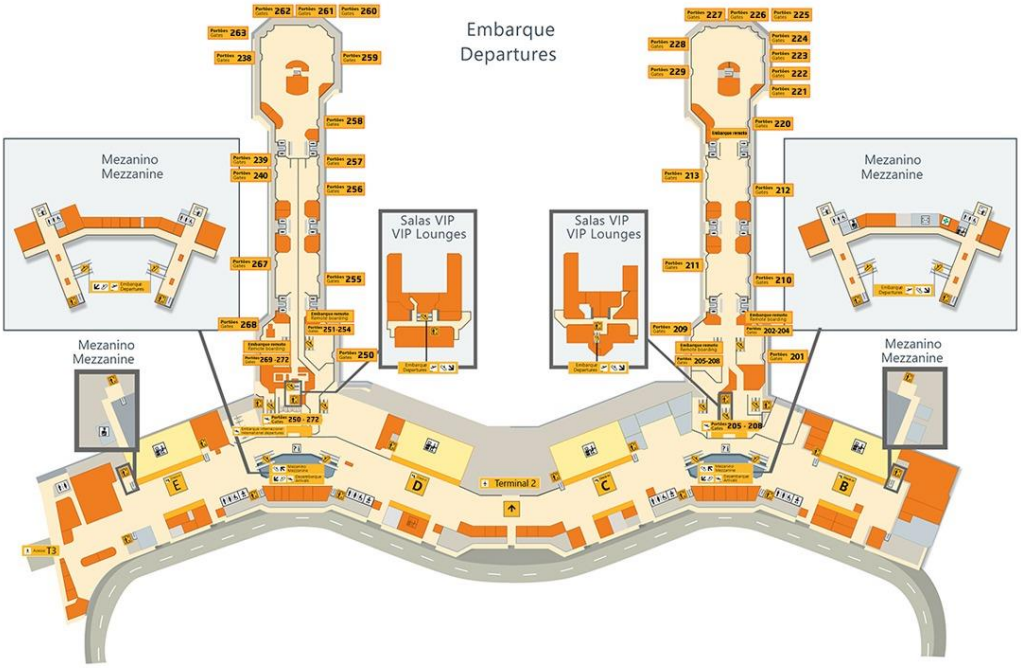


Figure 3: Layout of the terminal 2. Source: GRU Airport, 2024

Based on these factors, the suggested allocation policy prioritizes the assignment of flights with a high number of connecting passengers at nearby gates, aiming to reduce walking distances and times, thus increasing connection rates and enhancing passenger comfort and experience. This approach can help avoid disruptions and financial losses for both the airport and the airline. Moreover, it enables AOCC operators to make faster decisions in the dynamic environment of air operations.

Figure 4 below illustrates the decision-making process for assigning a landing slot to a flight with connecting passengers. The initial decision focuses on determining the minimum number of connecting passengers for a "feeder" flight based on the aircraft category. Subsequently, the nature of the flight (domestic or international) is considered. For international flights, passengers must complete immigration and customs procedures, which leads to longer connection times. Conversely, domestic flights with connections to international flights involve quicker emigration processes since luggage retrieval is not necessary (provided the flights are on the same ticket). The allocation prioritization process continues until the final step.

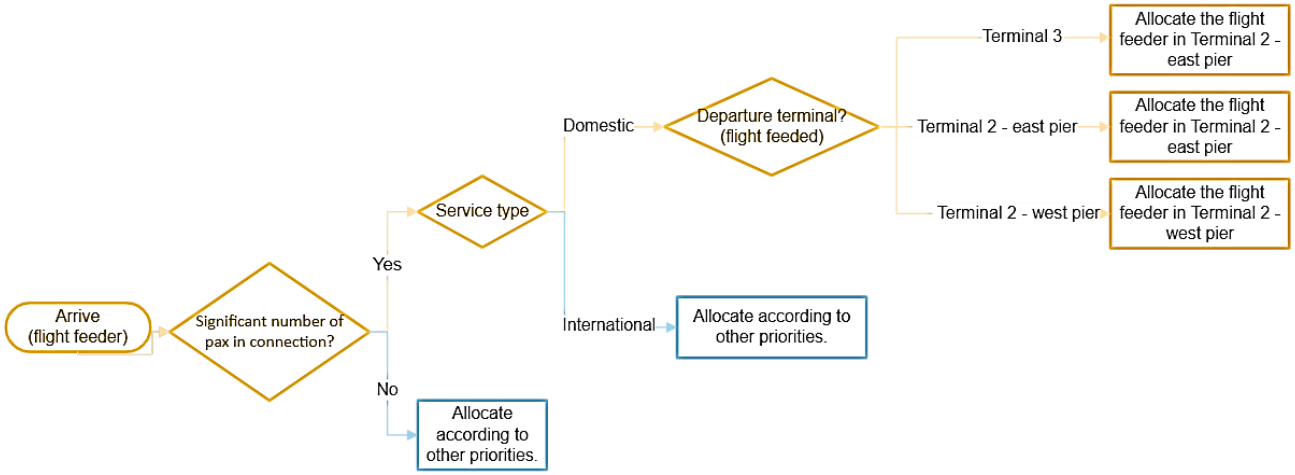


Figure 4: Decision-making flow for allocation of an aircraft, prioritizing connectivity. Source: Author, 2024

4. FINAL CONSIDERATIONS

After compiling the data, the number of connecting passengers is transmitted in the format of Table 1, which shows the number of passengers connecting between flights. This allows the analysis of the most connected routes within the IATA seasons and enables the scheduling of aircraft with the highest number of connecting passengers to be allocated near each other.

Table 1: Analysis of connections

Flight feeded	Destination	Flight feeder	Origin	Sum of pax
Domestic connections				
1234	Foz do Iguaçu	9999	Confins	136
		8888	Natal	129
		7777	Recife	121
0000	Maringá	6666	Recife	62
1111	Porto Seguro	5555	Porto Alegre	136
3333	Chapecó	2222	Recife	68
4444	Curitiba	1010	Manaus	144
International connections				
1234	Paris	9999	Santiago	136

		8888	Buenos Aires	129
		7777	Asunción	121
0000	Rome	6666	Lima	62
1111	Miami	5555	Santiago	136
3333	Buenos Aires	2222	London	68
4444	Santiago	1010	Paris	144

Using Terminal 2 as an example, where the distance between the piers is 270 meters (GRU Airport, 2024), a passenger connecting from Confins to Foz do Iguaçu would save approximately 4 minutes of walking when their flights are allocated nearby. This calculation considers an average walking speed of 1.2 m/s, the typical value for an interference-free flow (Virkler, 1994). In peak-hour situations, where passenger movement is higher, walking speed decreases, leading to increased walking times.

The findings from this study indicate that the proposed heuristic model significantly enhances gate allocation efficiency by reducing passenger walking distances and improving connectivity rates. However, these results must be considered within the context of the model's limitations, including potential challenges in adapting it to different airport configurations. Comparative analysis with existing models, such as those by Yan and Huo (2001) and Gu and Chung (1999), reveals that while our model offers quicker decision-making capabilities, it may require further refinement to handle more complex scenarios. The conclusions drawn suggest that this model could serve as a valuable tool for AOCCs, providing an operationally viable solution to dynamic gate allocation challenges.

Several authors have proposed effective solutions to address aircraft allocation issues at airports. These solutions include reducing the total distance walked by passengers, as analyzed in the model by Yan and Huo (2001); reprogramming planned versus performed allocation, as addressed by Gu and Chung (1999); and reducing remote positions for boarding and disembarkation, one of the functions of the mathematical model proposed by Ding et al. (2005).

According to the programming method utilized by Yan and Huo (2001), the primary variable considered is connection time, which benefits from reduced passenger walking distances. However, the approach used in this study emphasizes the use of databases commonly managed by airports. It proposes a method that is easy to implement and allows for quick analysis, primarily applicable to operational sectors where rapid decision-making is essential.

The model addresses the combinatorial problem faced by AOCCs when allocating gates to aircraft, taking into account connectivity to other flights. The study offers an operationally applicable solution, aiding operators in making timely decisions in the dynamic operating environment of airports. In the case studied, applying the model resulted in a reduction in passenger walking distances, consequently reducing the time required for connections. This reduction positively impacts connectivity and punctuality indicators, preventing passengers from missing their connections due to the distance between gates.

The study highlights the methodological approach for data extraction and analysis using the SELO2D, standardized by INFRAERO. This approach provides a systematic framework for handling large volumes of operational data through Python-based processing of SELO2D data, exemplifying a practical implementation that optimizes gate allocations and minimizes connection disruptions. This methodology is flexible and can be adapted for various airports with hub operations.

Future studies could expand this research by incorporating advanced machine learning techniques to predict passenger flows and optimize gate allocations in real-time. Additionally, comparative studies between different airport configurations and operational contexts would provide valuable information on the scalability and adaptability of these methods.

5. REFERENCES

ALVES, C. J. P. Modelo Heurístico de Designação de Posições de Estacionamento para Aeronaves em Pátios de Aeroportos. Tese (Doutorado em Pesquisa Operacional e Transporte Aéreo) — Instituto Tecnológico de Aeronáutica, 1987.

DEPARTAMENTO DE AVIAÇÃO CIVIL. (2000). Portaria nº 602/GC-5, de 22 de setembro de 2000.

DING, H.; LIM, A.; RODRIGUES, B.; ZHUB, Y. The over-constrained airport gate assignment problem. Computers & Operations Research, v. 32, p. 18671880, 2005.

GRU AIRPORT (Guarulhos) (org.). Institucional. 2024. Available in: https://www.gru.com.br/pt/institucional. Access: 10 jun. 2024.

GUÉPET, J., BRIANT, O., GAYON, J. P. (2016). The aircraft ground routing problem: Analysis of industry punctuality indicators in a sustainable perspective. European Journal of Operational Research, 248(3), 827–839. https://doi.org/10.1016/J.EJOR.2015.08.041

GU, Y.; CHUNG, C. A. (1999). Genetic algorithm approach to aircraft gate reassignment problem. Journal of Transportation Engineering, v. 125, p. 384–389, 1999.

HAGSPIHL, T., KOLISCH, R., FONTAINE, P. (2024). Apron layout planning–Optimal positioning of aircraft stands. Transportation Research Part B: Methodological, 179, 102854. https://doi.org/10.1016/j.trb.2023.102854

MALIGHETTI, P., PALEARI, S., & REDONDI, R. (2008). Connectivity of the European airport network: "Self-help hubbing" and business implications. Journal of Air Transport Management, 14(2), 53–65. https://doi.org/10.1016/J.JAIRTRAMAN.2007.10.003

MENDES, M. B., DE ARAUJO, R. R., ETGES, A. B., & BAZARGAN, M. (2020). Efficiency analysis of a congested Brazilian airport applying slots optimization control: Congonhas Airport Case. International Journal of Aviation, Aeronautics, and Aerospace, 7(2). DOI: https://doi.org/10.58940/2374-6793.1480

NIKOLIĆ, M., RAKAS, J., & TEODOROVIĆ, D. (2024). Formulation of the airport collaborative gate allocation problem and the Bee Colony Optimization solution approach. Engineering Applications of Artificial Intelligence, 128, 107433. https://doi.org/10.1016/j.engappai.2023.107433

TODESCO, F. Otimização da Designação dos Voos aos Gates nas Fases de Planejamento e Operação do Aeroporto Internacional de São Paulo/Guarulhos.— Instituto Tecnológico da Aeronáutica, São José dos Campos., 2008.

VIRKLER, Mark R.; ELAYADATH, Sathish. Pedestrian speed-flow-density relationships. Transportation research Research recordRecord, v. 1438, p. 51-58, 1994.

WANG, Y., LIU, C., WANG, H., & DUONG, V. (2023). Slot allocation for a multiple-airport system considering airspace capacity and flying time uncertainty. Transportation Research Part C: Emerging Technologies, 153, 104185. https://doi.org/10.1016/J.TRC.2023.104185

YAN, S., & HUO, C. M. (2001). Optimization of multiple objective gate assignments. Transportation Research Part A: Policy and Practice, 35(5), 413–432. https://doi.org/10.1016/S0965-8564(99)00065-8