Aircraft Boarding Strategies

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The pandemic caused by the COVID-19 virus (SARS-CoV-2) has been a source of concern for airlines regarding safe flight environments. The main reason is that infected people may experience no symptoms. Nevertheless, they may have high viral loads and spread the disease. To ensure the safety of passengers concerning virus propagation, such as COVID-19, and keep the turnaround time at low levels, airlines should seek efficient aircraft boarding strategies in terms of both physical distancing and boarding times.

Keywords: COVID-19 ; pandemic ; boarding strategies ; airlines ; boarding time ; passenger interference ; luggage

1. Introduction

The recent pandemic caused by the COVID-19 virus (SARS-CoV-2) has been a source of concern for airlines regarding safe flight environments. The main reason is that infected people may experience no symptoms. Nevertheless, they may have high viral loads and spread the disease [1]. Furthermore, the effects of pandemics may have an important economic impact on airline companies [2]. In this context, airlines struggle to increase passenger safety in air transport, and amongst other measures to reduce the risk of contagion, passenger boarding has been subjected to physical distancing [3]. A minimum distance of 1 to 2 m between passengers was recommended by the International Air Transport Association (IATA) [4]. IATA also recommended ensuring a limited number of passengers passing each other, sequential boarding, and keeping empty seats.

To ensure not only the safety of the passengers but also to reduce the boarding time, the interference between passengers should be minimized to smooth the passenger flow during the boarding process. This means that airlines must adopt efficient boarding strategies to reduce the turnaround time and increase profit. This is because the boarding process significantly contributes to delays in the turnaround time, an important source of uncertainty [5].

2. The Existing Aircraft Boarding Strategies in the Context of a Pandemic

The recent pandemic scenario has had a huge impact on mobility with serious implications for economic and social activities. In order to reduce the spread of the virus and prevent deaths and the burden on local health systems, most nations have promoted specific measures, such as physical distancing, travel restrictions, and the temporary suspension of commercial and social activities [6]. The airline industry has been no exception and was impacted on a worldwide scale by the pandemic. To keep air travel operational and restore passengers' confidence, airlines had to implement measures to prevent contagion and virus propagation [7]. The IATA medical advisory group has recommended measures such as keeping empty seats [4] and blocking middle seats have been implemented, for example, by Alaska Airlines, Wizz Air, and EasyJet [8].

For many airline companies, the issue of physical distancing has led to a reduction of approximately one-third in the maximum seating capacity of the aircraft. This was due to the implementation of the 'empty middle seat' policy, which required the seat in the middle, between the window and the aisle, as shown in **Figure 1**, to be kept empty. A research undertaken by Barnett and Fleming [9] indicates that if the middle seat is kept unoccupied, the risk of COVID-19 contagion is reduced by half. Nevertheless, physical distancing between passengers in the aisle of the aircraft may lead to delays in the boarding process.

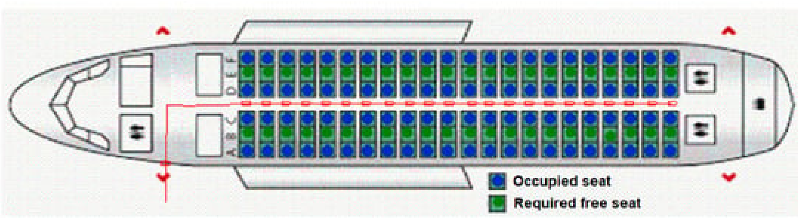

Figure 1. Configuration of an aircraft in a pandemic context.

Passenger interference in the boarding process occurs when one passenger blocks another passenger attempting to access their seat [10]. We assume there is a correspondence between the number of passenger interferences and the boarding time. Thus, by reducing passenger interferences, individual passengers' seating times will be shortened, and the overall boarding time will be reduced.

Passenger interference can be of two types: aisle interference and seat interference. Aisle interference occurs when a passenger is blocked in the aisle by another passenger, which usually occurs when hand luggage is stowed in the designated compartment. Seat interference occurs when a passenger wants to sit down but needs to ask a passenger already seated to get up. According to Delcea et al. [11] and Cotfas et al. [12], passengers may encounter four types of seat interference during the boarding process. However, in the context of the 'empty middle seat policy', the only possible type of interference is that of type 3; i.e., the passenger with a window seat will have to ask the passenger in the aisle seat to get up.

Several boarding strategies have been used by airlines. These aim to sequence passengers during the boarding process to minimize the impact of the interferences. The main boarding strategies are as follows (see, e.g., [12]):

- Random: All passengers belong to a single boarding group, with passengers entering the aircraft randomly, allowing passengers traveling with friends or family members to board together. This approach is often used as a benchmark for other boarding strategies [13].

- Back-to-Front: In this strategy, the first passengers to board are those seated in the last rows of the plane. Boarding continues until the front rows are reached [13]. The back-to-front boarding strategy is usually simplified (to increase practicality) by aggregating rows of seats in blocks.

- Outside-In: In this strategy, the first passengers to board are those who have window seats. They are followed by passengers in the middle seats and, finally, those in the aisle seats. This strategy eliminates seat interference [14].

- Reverse Pyramid: This strategy is a combination of the back-to-front and outside-in strategies. Boarding takes place by allowing the simultaneous entry of passengers from back to front, as well as from the outside inwards. The first passengers to board are those in window seats and those who have middle seats at the rear of the aircraft. Passengers seated in the aisle in the front section of the plane are the last to board. This strategy eliminates seat interference [14].

- Blocks: In this strategy, airplane rows are divided into zones, each of these containing several rows. This strategy first boards passengers in the last rows (zone 1). The passengers who are in the front rows (zone 2) then follow. Subsequently, the order is repeated for the farthest zone (the last unoccupied rows), the front rows, and so on [14].

- Steffen: This strategy implies the call of the passengers one by one to board the airplane. This is carried out from back to front and from the windows to the aisles. Adjacent passengers in each row are seated two rows away from each other in corresponding seats (for example, 12F, 10F, 8F, 6F, 4F, and 2F). Passengers first occupy the even and odd rows on each side of the aircraft cabin, following the order of window seats, then middle seats, and, finally, aisle seats [13].

- Modified Optimal: This method consists of boarding passengers in alternating rows. Passengers are divided into four boarding groups. The first of these consists of all the passengers in even rows but only on one side of the plane. The second group includes all the passengers seated on the other side of the plane. The third and fourth groups are the passengers seated in odd rows on either side of the plane [14].

Several studies have been conducted to test boarding strategies on an aircraft. Different approaches have been used to address the problem, including simulation (e.g., [14][15][16][17][18]), analytical methods (e.g., [10][19]), and (3) experiments on the aircraft (e.g., [13][20]). The research of Bidanda et al. [21] reviews the literature dealing with the implementation of models aiming to optimize the boarding processes, achieving maximum efficiency.

Upon analyzing the literature results, Jaehn and Neumann [22] concluded that simple methods or even random boarding are more effective than the commonly used back-to-front strategy. The researchers concluded that random boarding outperforms block strategies like back-to-front because it effectively channels the congestion caused by passengers stowing their carry-on baggage into a localized section of the airplane.

Concerning the impact of hand luggage, Nyquist and McFadden [23] showed that baggage restrictions may reduce boarding times. Later, Qiang et al. [24] developed a simulation model in which passengers carrying more luggage were allowed to board first. Kisiel [25] analyzed the sensitivity of the most common strategies regarding the number of priority passengers involved. Schultz [26] suggested modifying aircraft infrastructure to reduce the number of interferences between passengers.

Recently, Cotfas et al. [12] used a simulation to analyze the impact of the restrictions imposed or mooted worldwide on the boarding strategies used by the airlines, leaving the middle seat empty on each side of the aisle and compared their effectiveness with the classical airplane boarding methods. The researchers concluded that the risk of contamination is reduced for most boarding strategies when the social distance between adjacent passengers advancing down the aisle is increased. Schultz and Soolaki [27] implemented passenger behavior in a stochastic cellular automata model, where passengers traveling together should be boarded and seated in a group, which is extended using a module to evaluate the transmission risk. This research shows that these groups significantly contribute to faster boarding and less transmission risk compared to the standard random boarding procedures when applied in a pandemic scenario.

Shultz et al. [28] studied the boarding problem in the context of COVID-19 using a stochastic agent-based model. They considered three scenarios regarding airplane occupation, namely 50%, 66%, and 80%. The researchers sought to minimize the boarding time and the risk of contamination, first seating passengers next to the window and, lastly, next to the aisle. The results obtained were promising, with savings of more than 30% in the boarding time. In turn, Qureshi and Qureshi [29] developed a model using a Discrete Event Simulation (DES) under different policies and boarding strategies. The researchers concluded that the most effective way to reduce contamination is Steffen's strategy, although it is the one that presents the greatest difficulties in practical implementation. On the other hand, they concluded that it becomes much easier to implement strategies such as the Reverse pyramid and Window Middle Aisle, with a marginal loss of effectiveness compared to Steffen's, also keeping the risk of COVID-19 contagion very low.

Qiang and Huang [30] studied the optimization of boarding in airplanes with a cabin that was equipped with side-slip seats. To assist the implementation of more complex strategies, the researchers considered the development of a boarding assistant system. This system improves the process of automatically assigning seats to newly arriving passengers at an automatic seat distribution gate. Kobbaey et al. [31] address the issue of reducing boarding times through economic sustainability, given that airport occupancy is an important economic factor for airline companies and airport management. The researchers used an autonomous agent-based simulation (ABS) to evaluate the impact of nine different boarding strategies. The results showed that a random strategy was the least affected by passenger non-compliance. They also concluded that the individual seating method is the one that performs better when the occupancy rate of the flight is high. When the flight occupancy rate is relatively low, all strategies perform acceptably. Withanachchi and Adikariwattage [32] also analyzed the different factors that impacted the boarding process considering variables such as the boarding strategy, the number of pieces of luggage, arrival rate, and average speed of passengers during boarding. The research made it possible to draw recommendations considering the parameters analyzed both for pre-pandemic and pandemic situations. Finally, Kobbaey and Bilquise [33] conducted a critical review of 12 studies that investigate the aircraft boarding problem using ABS, classifying the literature as follows: (a) studies that evaluated the efficiency of different boarding strategies, (b) studies that developed new boarding strategies, and (c) studies that analyzed the impact of restrictions imposed during the pandemic period.

References

1. Regnier, E.; Sanchez, S.M.; Sanchez, P.J. Testing-Based Interventions for COVID Pandemic Policies. In Proceedings of the 2020 Winter Simulation Conference, Orlando, FL, USA, 14–18 December 2020; p. 2. Available online: https://informs-sim.org/wsc20papers/074.pdf (accessed on 11 January 2023).
2. Sun, X.; Wandelt, S.; Zheng, C.; Zhang, A. COVID-19 pandemic and air transportation: Successfully navigating the paper hurricane. J. Air Transp. Manag. 2021, 94, 102062.
3. Milne, R.J.; Delcea, C.; Cotfas, L.-A. Airplane Boarding Methods that Reduce Risk from COVID-19. Safety 2021, 134, 105061.
4. IATA. Restarting Aviation Following COVID-19. 2020. Available online: https://www.iata.org/contentassets/f1163430bba94512a583eb6d6b24aa56/covid-medical-evidence-for-strategies-200423.pdf (accessed on 11 February 2021).
5. Serter, I.; Clinton, F.; Yarlagadda, P. Agent-based modelling of aircraft boarding methods. In Proceedings of the 4th International Conference on Simulation and Modeling Methodologies, Technologies and Applications (SIMULTECH),

Vienna, Austria, 28–30 August 2014; IEEE: Piscataway, NJ, USA, 2014; pp. 148–154.

6. Schultz, M.; Fuchte, J. Evaluation of Aircraft Boarding Scenarios Considering Reduced Transmissions Risks. Sustainability 2020, 12, 5329.
7. Elcheroth, G.; Drury, J. Collective resilience in times of crisis: Lessons from the literature for socially effective responses to the pandemic. Br. J. Soc. Psychol. 2020, 59, 703–713.
8. Walton, J. Will Empty Middle Seats Help Social Distancing on Planes? 2020. Available online: https://www.bbc.com/worklife/article/20200422-when-can-we-start-flying-again (accessed on 11 January 2023).
9. Barnett, A.; Fleming, K. COVID-19 Risk Among Airline Passengers: Should the Middle Seat Stay Empty? MedRxiv 2020.
10. Soolaki, M.; Mahdavi, I.; Mahdavi-Amiri, N.; Hassanzadeh, R.; Aghajani, A. A new linear programming approach and genetic algorithm for solving airline boarding problem. Appl. Math. Model. 2012, 36, 4060–4072.
11. Delcea, C.; Cotfas, L.-A.; Chirita, N.; Nica, I. A Two-Door Airplane Boarding Approach When Using Apron Buses. Sustainability 2018, 10, 3619.
12. Cotfas, L.A.; Delcea, C.; Milne, R.J.; Salari, M. Evaluating Classical Airplane Boarding Methods Considering COVID-19 Flying Restrictions. Symmetry 2020, 20, 1087.
13. Steffen, J.; Hotchkiss, J. Experimental test of airplane boarding methods. J. Air Transp. Manag. 2012, 18, 64–67.
14. Jafer, S.; Mi, W. Comparative Study of Aircraft Boarding Strategies Using Cellular Discrete Event Simulation. Aerospace 2017, 4, 57.
15. Kalic, M.; Markovic, B.; Kuljanin, J. The airline boarding problem: Simulation based approach from different players' perspective. In Proceedings of the 1st Logistics International Conference, Belgrade, Serbia, 28–30 November 2013; pp. 49–54.
16. Marelli, S.; Mattocks, G.; Merry, R. The Role of Computer Simulation in Reducing Airplane Turn Time. 1998. Available online: https://www.boeing.com/commercial/aeromagazine/aero_01/textonly/t01txt.html (accessed on 26 October 2020).
17. Van Landeghem, H.; Beuselinck, A. Reducing passenger boarding time in airplanes: A simulation based approach. Eur. J. Oper. Res. 2002, 142, 294–308.
18. Zeineddine, H. A dynamically optimized aircraft boarding strategy. J. Air Transp. Manag. 2017, 58, 144–151.
19. Tang, T.; Wu, Y.H.; Huang, H.; Caccetta, L. An aircraft boarding model accounting for passengers' individual properties. Transp. Res. Part C Emerg. Technol. 2012, 22, 1–16.
20. Ren, X.; Xu, X. Experimental analyses of airplane boarding based on interference classification. J. Air Transp. Manag. 2018, 71, 55–63.
21. Bidanda, R.; Winakor, J.; Geng, Z.; Vidic, N. A review of optimization models for boarding a commercial airplane. In Proceedings of the 24th International Conference on Production Research, Poznan, Poland, 30 July–3 August 2017; pp. 1–6.
22. Jaehn, F.; Neumann, S. Airplane Boarding. Eur. J. Oper. Res. 2015, 244, 339–359.
23. Nyquist, D.; McFadden, K. A study of the airline boarding problem. J. Air Transp. Manag. 2008, 14, 197–204.
24. Qiang, S.-J.; Jia, B.; Xie, D.-F.; Gao, Z.-Y. Reducing airplane boarding time by accounting for passengers' individual properties: A simulation based on cellular automaton. J. Air Transp. Manag. 2014, 40, 42–47.
25. Kisiel, T. Resilience of passenger boarding strategies to priority fares offered by airlines. J. Air Transp. Manag. 2020, 87, 101853.
26. Schultz, M. Dynamic change of aircraft seat condition for fast boarding. Transp. Res. Part C Emerg. Technol. 2017, 85, 131–147.
27. Schultz, M.; Soolaki, M. Analytical approach to solve the problem of aircraft passenger boarding during the coronavirus pandemic. Transp. Res. Part C Emerg. Technol. 2021, 124, 102931.
28. Schultz, M.; Soolaki, M.; Salari, M.; Bakhshian, E. A combined optimization–simulation approach for modified outside-in boarding under COVID-19 regulations including limited baggage compartment capacities. J. Air Transp. Manag. 2023, 106, 102258.
29. Qureshi, S.M.; Qureshi, H. Exploring the Impact of COVID-19 on Aircraft Boarding Strategies Using Discrete Event Simulation. Oper. Supply Chain. Manag. 2022, 15, 424–440.

30. Qiang, S.; Huang, Q. New boarding strategies for a novel aircraft cabin installed with side-slip seats. Transp. B Transp. Dyn. 2022, 10, 1010–1031.
31. Kobbaey, T.; Bilquise, G.; Naqi, A.A. A Comparative Evaluation of Airplane Boarding Strategies with a Novel Method for Sustainable Air Travel. In Proceedings of the 2023 9th International Conference on Information Technology Trends (ITT), Dubai, United Arab Emirates, 24–25 May 2023; IEEE: Piscataway, NJ, USA, 2023; pp. 169–174.
32. Withanachchi, O.; Adikariwattage, V. Evaluation of Variability in Boarding Time Under Different Boarding Strategies used for Airline Passenger Boarding Process. J. East. Asia Soc. Transp. Stud. 2022, 14, 2377–2395.
33. Kobbaey, T.; Bilquise, G. Agent-Based Simulations for Aircraft Boarding: A Critical Review. In ICETIS, Proceedings of the International Conference on Emerging Technologies and Intelligent Systems, Virtual, 2–3 September 2022; Springer International Publishing: Cham, Switzerland, 2022; pp. 42–52.