A Simulation Study Regarding Different Aircraft Boarding Strategies

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Abstract. The airline industry is constantly subject to the search of new methods in order to increase efficiency, profitability, and customer satisfaction. Since airlines only generate revenue when their airplanes are on the air, the time they spend at the airports should be the shortest possible. Hence, the airplane turnaround time becomes a process which airlines pay special attention on. The boarding process has a very important role, since it is one of the significant elements of the turnaround time, and a slow boarding process might lead to many kinds of problems to the airline, from financial issues to customer complaints. This paper analyzes the major interferences among the passengers that cause delays in boarding times, and after comparing the different aircraft boarding strategies, it proposes the most efficient strategy.

Keywords: Aircraft Boarding, Simulation, Delay Times.

1 Introduction

Ground handling operations include all services that are carried out during the aircraft turnaround. The aircraft turnaround comprises the time from which the captain sets the airplane parking breaks, until he releases its breaks again. In other words, the turnaround begins when the ramp staff blocks the airplane (chocks on), and finishes when the chocks are off and the airplane starts the pushback. Most of the activities are independent and can take place simultaneously, such as catering, cleaning, and fueling; however, other activities such as the passenger boarding, cannot start until other processes have been finished.

It has been found that many previous works refer to the boarding process as a problem, since it is an activity that cannot start until processes such as fueling, cleaning or catering are ready. Likewise, Figure 1 shows that the passenger boarding process constitutes a critical path. Of course, the main priority during a boarding process is always safety, rather than carrying out a fast boarding. This explains why sometimes the boarding process does not start until fueling is finished, even when it could be done.

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M.Á. Fernández-Izquierdo, M.J. Muñoz-Torres, R. León (Eds.): MS 2013, LNBIP 145, pp. 145–152, 2013.

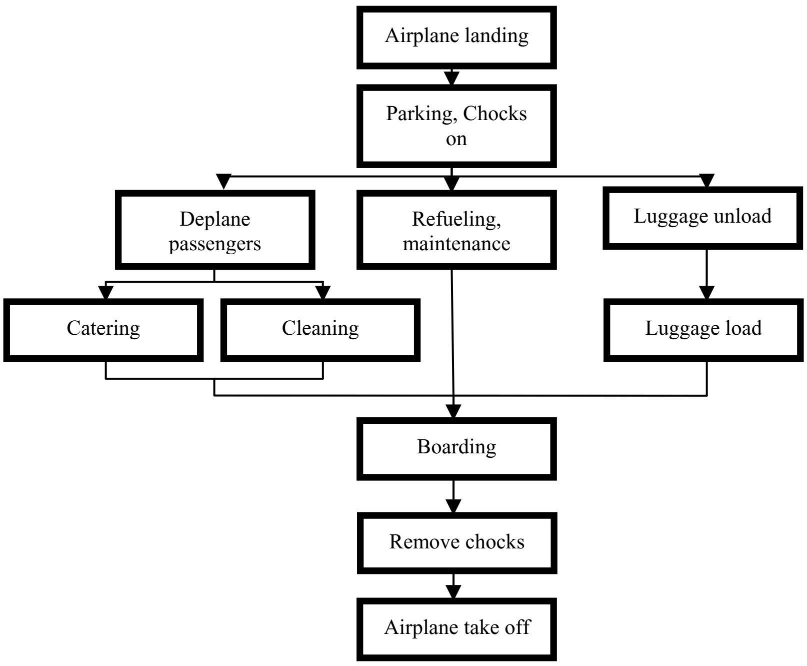

Fig. 1. Turnaround Scheme, Albert Steiner and Michel Philipp [1]

In addition to this, airline managers have to be aware that the most cost-effective boarding process will have to maintain quality and customer satisfaction.

One of the purposes in reducing the boarding time refers to reduce the number of interferences between passengers inside the airplane. A boarding interference is defined as an instance of a passenger blocking the access of another passenger to his seat. Therefore, the minimization of the total boarding time is related to the minimization of passenger interferences. Also, the total boarding time is related to the number of carry-on luggage that passengers have.

This paper is mainly focused on the boarding process while using a bridge. The most popular boarding strategies adopted by many of the airlines are the following:

- Back-to-front (BF) boarding policy (Figure 2) is the traditional strategy, adopted by most airlines for both narrow and wide-body aircraft. This strategy consists in boarding first class firstly (block 1). Then, passengers are called in groups to board the aircraft, following the sequence from back to front –i.e. blocks 2, 3, 4, 5, and 6.
- Outside-inside boarding strategy (Figure 3), also known as window-middle-aisle boarding. First class passengers are boarded first (block 1). Then, passengers in window seats are boarded (block 2), then middle seats (block 3), and finally aisle seats (block 4).

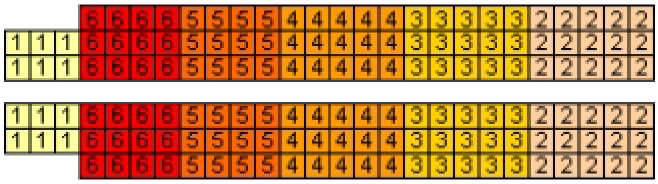

Fig. 2. Back-to-front boarding policy

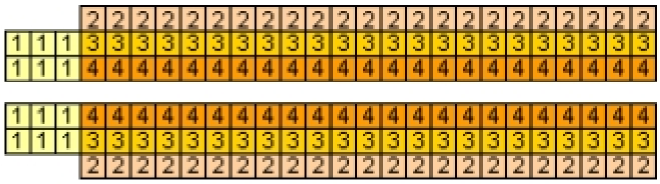

Fig. 3. Outside-inside boarding policy

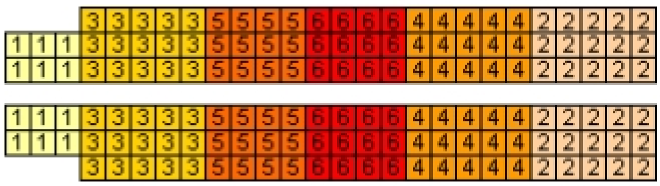

Fig. 4. Rotating zone boarding policy

- Rotating zone boarding strategy consists in boarding passengers sitting in the middle of the aircraft last (Figure 4). Thus, passengers are grouped into zones and board the aircraft first in the front (block 1), then in the back (block 2), then front again (block 3), then back (block 4), and so on.
- Random boarding strategy does not specify any condition while boarding passengers and the aircraft is boarded in one zone randomly (Figure 5). First class passengers are also boarded firstly (block 1). Then, passengers board the airplane in a first-come first-serve basis (block 2); or in other words, following a FIFO process (first-in first-out).

In this paper, simulation is used to analyze some of the aforementioned policies in order to search for the most efficient boarding strategy. The paper is structured as follows: Section 2 provides a brief overview of related work. Section 3 describes our approach. Section 4 includes some numerical experiments. Finally, Section 5 summarizes the main results.

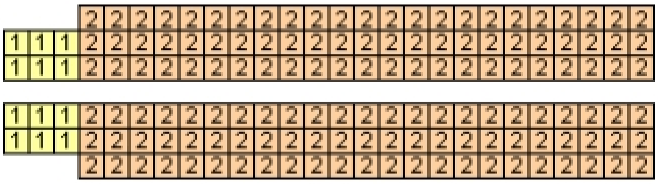

Fig. 5. Random boarding policy

2 Related Work

The aircraft passenger boarding problem has been previously studied mostly through simulation-based solutions for analyzing and improving passenger airplane boarding. **Marelli et al. [2]** conducted a simulation-based analysis performed for Boeing. Boeing Corporation created a computer simulation model called *Boeing Passenger Enplane/Deplane Simulation* (PEDS). The result of its study was that the outside-inside boarding strategy reduced boarding times significantly. **Van Landeghem and Beuselinck [3]** carried out a simulation study based on airplane boarding. According to this study, the fastest way to board the passengers on an airplane was to do it individually by their row and seat number. **Van den Briel et al. [4]** did not take into account airplane design parameters, and the study showed how strategies based on reducing interferences are better than the traditional back-to-front policy. These authors designed the so-called reverse-pyramid method, with the aim of boarding passengers while utilizing as much as possible the aircraft. The model was mainly developed to minimize passenger boarding interferences, and it was used MINLP, a mixed-integer nonlinearly constrained optimization solver.

Bauer et al. [5] developed a computer simulation to model the boarding process. These authors considered different boarding strategies and individual variations of passengers. Additionally, they treated the boarding problem as a stochastic process, and specifically, they used queuing theory to reach a better understanding of bottlenecks and their effects.

3 An Overview of Our Approach

By implementing a simulator in Visual Basic for Applications (VBA), using Excel, all the possible scenarios are tested; Figure 6 shows the interface of the simulator created. In order to obtain a reliable conclusion about which boarding policy performs better, we have considered 18 different scenarios. For the three different boarding strategies studied (random, back-to-front, and front-to-back), three specific aircraft models are determined:

- Medium-small airplanes with capacity for up to 152 passengers.
- Medium airplanes with capacity for up to 178 passengers.
- Medium-large airplanes with capacity for up to 212 passengers.

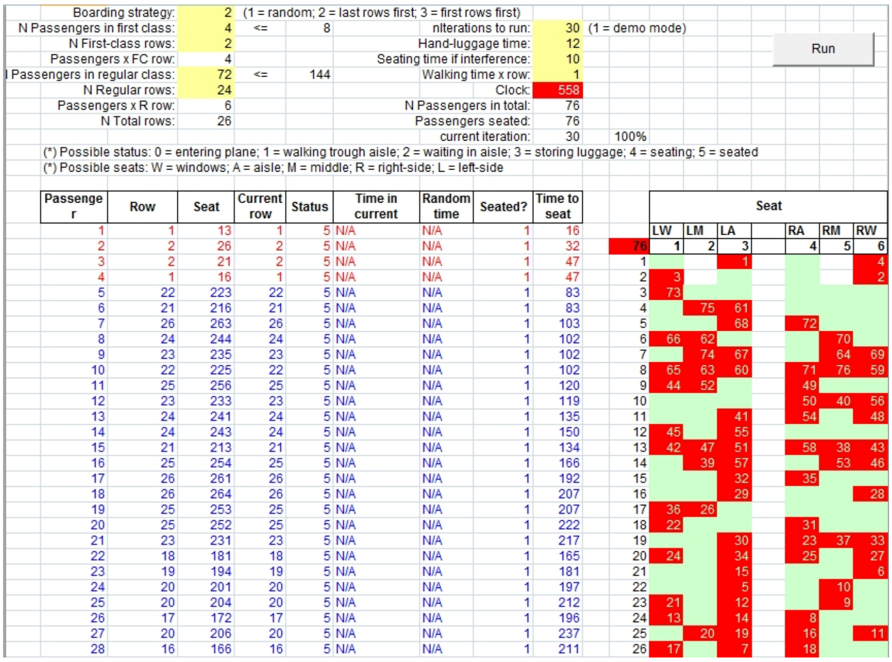

Fig. 6. Simulator overview

Moreover, for each model of airplane considered, an occupancy parameter is applied. Obviously, the more occupancy level, the more passenger interference, and therefore, more time will be required to board all passengers. In addition to this, we also want to model the occupancy level in order to find out how this parameter affects to a certain boarding procedure. Thus, in our model we consider two different occupancy levels: medium (50% occupancy), and high (100% occupancy).

In this context, we will try to figure out which policy works better according to the specific airplane size, and the current occupancy level of passengers. Notice that we have not considered the outside-inside boarding strategy since this policy cannot be easily employed in a real-life situation –if applied, passengers traveling together such as families or friends would have to board into the plane separately.

Firstly, according to the boarding strategy being analyzed, the model makes a pre-assignation of several parameters, and keeps them in memory. In order to determine the parameters, real times during 30 boarding processes at the airport of Barcelona were observed, and average estimates were derived from those observations. The current model assumes that these parameters are constant values. Thus, for our simulation trials the following values are used:

- Walking time per row = 1 time unit (0.5 seconds)
- Seating time interference = 10 time unit (5 seconds)
- Baggage stowage time = 12 time unit (6 seconds)

Secondly, there is a need to specify which boarding strategy is going to be executed. For instance, we can indicate the random approach, the back-to-front method, or the front-to-back strategy. Except the boarding approach where no seats are assigned to passengers, in the rest of strategies each passenger has a certain pre-assigned seat. Then, according to the aircraft type, there is a need to describe the number of rows and seats located in first class and in economy class, as well as the number of passengers that will occupy each class. Also, it is interested to model the time required for a passenger to walk and to stow the luggage, as well as the time provided by a seating interference. As explained before, in the current version of our model these three parameters have been considered as constants. Finally, the number of iterations to run the simulation has to be chosen. This collection of data is thrown in a grid that represents the airplane, where the different seats and the aisle are shown. The model divides the airplane in four blocks where passengers are assigned to, so they will be seated according to these blocks. Within a certain block, passengers are randomly sorted. Finally, simulation parameters such as the clock time or the total number of passengers being boarded are being tracked during the simulation.

4 Numerical Experiments

In this article, three boarding strategies are tested (Random, Back-to-Front, and Front-To-Back). Each strategy is used in every plane also having two different occupancy rates, so 18 different scenarios are tested. In each scenario 30 iterations have been computed to test its robustness. Because of the quantity of information extracted from each scenario, a sample has been chosen. Figure 7 shows an Analysis of Variance (ANOVA) for the scenario Medium–Large aircrafts with Medium Occupancy level. The results from this ANOVA tests with a p-value = 0.000 and non-overlapping confidence intervals, allow us to conclude that there exist significant differences in average boarding times among the different boarding policies considered.

```
                                     Individual 95% CIs For Mean Based on
                                     Pooled StDev
Level     N   Mean       StDev    -----+---------+---------+---------+----
Random   30   663,13     41,77    (*-)
BtF      30   754,53     38,57             (*-)
FtB      30   957,57     43,96                                (-*)
                                  -----+---------+---------+---------+----
                                      700       800       900      1000

Pooled StDev = 41,49
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Fig. 7. ANOVA Results for Medium – Large Aircraft with Medium Occupancy

Similar results can be observed in Figure 8, which illustrates an ANOVA test for the scenario Medium-Large aircraft with High Occupancy level. Notice that, again, the associated p-value is really low (p = 0.000) and, as in the previous experiment, confidence intervals do not overlap.

```
                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level    N   Mean      StDev  -----+---------+---------+---------+----
Random  30  1314,3      53,7  (*)
BtF     30  1707,8      48,8                   (*)
FtB     30  1934,1      68,3                               (*)
                              -----+---------+---------+---------+----
                                 1400      1600      1800      2000

Pooled StDev = 57,6
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Fig. 8. ANOVA Results for Medium – Large Aircraft with High Occupancy

Finally, Table 1 summarizes the results associated to the 18 different scenarios considered. It is worthy to highlight that, according to these results, in all scenarios the Random method results to be the one employing less time to complete the boarding. Also, notice that the higher the occupancy level, the larger the difference among the different strategies.

Table 1. Summary Results (times in time-based units)

	Medium-Small Aircraft			
	Random	BtF	FtB	nIterations
Medium Occupancy Level	495.8	565.1	747.1	30
High Occupancy Level	1008.5	1330.9	1522.7	30
	Medium Aircraft			
	Random	BtF	FtB	
Medium Occupancy Level	574.1	654.4	855.7	30
High Occupancy Level	1140.8	1517.9	1746.2	30
	Medium-Large Aircraft			
	Random	BtF	FtB	
Medium Occupancy Level	663.1	754.5	957.6	30
High Occupancy Level	1314.3	1707.8	1934.1	30

5 Conclusions

This paper has analyzed, using simulation, different boarding strategies in a set of common scenarios. Our results seem to confirm that the traditional and most common boarding method, which corresponds to the back-to-front approach, is not the most efficient one. In contrast, the random boarding strategy seems to perform the best in all scenarios. This conclusion is coherent with some previous studies, which suggested that airline managers should apply a certain boarding method according to the airplane size, or the occupancy of the flight. Also, as observed in our simulation study, the passenger occupancy level becomes a very important issue. In fact, our results help to quantify how the time difference among boarding methods increases as the occupancy level raises. For future work, we plan to consider planes with two boarding doors and two aisles.

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