Journal of Air Transport Management 18 (2012) 64–67

Contents lists available at SciVerse ScienceDirect

Journal of Air Transport Management

journal homepage: www.elsevier.com/locate/jairtraman

Experimental test of airplane boarding methods

Jason H. Steffen [a,*], Jon Hotchkiss [b]

[a] Fermilab Center for Particle Astrophysics, MS 127, PO Box 500, Batavia, IL 60510, USA
[b] Hotchkiss Industries, Sherman Oaks, CA, USA

Keywords:
Airplane boarding methods
Aircraft turn arounds

ABSTRACT

We report the results of an experimental comparison of airplane boarding methods. This test was conducted in a mock Boeing 757 fuselage, located on a Southern California soundstage, with 12 rows of six seats and a single aisle. Five methods were tested using 72 passengers of various ages. We found a significant reduction in the boarding times of optimized methods over traditional methods. These improved methods, if properly implemented, offer the potential for significant savings to airline companies.

1. Introduction

Recently Nyquist and McFadden (2008) found that the average cost to an airline company for each minute of time spent at the terminal is roughly $30. Thus, each minute saved in the turn-around time of a flight has the potential to generate over $16,000,000 in annual savings assuming 1500 flights per day. While the boarding process may not be the primary source of delay in returning an airplane to the skies, reducing the boarding time may effectively eliminate passenger boarding as a contributor in any meaningful measure.

Nagel and Ferrari (2005), Bazargan (2007), Landeghem and Beuselinck (2002), Bachmat et al. (2006), Steffen, (2008a,b) and others conclude that optimization is essentially a reduction of the number of times that passengers must either wait for or traverse each other, whether in the aisle (an aisle interference) or within a given row of seats (a seat interference). One optimized method of boarding is having the passengers seated at the windows boarding first, followed by the middle and aisle seats (hereafter called "Wilma"). Another method is the "Reverse Pyramid" method that adds an emphasis on boarding the rear of the cabin first (van den Briel et al., 2005). Both the Wilma and the Reverse Pyramid methods eliminate seat interferences and, to differing degrees, aisle interferences.

Many of these studies concentrated on methods involving boarding groups rather than having passengers line up in a specified order. Thus, one can identify the best method of those that were tested, but not the optimum boarding method overall. Steffen (2008a) claims to have identified the optimum boarding method under certain assumptions. The "Steffen method" added to the reduction of aisle and seat interferences the idea of efficient, parallel use of the aisle. For example, if passengers are ordered such that the plane boards from the rear window seats, row-by-row to the front aisle seat there would be no seat interferences and no passenger would need to pass another in the aisle. In this scenario, however, only the lead passenger or two would be able to stow their luggage with the rest of the passengers simply be filling the aisle; aisle interferences become universal instead of being eliminated.

The Steffen method, on the other hand, orders the passengers in such a way that adjacent passengers in line are sitting in corresponding seats two rows apart from each other (e.g., 12A, 10A, 8A, 6A, etc.). This method eliminates seat interferences and, as much as possible, aisle interferences while allowing multiple passengers to stow their luggage simultaneously. The separation between adjacent passengers provides some space for each passenger to manipulate their luggage into the bins. Other methods, such as Wilma and the Reverse Pyramid also realize parallel use of the aisle in a natural way as adjacent passengers are frequently sitting in widely separated rows.

Practical implementation aside, the Steffen method claims to be the fastest possible way on average to board passengers onto a plane with a single door and a single aisle. We test that claim, as well as whether random boarding, where passengers have assigned seats but are allowed to board at any time, performs as well as Wilma and whether boarding in blocks perform worse than the Wilma, random, and Steffen methods.

2. Experimental setup

The experiment is conducted at the Air Hollywood soundstage in Studio City, California. The narrow-body mock Boeing 757

* Corresponding author.
E-mail address: jsteffen@fnal.gov (J.H. Steffen).

0969-6997/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jairtraman.2011.10.003

airplane used has 12 rows of six seats with a single, central aisle. A small first-class section of two rows of seats is used for camera and lighting equipment. The width of the fuselage is 11′ 7″. Each seat has the standard 17″ width not including the 2″ armrest. Rows of seats are spaced at 32″ and the aisle is 21″ wide. The overhead bins are standard for older-model aircraft, but are slightly smaller than modern bins. They do not accommodate standard size roll-aboard luggage when inserted wheels first.

We employed 72 volunteers and Hollywood extras ranging from young children age five through retired seniors with the bulk being employment-age adults as passengers. They generally had a bag, roll-aboard carry-on, or both, though a number had no luggage. When all passengers were on board with their luggage stowed there was very little remaining space in the overhead bins; none that was useful for additional storage. Thus, when the airplane was full, so were the overhead bins, although, there was never a time when a piece of luggage would not fit somewhere in the aircraft. Since excess luggage would likely affect each boarding method in a similar way the relative ranking of the methods in terms of the boarding time would not be affected.

Each passenger was given a set of five tickets with a seat assignment and either a passenger number or boarding group number depending upon the method being tested. The methods were labeled numerically so that the passengers did not know which was being tested. Seat assignments were chosen randomly such that passengers did not sit in the same seat with each method, nor were they deliberately placed in the same location in the line or in the same boarding group. The only exceptions to these rules were three parent–child pairs who always had two adjacent seats, and who were always at the front of the line, boarding first.

Finally, passengers used their individual luggage and did not swap luggage with other passengers. One could argue that swapping luggage would make the test of each method more robust, but it is not clear this would be the case as fatigue with boarding the aircraft several times could mitigate the benefit of practice. Moreover, the scenario is more representative of airplane boarding as passengers are likely to have the same or similar bags with them whenever they travel. Also, since passengers were generally not sitting in the same seats, and did not board at the same time with each method, the luggage that was already stowed in the overhead bins would be different with each test adding, to some extent, the desired randomness.

3. Boarding methods

The five methods that were tested were; boarding from the back to the front of the aircraft in a specified order, boarding in four-row blocks, the Wilma method, the Steffen method, and, random boarding (see Figs. 1–5).

The back-to-front method had passengers in a specific order starting with the back row window seats, then middle seats, then aisle seats. This pattern repeated itself for the rest of the rows moving toward the front of the plane. A naive guess regarding the most efficient method to board an airplane might suggest that this method is optimal as it is orderly, boarding passengers from the back of the plane to the front and from the windows to the aisle, and it avoids all seat interferences, excepting priority boarding.

The block method divided the 12 rows into three groups of four rows. The back four were the first group, followed by the front four, and finishing with the center four rows. The decision to use this method rather than boarding in blocks from the back to the front was arbitrary, but the results should be representative of either method. We also use three boarding groups rather than four so that each would involve a larger number of rows, making it more similar to what would be expected on a full-size aircraft and capturing more of the benefits of having more rows available to the passengers in each group.

Front						
						13
8	10	12		11	9	7
2	4	6		5	3	1

Fig. 1. Back to front seating order.

The Wilma method used three boarding groups with the first being all window seats, the second being all middle seats, and the third group being all aisle seats. Within each group the passengers were essentially random. Thus, the method when followed would avoid passenger seat interferences, but would have passenger aisle interferences.

The Steffen method has the passengers lining up in a prescribed order that incorporates, in a specific way, boarding from the back to the front and from the windows to the aisle. Adjacent passengers in line are sitting two rows apart from each other in corresponding seats (e.g. 12F, 10F, 8F, 6F, 4F, 2F) and there are 12 successive waves of passengers that fill the window, middle, and aisle seats on each side of the cabin for the even- and odd-numbered rows.

The final method was random boarding with a single boarding group. Since each passenger still had an assigned seat, it is not equivalent to the free-for-all method where passengers select their seats at will. There is an important distinction between random boarding where the passengers have assigned seats but not an assigned place in line and free-for-all boarding. Free-for-all boarding is not random because passengers can make decisions about where to sit once they observe the state of the cabin; they can

Front						
2	2	2		2	2	2
2	2	2		2	2	2
2	2	2		2	2	2
2	2	2		2	2	2
3	3	3		3	3	3
3	3	3		3	3	3
3	3	3		3	3	3
3	3	3		3	3	3
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1

Fig. 2. Block boarding groups.

Front						
1	2	3		3	2	1
1	2	3		3	2	1
1	2	3		3	2	1
1	2	3		3	2	1
1	2	3		3	2	1
1	2	3		3	2	1
1	2	3		3	2	1
1	2	3		3	2	1
1	2	3		3	2	1
1	2	3		3	2	1
1	2	3		3	2	1
1	2	3		3	2	1

Fig. 3. Wilma boarding groups.

Front						
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1
1	1	1		1	1	1

Fig. 5. Random method boarding group.

choose to avoid an aisle or seat interference where passengers in the random boarding method cannot.

4. Results

For each method there are two reported boarding times. The first "official" time is the elapsed time from when the first passenger set foot in the aircraft until the last one was seated. The "extended" time is the elapsed time from when the passengers were told to proceed to board until the last passenger was seated. These times differ by only a few seconds and we report both; the difference representing the time it took passengers to walk approximately six feet and to climb two stairs into the airplane (Table 1).

We recognize that there are random fluctuations in the boarding process and that in the absence of multiple realizations of the experiment our boarding times are only estimates of the mean boarding time for each method. It was not feasible to re-run each boarding method several times. As the variance in the boarding time comes from a series of random interferences, a reasonable estimate of the fractional uncertainty of the mean boarding time is approximately ,$1/\sqrt{72}\sim 10\%$.

Front						
24						18
12						6
23						17
11						5
22						16
10					28	4
21						15
9					27	3
20						14
8					26	2
19						13
7					25	1

Fig. 4. Steffen method seating order.

There may be some systematic biases at play in the results; for example, the quantity and size of the luggage that the passengers carried may be different to that a similar group might take. This difference, and others are more likely to affect the length of time each method takes to board than they are to affect the ratios of those times. Thus, while our times may be systematically low or high compared to what one would experience at an airport, the ratios of those times should be very similar in the various environments. Regardless, given the full capacity of both the airplane and the overhead storage areas, the wide range in passenger ages, and the random nature of the experiment, the potential sources of bias will likely have a relatively small effect on the boarding times.

5. Discussion

One thing that became apparent in this exercise is that not all seat interferences have an equal effect on boarding times; only those seat interferences that cause an aisle interference turn out to be important. If the line of passengers is held up at the front of the cabin, then seat interference near the rear of the cabin will have a reduced effect, or no effect, on the boarding process. Similarly, not all aisle interferences are equal. An aisle interference where one passenger blocks another that is seated in an adjacent row is somewhat less important than an interference where the blocked passengers needs to subsequently walk several rows to reach their seat. These two subtleties in the effects of interferences can play off of each other in useful ways; for example, in accommodating traveling companionships.

The Steffen method places all of the aisle interferences near the front of the cabin. Thus, a seat interference, or even a second aisle interference, near the rear of the cabin will have reduced effect on the boarding time since rest of the line is stopped far from it, and will take time to reach it once that interference has cleared. In this

Table 1
Elapsed time for each boarding method in minutes and seconds.

Method	Official	Extended
	Time	Time
Back-Front	6:11	6:16
Blocks	6:54	6:56
Wilma	4:13	4:21
Steffen	3:36	3:40
Random	4:44	4:48

manner, traveling companionship who wish to board together could be strategically inserted into the queue in a way that naturally allows them a little extra time to vacate the aisle before the remainder of the line reaches them. Indeed, doing so would yield a slight improvement to the boarding time, at best the savings would be roughly the time it takes for a single wave of passengers to start from rest and reach their seats in the airplane, although it is not clear that all of this time savings can be achieved.

6. Conclusions

The evidence from our experiments strongly supports Steffen's heuristic argument that parallelize the airline boarding process by more efficiently utilizing the aisle by having more passengers stow their luggage simultaneously will lead to quicker boarding. Given the observed boarding times, the Wilma method boards faster than block boarding by a factor of almost 1.7 while the Steffen method boards faster by almost a factor of two. While random boarding did not perform as well as Wilma, it was respectably fast, with the difference in time being due to the increased number of seat interferences. Block boarding performed worse than all methods tested.

Acknowledgments

We wish to thank the staff at Hotchkiss Industries for their work in preparing and executing this experiment. We also wish to thank the many participants who devoted the greater part of a day to the project.

References

Bachmat, E., Berend, D., Sapir, L., Skiena, S., Stolyarov, N., July 2006. Analysis of aeroplane boarding via spacetime geometry and random matrix theory. Journal of Physics A Mathematical General 39, L453–L459.

Bazargan, M., 2007. A linear programming approach for aircraft boarding strategy. European Journal of Operational Research 183, 394–411.

Landeghem, H.V., Beuselinck, A., 2002. Reducing passenger boarding time in airplanes: a simulation based approach. European Journal of Operational Research 142 (2), 294–308.

Nagel, K., Ferrari, P., 2005. The secrets to faster boarding. International Airport Review 3, 41–45.

Nyquist, D.C., McFadden, K.L., 2008. A study of the airline boarding problem. Journal of Air Transport Management 14, 197–204.

Steffen, J.H., 2008a. Optimal boarding method for airline passengers. Journal of Air Transport Management 14, 146–150.

Steffen, J.H., 2008b. A statistical mechanics model for free-for-all airplane passenger boarding. American Journal of Physics 76, 1114–1119.

van den Briel, M.H.L., Villalobos, J.R., Hogg, G.L., Lindemann, T., Mule, A.V., 2005. America west airlines develops efficient boarding strategies. Interfaces 35, 191–201.