Boarding of an airplane

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Abstract

Boarding an airplane is time consuming and a bit chaotic. To ensure that this procedure is smooth and efficient it is relevant to study different ways of boarding. A quick boarding saves time and money, but the most time efficient course of action might not be a realistic solution or one that makes the customers satisfied. In this report an agent based model was implemented to simulate the boarding procedure and five different boarding methods were evaluated, namely Back to front, WILMA, Random, Rotating blocks and Steffen modified. These simulations where used to estimate the time efficiency of the different methods. It is easy to assume that a random boarding will be the most inefficient method, but this turned out to be false and the efficiency was average compared to the other four methods. The method WILMA outperformed the other methods in every aspect that was taken into account for this simulation. The obtained results mostly coincides with previously done studies, but Steffen modified ought to have performed better than it did in this study. This suggests that the used model is too simplified to receive fully reliable results, but in broad strokes they seem accurate.

1 Introduction

An efficient boarding is an important part of a pleasant flight for all passengers and a crucial component of maximising income for the airline. This study aims to investigate the fastest method to board an airplane. The performance of five methods will be compared, and the results will be put in contrast to other studies on the topic. The used boarding methods are a mix of methods used in real life and methods commonly investigated in other articles regarding boarding efficiency.

The turnaround time of an airline is defined as the time that passes from that the captain sets the break until the airplane starts moving again. The cost for an airline to have an airplane at the terminal is roughly $30 per minute and for an airline with many airplanes, reducing the turnaround time can reduce the annual costs significantly [1]. Many of the necessary processes can take place simultaneously, such as cleaning, catering and fuelling. However, the boarding process cannot start until most of the other processes have been finished, and it takes up a significant part of the turnaround time. For this reason, by reducing the boarding time one will also reduce the turnaround time [2]. While the airlines are exposed to a highly competitive market and therefore always must try to increase the efficiency in order to reduce the costs, the customer satisfaction needs to increase at the same time.

From the passengers point of view, the fastest way to board an airplane might not result in the best experience. The passengers have different needs, some travel as families or as groups and therefore wants to board together, they carry luggage, have different walking speeds etc. In addition to the boarding time, the customers satisfaction is important to consider for an airplane when choosing what boarding method to use [3].

Nevertheless, an efficient boarding is essential to avoid delays in the flight schedule and hence interference in the process are one of the main reasons for delays. There are two main bottlenecks when it comes to the boarding process. One is seat interference, when one passenger is blocking the seat for another passenger and have to get up and let the other in. The other is aisle interference, mainly caused by storing the hand luggage [4].

There are some methods of boarding that are more commonly studied and used than other, regardless of efficiency and customer satisfaction. The most commonly studied methods are listed below and showed in Figure 1.

- *Back to front* - The plane is divided in a number of blocks, where the passengers in the backmost block boards first, then the passengers in the block next to the backmost block and so on. Lastly the passengers in the foremost block board [5] [3] [2].
- *WILMA, also known as Outside in* - The passengers with a window seat boards first, then the ones with a seat in the middle of the row, and lastly the passengers with a seat beside the aisle are allowed to board [5] [3] [2].
- *Random* - The order of boarding is decided by the principle "first come, first serve", but the seats are assigned beforehand [5] [3] [2].

- *Rotating blocks* - The plane is divided in a number of blocks and the passengers in the backmost block boards first, as in *Back to front*. Then, a block that is not connected to the back most block is boarded. This will continue until all blocks are boarded [2].

- *Steffen perfect* - Each passenger has a specific position in the boarding order. These positions are given with respect to row and seat, since this method boards the passenger in a WILMA like style, but the passengers are ordered back to front (not in blocks), and only each other row is boarded at the same time. [3] The Steffen perfect method of boarding an airplane is developed to be the fastest possible boarding method [6].

- *Steffen modified* - One of the advantages with Steffen perfect is that the passengers that are boarding don't sit near each other and therefore can load their luggage at the same time. One other way to achieve this is with the Steffen modified boarding method. There are four boarding groups, the first is all even rows on one side of the airplane, the second group is the even rows on the other side of the plane. The third and fourth group consists of the odd rows of respective side of the airplane [6].

There have been many studies to determine which the fastest boarding method is. Most of them show that Back to front performs worse than other methods like for example the methods WILMA or Random. It has been concluded that the fastest way to board is to board by seat instead of block, a method like this is Steffen perfect, though these methods are often complicated to use and not the most customer friendly ones [7]. According to a study by Steffen and Hotchkiss, the Steffen perfect method performed the best followed by WILMA and Random. Rotating blocks took the longest time followed by Back to front, however, in this study the back to front method was not by block but instead by seat [2]. In another study done by Steffen, the method Steffen modified was decided to be the next fastest method, again followed by WILMA and Random. In this study Back to front as defined here was used as well, which performed worse than Random but better than the method ordering the passengers by seat from back to front [6].

2 Model

An agent based model is used to simulate the boarding precedure. It consists of an airplane represented by two different two dimensional matrices, and agents who can move in a Von Neuman neighbourhood in the plane. The first matrix of the plane has elements that takes three different values depending on if the tile is a seat, aisle or unavailable space. The second matrix keeps a map of where all passengers are in the plane and which tiles that are empty. The passengers are the agents of the model. They are moving at a pace of one tile per time step and there can only be one agent on a tile for each given time. Putting luggage in the luggage bin takes two time steps, this approximation of time duration is loosely based on a similar study [3], and will leave the passenger blocking the aisle during this time. Every agent has its own seat destination and are boarding the plane in different groups depending on the boarding scheme, but the boarding is done continuously without a hiatus between the groups.

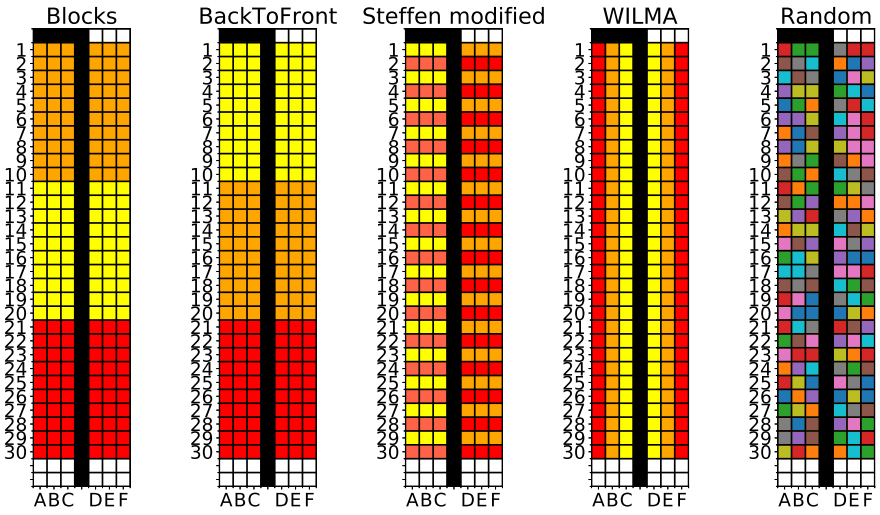

Figure 1: A map over the boarding methods described in the introduction. Red color boards first, followed by light-orange, dark-orange and lastly yellow. The different colors in Random shows that this method is boarded by seat and in a random pattern.

The measured time to board will be the number of time steps between the first agent entering the airplane and the last agent to find its seat. Five different boarding methods will be reviewed: Back to front, Steffen modified, WILMA, Rotating Blocks and Random.

A model used to simulate the boarding could be varied indefinitely. The limitations and rules that is used in this model are listed below.

- The airplane used is similar to a Boeing 737. It has a narrow aisle with three seats on each side and 30 rows of seats.
- All seats are regarded as economy class and no passenger are prioritised during boarding.
- The plane is fully occupied.
- The aisle can fit one passenger per row of seats.
- The luggage will always fit in the bin above the row in which the passenger is seated.
- If a passenger is at the correct row and blocking another passenger from reaching their seat, then the first passenger will move out and down the aisle to let the second passenger pass.
- Every passenger has the same properties, i.e. they walk at the same speed, have the same amount of luggage and have no special needs.
- Passengers are viewed as individuals and no groups are considered.

- Nothing unexpected will happen during boarding and the boarding method will be followed perfectly, i. e. no passenger will take the wrong seat or take a wrong turn.

3 Results

The simulation was run 1000 times for each method. The resulting distribution for the measured time it takes to board the plane, time before seated, time spent in aisle and number of times to stand up while seated is visualised by box plots.

The boarding time, i. e. the time it took from the first passenger to take the first step into the airplane until all passengers where seated, was measured in number of time steps for all the five methods. Figure 2 shows the resulting distribution after 1000 runs on each method. Table 1 in Appendix A shows the exact mean and median values.

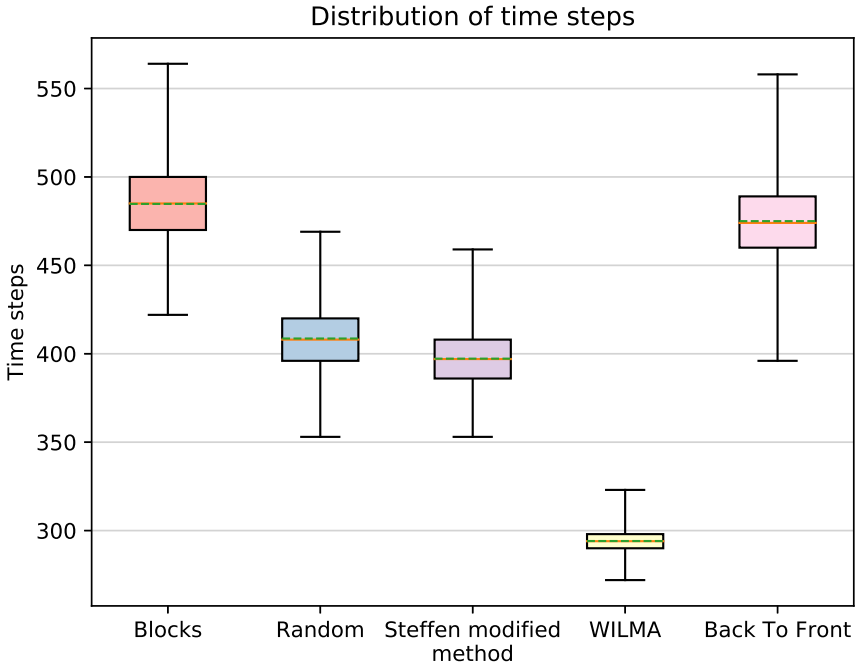

Figure 2: The figure shows the distribution of the number of time steps it takes to fully board the airplane for five different boarding methods. The median and the mean for each distribution are represented by a red line and a green dashed line respectively.

Some factors that could be important in regards to the passengers experience of the boarding process was measured and that data is collected in Appendix A. The distribution of time it took for each passenger to get to its correct seat, using the different boarding methods, was measured over 1000 runs and is shown in Figure 3. The distribution of time each passenger spent in the aisle is shown in Figure 4.

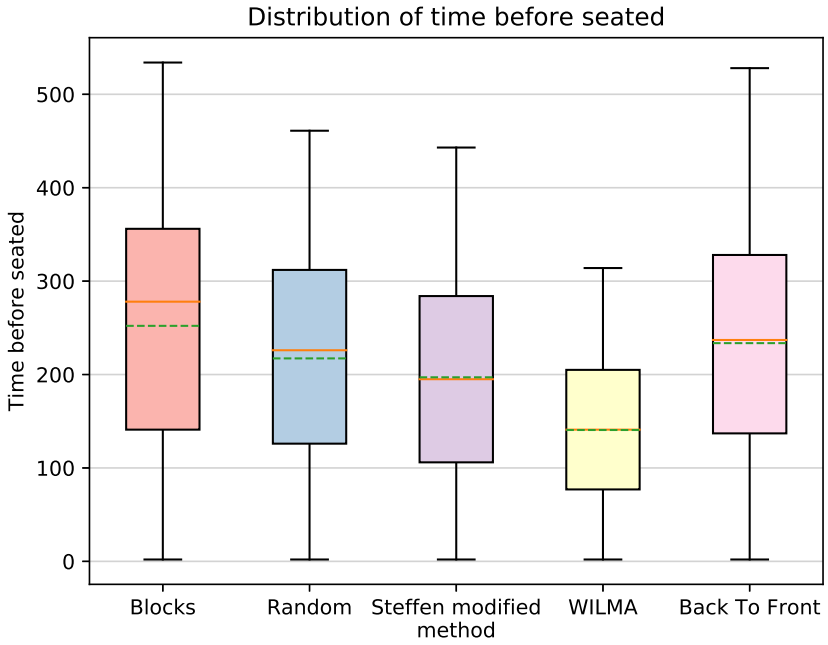

Figure 3: The graph above shows the distribution of time it took each passenger to finding the right place, including time waiting outside the airplane, during the boarding of an airplane for five different boarding methods. The median and the mean for each distribution are represented by a red line and a green dashed line respectively.

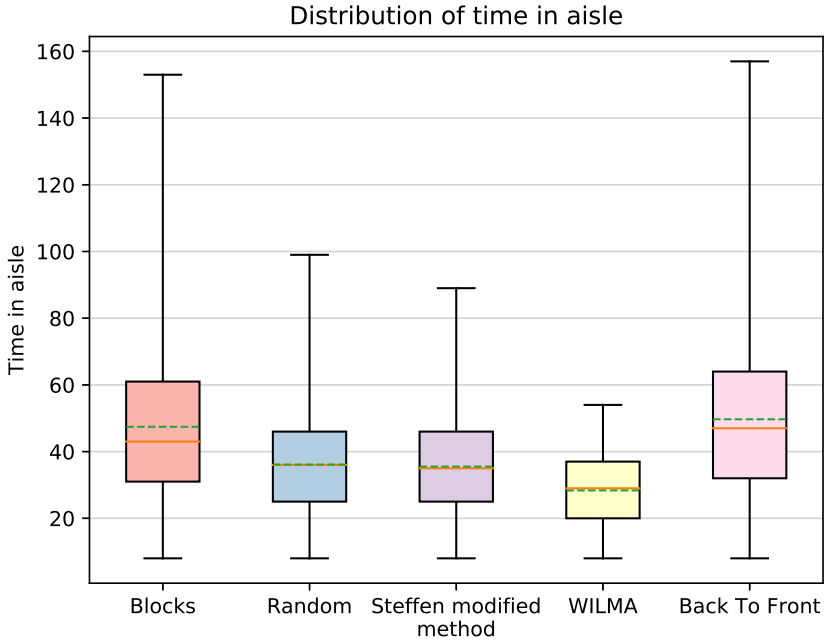

Figure 4: The figure shows the distribution of time each passenger had to wait in the aisle during the boarding of an airplane for five different boarding methods. The median and the mean for each distribution are represented by a red line and a green dashed line respectively.

The distribution of the number of times each passenger had to rise from seated and let another passenger in to it's seat was also measured and can be seen in Figure 5.

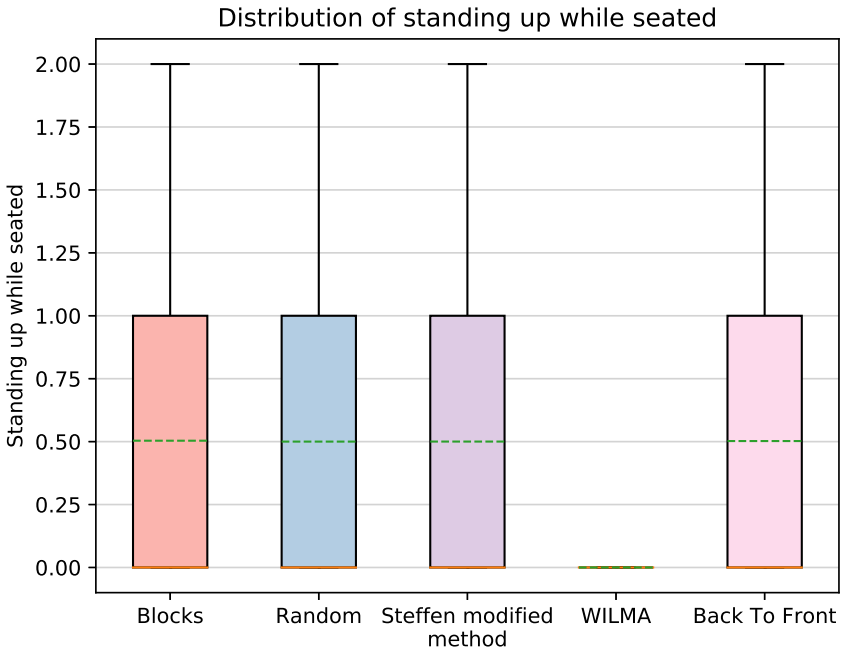

Figure 5: The distribution of number of time each passenger had to stand up from seated, to let another passenger in during boarding for five different boarding methods. The median and the mean for each distribution are represented by a red line and a green dashed line respectively.

4 Discussion

The results obtained from the performed simulation, seen in Table 1, largely agrees with the results found in literature. As stated in the introduction, the method Back to front generally performs worse than if one of the boarding methods Random, Steffen modified or WILMA were to be used, which corresponds well with the obtained results. The results show that the boarding method WILMA by far performs the best of all methods in the simulations done with this model. The biggest deviation in the obtained results in comparison with the results found in previous studies is the performance of the method Steffen modified. This method usually performs very well, usually a bit better than WILMA, but in this case it doesn't stand out either as a slow or fast method [6]. This indicates that the rules and limitations used to set up the model might not be ideal for this problem and that the model is a bit oversimplified.

The strength of the WILMA method is that the boarding is constructed so that no seat interference occur at all, which suggests that the seat interference is the greatest reason for a slowed down boarding. However, the accuracy of the used model should be considered before any definitive conclusions could be reached. It is especially important to analyse the estimation of time duration for each procedure. In this model, each passenger is taking two time steps to store the luggage in the storage area and, given that the aisle is empty, takes two respectively three time steps to move from

ones seat to let another passenger in, depending on where the passenger sits. If the aisle is crowded it will take more time for the passenger to enter the aisle and let the other passenger pass, but the extra time will not prolong the boarding time since it is only an extension of the blocking further down in the aisle. The accuracy of these time estimations in relation to each other will have an impact on the performance of the methods and how they compare, since some of the methods reduces the number of seat interferences and other instead reduces the number of aisle interferences.

If the time it takes for a seat interference is overestimated, it is likely that the performance of the methods that avoids these kinds of events performs better than what is realistic. Based on Figure 5, a change in the estimation of consumed time to get up and let another passenger in would not affect boarding using WILMA. Hence an overestimation of the time of seat interference will slow down all other methods except for WILMA . This could explain why WILMA is much faster than the other methods, but it does not explain why Steffen modified is not as good as other studies show. In that case, it is more probable that a change in the estimation of time for putting away luggage would have a greater impact. This will make the methods with crowded aisles even more crowded, but will not affect less crowded methods like Steffen modified as much.

The model used here is a very simplified version of an actual boarding, which makes it possible, and probable, that the results are misleading. A big problem during boarding is to find space for the carry on luggage since the bins over the seat often get full, which forces passengers to scramble through a crowded aisle. This time consuming aspect has not been taken into account in the results presented above. If this would be added, it would probably affect the used boarding methods differently. With a more realistic model the various advantages and disadvantages of the boarding methods would become more prominent. Since one of the greatest advantages of Steffen modified is to avoid a very crowded aisle this method is likely to be less affected, but a method like Back to front is expected to drastically become more time consuming. From Figure 4 it can be seen that the passengers spend the most time in the aisle using Back to front out of all the methods, and therefore the aisle will be very crowded using this method. Furthermore, it is also probable that the Blocks method will be slowed down significantly by a more complex luggage management since the time in the aisle is almost as long as with Back to front boarding.

Not all methods used in this report would be possible to implement perfectly due to various reasons. Some of the methods have high demands on the order of the passengers, and will not work as expected if this order is not followed. It can be difficult to implement such methods since some groups and families are less content with being separated during boarding. A boarding using the WILMA method forces passengers that sit in the same row to board at different times, which is simply not possible for families with younger children. This model does not take these limitations in to account, and neither does it measure the passengers satisfaction with the boarding procedure. The random method is here implemented as if all passengers travel alone and board randomly. In reality groups would board together if no specific boarding order was enforced which could affect the boarding time. Groups and families would be a crucial aspect to include to be able to draw more realistic conclusions.

5 Conclusion

Solely based on the obtained results, using the method WILMA would be the fastest way to board an airplane. This differs from previous studies where Steffen modified is found to be the fastest method among those used in this study. The deviation is probably obtained through oversimplification. An analysis of the time spent in different stages shows that aisle interference is an important factor when minimizing the boarding time.

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A Appendix

Method	Mean time steps	Median time steps
Blocks	484.7	485
Random	408.6	408
Steffen modified	397.2	397
WILMA	294.1	294
Back to front	475.0	474

Table 1: The mean boarding time for five boarding methods, calculated over 1000 runs.

	Boarding method:	Blocks:	Random:	Steffen modified:	WILMA:	Back to front:
Time in aisle:	Mean Min/Max Median	47.4 11/108.1 43.2	36.1 8.9/73.3 35.8	35.5 9/69 35.5	28.4 8.6/48.3 28.6	49.7 11/108.8 47.6
Times to stand up while seated:	Mean Median	0.5 0	0.5 0	0.5 0	0 0	0.5 0
Time to get seated:	Mean Min/Max Median	252.1 2.2/453.4 281.5	217.3 2.2/395 226.1	197 2.2/383.4 194.7	140.6 2/279.8 140.7	233.6 2.2/443.6 237.8

Table 2: The measured data that could have an impact on the customers experience of the boarding process. The simulation was run 1000 times. Min/Max are the mean maximum and minimum values.