A Practical Approach to Boarding/Deboarding an A380

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ABSTRACT

The highest source of inefficiency in an airplane's day of flying is its time spent on the ground. This paper presents an analysis of different boarding and deboarding methods onto an Airbus A380, the largest passenger airplane to date. The methods surveyed are various adaptations of the WilMA (Window, Middle and Aisle) method of boarding a plane, which are tested by computer program. The result of the analysis showed that loading the back of the plane before the front of the plane in the WilMA style yielded the fastest results. However, due to the impracticality and complexity involved in getting passengers lined up in WilMA order and in the "front to back" order at the same time, we decided to choose the second fastest method as the most efficient method for boarding the A380 airbus considering the method is more practical than our fastest method.

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1. Introduction

On December 17th, 1903, Orville Wright was airborne for twelve seconds in what would be the first powered and piloted flight in history. More than a century since then, air travel has become the standard means of travel for millions of businessmen, immigrants, and tourists. A growing global population means a growing demand for mass transit, and the airline industry meets this demand by building more airports, airing more flights, and purchasing bigger planes. To deal with the growing market, engineers at Airbus devised the A380, reputed to have "the most spacious interior of any jetliner every built, the biggest wings, and the greatest overall thrust" (Norris). However, this spacious interior holds a huge number of seats, which must be filled in an efficient fashion to minimize the time that the jumbo jet spends on the ground. Two levels of passenger seating combined with several entry points to the plane provide both an unparalleled capacity and previously unseen potential for fast loading. Airports around the world are scrambling to retrofit their airports to make use of the two-level boarding options that the A380 presents, building two Passenger Load Bridges (PLBs) to the lower level of the plane and one to the top. This paper explores previously-researched boarding methods as well as several variations of the WilMA style of boarding.

2. A380 Boarding Efficiency

Airports around the world are in preparation to allow for the A380 airplane to dock at terminals using two or three PLBs. Narita airport is expecting to have eight docks for A380's and five of these to be equipped with three PLBs by 2008. Frankfurt airport is also preparing for the A380 and equipping all 13 of their terminals that the A380 will dock at with three PLBs each. Figure 1 displays the way the three PLBs will be placed for boarding the aircraft. The task to board airplanes as quickly as possible has always been a challenge for airlines. An efficient method of boarding for the A380's claimed maximum seating of 853 passengers presents an even bigger problem. Currently, the A380 airbus that has been designed can carry only 555 passengers. As of today, there is no information available to the public about the design and the seat arrangement layout of the A380 with 853 seats, and no planes of this configuration have been ordered. Hence, in tackling the boarding problem given to us, we do not consider the A380 with 853 and our models will be based off the seating arrangement of 555 three-class seats for the A380.

Figure 1: Location of three PLBs to the A380

Boarding procedures in general have been meticulously calculated by experts around the world using examples of single aisle planes with 3 seats on each side of the aisle. There has also been some research done on boarding procedures by scientists at Arizona State University and a few graduate students across the country. Using the data and some results from their research, we have come up with the most efficient boarding method that takes advantage of the design of the plane (whose highlights are three PLBs, two decks connected by stairs and two aisles in each deck). Our method utilizes the design of the A380 and combines it with strategies that minimize seat interference during the boarding process. Our group has come up with a boarding method that is fast considering that there will be a large number of passengers (up to 555) to be loaded. In fact, our method devised for the 555-seater A380 allows for quicker boarding than single aisle planes with far fewer passenger capacities.

2.1 Important Considerations for the Model

What goes into making a good model for boarding an airplane? Airlines want to be as fast as possible in the boarding of passengers but not in a way that will cause distress or complaints from the passengers. It is customary that first class passengers and those who may be disabled are boarded first on planes. Our model takes that into account and we have been able to maintain the expectance that many passengers have when boarding planes.

Airlines want the process of boarding to be as fast as possible as well as maintain a controlled environment for the passengers. Typically airlines such as Southwest have adopted “random” seating in which passengers come on a first come first serve basis for sitting in an airplane. Studies have shown “random” seating to be faster than block seating arrangements or row seating. However due to the fact that the A380 is a double-decked plane and the fact that it has a passenger load of 555 people, the idea that “random” seating would work is realistically out of the question. With the number of people as large as 555 (the current A380 capacity), “random” seating would be very inefficient because of the great amount of seat and aisle interference from passengers transferring from one deck to another, looking for window seats, etc. In this situation, “random” seating will be far less efficient compared to calling out one row at a time.

Our intuition and logic suggested that the best way to minimize seat interference would be by filling up all of the window or inner seats first, followed by the middle seats and then the aisle seats. This type of seating method has been mathematically proven to be the most time efficient way of boarding. This method is known as “WilMA” (Windows, Middle and Aisle). Given that we have three PLBs to the plane and two aisles in each of the decks, we can simultaneously board passengers to the lower and upper decks and to all classes (business, first and economy). At each of the PLBs, we can board the plane in three stages, each time boarding passengers with the same “type” (Window/Innermost, Middle and Aisle) of seats together. The presence of three PLBs, two aisles in each deck and the stairs connecting the two decks may even allow for a faster boarding time than a single aisle airplane that normally would take 23 minutes to fully load.

2.2 The design and the seat arrangement layout of the A380 (555 seats)

The A380 has three entry points for passengers to come in, which we have labeled as PLB A, PLB B and PLB C in Figure 2. This allows us to have three flows of passengers entering the plane simultaneously, thus reducing the boarding time significantly. The main question is which sections of the plane must be filled using which PLBs as there are only three PLBs and a total of seven sections to be filled. The sections are labeled 1, 2, 3, 4, 5, 6 and X+Y as show in Figure 2 below. Section 1 is the first class, sections 4 and 5 are business class and sections 2, 3, ‘X+Y’ and 6 are all economy class. We have carefully measured the length of each section in terms of how many economy-size class rows we are able to fit in each section. We used the length of one economy-size row as our standard unit of measurement for the length of the various sections of the airbus.

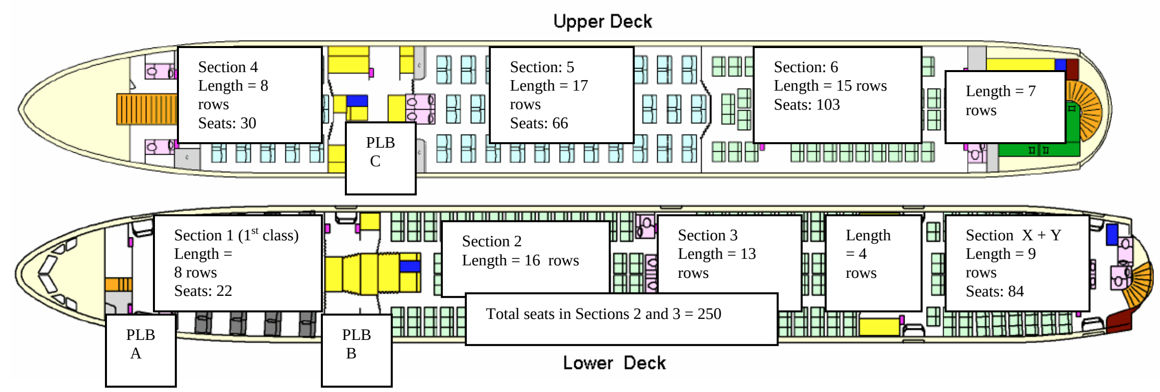

Figure 2: Design of the A380 and the seat arrangement layout.
Section 1 is first class, sections 4 and 5 are business class and sections 2, 3, 6 and X+Y are all economy class. A row, the unit of measurement for the length of the sections, is defined as follows: 1 row = length of 1 economy-size row.

Using logical reasoning, we have come up with the following plan for determining the flow of passengers into the A380. Disabled passengers and passengers with special needs are boarded first to avoid any potential congestion these passengers may cause if boarded with the rest of the passengers. This will also make it easier for the disabled passengers, hence keeping the customer satisfaction high which to the airlines is as important as minimizing the boarding time. Disabled passengers and passengers with special needs whose seats are in Section 1(the first class) will be boarded through PLB A; those whose seats are in Section 4 and 5 (business class) and Section 6 (economy class) will enter through PLB C and those whose seats are in Section 2, 3 and X+Y will board through PLB B.

After the disabled passengers and passengers with special needs have been boarded, the boarding of the rest of the passengers will begin. If we were to use PLB C for boarding all the passengers of the upper deck and PLB B for boarding all the passengers of the lower deck, we would be boarding 169 passengers through PLB C and 334 passengers via PLB B. In this case, common logic suggests that the boarding of the passengers in the upper deck (through PLB C) will be complete long before the boarding of the passengers in the lower deck (through PLB B). No matter how fast boarding through PLB C is done, as long as the boarding through PLB B is not complete, the airplane cannot take off. Therefore, we must find a way which would allow for boarding through PLB B and PLB C to occur in the same amount of time so that no time is spent just waiting for boarding through PLB B to be done.

The best way to do this is by having some of the passengers whose seats are in the last section of the lower deck board through PLB C, go all the way to end of the upper deck and take the stairs down to the lower deck. The last (rear most) section of the lower deck is called 'X + Y' because it has X+Y number of rows, where X (unknown) is defined to be the number of rows (counting from the back of the section 'X +Y') that will seat passengers coming in from PLB C and Y(unknown) is defined to be the number of rows (counting from the front of the section X +Y) that will seat passengers coming in from PLB B. So, we set the amount of time it takes for boarding through PLB B equal to the time it takes for boarding through PLB C in addition to the time that it takes for passengers whose seats are in the ‘X’ region to walk some extra and walk down the stairs from the upper deck to the lower deck.

$$T_{PLB\,B} = T_{PLB\,C} + T_{stairs} + T_{extra\ walk\ by\ 'X'\ passengers} \quad (1)$$

Since WilMA has been mathematically shown to be the best method for boarding passengers in their seats[i], there will be three calls made at each PLB: the first call will be for all passengers in the window/inner seats, the second call will be for all those who have middle seats and the third call will be for passengers who have aisle seats. The time it takes to board sections 2, 3, and ‘Y’ through PLB B is simply the time it takes to board all the window/inner seat passengers, followed by all the middle seat passengers and finally the aisle seat passengers in sections 2, 3 and ‘Y’:

$$T_{PLB\,B} = T_{Window/Inner(2+3+'Y')} + T_{Middle(2+3+'Y')} + T_{Aisle(2+3+'Y')} \quad (2)$$

Similarly,

$$T_{PLB\,C} = T_{Window/Inner(5+6+'X')} + T_{Middle(5+6+'X')} + T_{Aisle(5+6+'X')} \quad (3)$$

The time it takes to fill up all the window seats in sections 2, 3 and ‘Y’ is the time it takes for these window-seat passengers to walk the length of the sections 2, 3 and ‘Y’ and the length of the sections connecting each of these sections and the time taken by some passengers to put away their luggage:

$$T_{Window/Inner(2+3+'Y')} = T_{Walk(16+13+4+Y)\,rows} + T_{luggage\ Window/Inner(2)} + T_{luggage\ Window/Inner(3)} + T_{luggage\ Window/Inner('Y')} \quad (4)$$

Similarly,

$$T_{Middle(2+3+'Y')} = T_{Walk(16+13+4+Y)\,rows} + T_{luggage\ Middle(2)} + T_{luggage\ Middle(3)} + T_{luggage\ Middle('Y')} \quad (5)$$

and

$$T_{Aisle(2+3+'Y')} = T_{Walk(16+13+4+Y)\,rows} + T_{luggage\ Aisle\ (2)} + T_{luggage\ Aisle(3)} + T_{luggage\ Aisle('Y')} \quad (6)$$

We know from previous research done by a team of scientists at Arizona State University led by Menkes H. L. van Den Briel that the speed of a passenger traveling from one row to next is a triangular distribution with an average of 0.95 second/row. Van Den Briel’s data also measured that 60% of passengers stop to store their luggage with an average time of 7.1 seconds/person while 40% of passengers have a luggage time of 0 seconds/person.[1]

So,

$$T_{Walk(16+13+4+Y)\,rows} = Row\,Speed \times Number\,of\ Rows = 0.95 \times (16+13+4+\mathrm{Y}) = 30.40 + 0.95\mathrm{Y} \quad (7)$$

$$T_{luggage(i)} = 60\%\,of\ the\,number\,of\ seat\ passengers\ \ in\ \sec tion\,(i) \times \frac{7.1\sec}{passenger} \quad (8)$$

$$T_{luggage\,Window/Inner(2)} + T_{luggage\,Window/Inner(3)} = 60\%\,of\ 49 \times \frac{7.1\sec}{passenger} \quad (9)$$

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[1] http://www.public.asu.edu/~dbvan1/papers/MatthewPanEssay.pdf

We find the number of passengers of a certain type (window/inner, middle or aisle) in a certain section *i* by counting the number of that type of seats in one half of the that section since there are two aisle serving the total number of passengers.

$$T_{luggage\ Middle(2)} + T_{luggage\ Middle(3)} = 60\%\ of\ 50\ passengers \times \frac{7.1\sec}{passenger} \quad (10)$$

and

$$T_{luggage\ Aisle\ (2)} + T_{luggage\ Aisle(3)} = 60\%\ of\ 26\ passengers \times \frac{7.1\sec}{passenger} \quad (11)$$

For the time taken by window seat passengers in Section 'Y' to load their luggage, we have:

$$T_{luggage\ Window/Inner('Y')} = 60\%\ of\ (2*y)\ passengers \times \frac{7.1\sec}{passenger} \quad (12)$$

$$T_{luggage\ Middle('Y')} = 60\%\ of\ (2*y)\ passengers \times \frac{7.1\sec}{passenger} \quad (13)$$

$$T_{luggage\ Aisle('Y')} = 60\%\ of\ (y)\ passengers \times \frac{7.1\sec}{passenger} \quad (14)$$

Substituting (7),(9) and (12) into (4) we get:

$$T_{Window/Inner(2+3+'Y')} = 239.14 + 9.47Y \quad (15)$$

Substituting (7), (10) and 13 into (5), we get:

$$T_{Middle(2+3+'Y')} = 243.40 + 9.47Y \quad (16)$$

Substituting (7), (11) and (14) into (6), we get:

$$T_{Aisle(2+3+'Y')} = 141.16 + 5.21Y \quad (17)$$

Now we substitute (15), (16) and (17) into (2):

$$T_{PLB\ B} = 623.70 + 24.140Y \quad (18)$$

Calculations analogous to those done in (9), (10) (11), (12), (13) and (14) were performed to find:

$$T_{PLB\ C} + 3T_{extra\ walk\ for\ X} + 3T_{stairs} = (3 \times T_{walk(17+15+X)}) + (3 \times T_{extra\ walk\ for\ X}) + (3 \times T_{stairs}) \\ + T_{luggage\ Window/Inner(5)} + T_{luggage\ Window/Inner(6)} + T_{luggage\ Window/Inner(X)} \\ + T_{luggage\ Middle(5)} + T_{luggage\ Middle(6)} + T_{luggage\ Middle(X)} \\ + T_{luggage\ Aisle(5)} + T_{luggage\ Aisle(6)} + T_{luggage\ Aisle(X)}$$

The value used for T_{stairs} was measured by doing three trials of going down 16 average size, which is the number of steps that the A380 has. Traversing sixteen steps took an average of 7.6 seconds, and by Matthew Pan's calculations, this is equivalent to walking down eight rows. Thus, traversing the steps is the equivalent of walking eight rows.

$$T_{PLB\ C} + 3T_{extra\ walk\ for\ X} + 3T_{stairs} \\ = 3(0.95 \times 32) + 3(0.95X) + 3 \times 0.95(7+3) + 3 \times 0.95 \times 8 + (0.6 \times 22 \times 7.1) + (0.6 \times 26 \times 7.1) + (0.6 \times 2X \times 7.1) \\ + (0.6 \times 11 \times 7.1) + (0.6 \times 26 \times 7.1) + (0.6 \times 2X \times 7.1) + (0.6X \times 7.1)$$

$$\therefore T_{PLB\,C} + 3T_{extra\ walk\ for\ X} + 3T_{stairs} = 504.60 + 24.150X \tag{19}$$

Substituting (18) and (19) into (1):
623.70 + 24.150Y = 504.60X +24.150 (20)
Since we know that X+Y= 9, we can solve (20) for X:

X= 6.964 rows $\approx 7\ rows \qquad \Rightarrow \qquad Y = 2\ rows$

This means that, in order to board in the least amount of time, passengers whose seats are in sections 5, 6 and the last seven rows of section 'X+Y' should be boarded through PLB C. Passengers whose seats are in sections 2, 3 and the first two rows of section 'X +Y' should be boarded through PLB B.

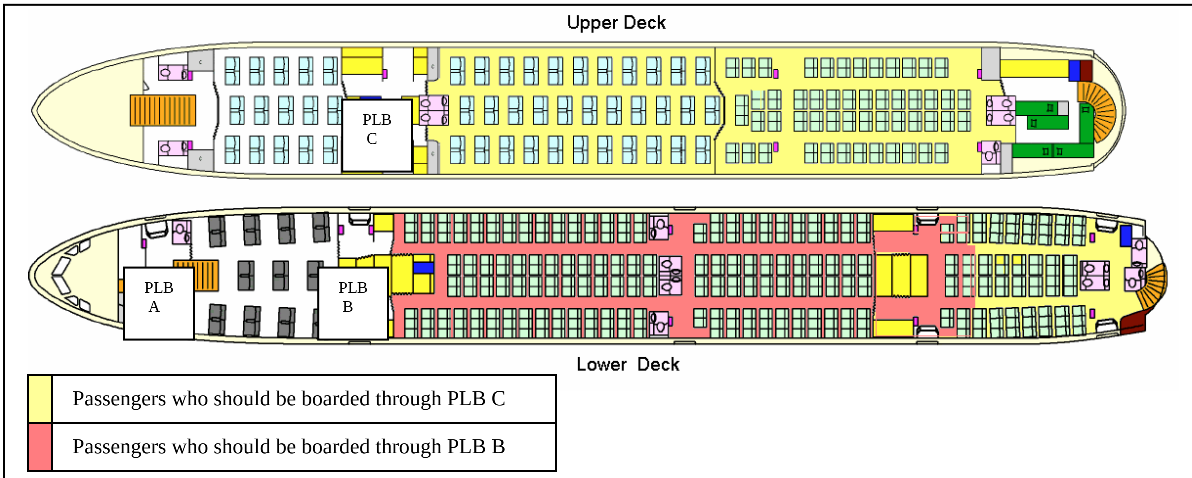


Figure 3: The flow of passengers through PLB C and PLB B which will minimize the time need to board the plane.

The time it takes to board passengers through PLB B and PLB C is going to be much more than the time it takes to board passengers through PLB A. When considering the best way to minimize the boarding time, we do not bother about trying to minimize the time for boarding through PLB A because boarding through PLB A will be far faster than boarding PLB B and PLB C with even the most efficient strategies for B and C. This is because the number of passengers boarding through PLB A is only 52, while 268 board through PLB B and 235 passengers board through C.

To minimize the amount of time for boarding, we have come up with four methods, each of which uses the basic concept of the WilMA method (i.e. boarding in the order: Windows, Middle and then Aisle) and based on the plan of boarding the last seven rows of the last section on the lower deck through PLB C. All four models are based on these two features but the order in which the passengers are boarded is slightly different. In all of these methods, passengers in the last seven rows of the lower deck are boarded through PLB C along with passengers of the upper deck. The calculations above show why the last seven rows of the lower deck were selected to board from PLB C.

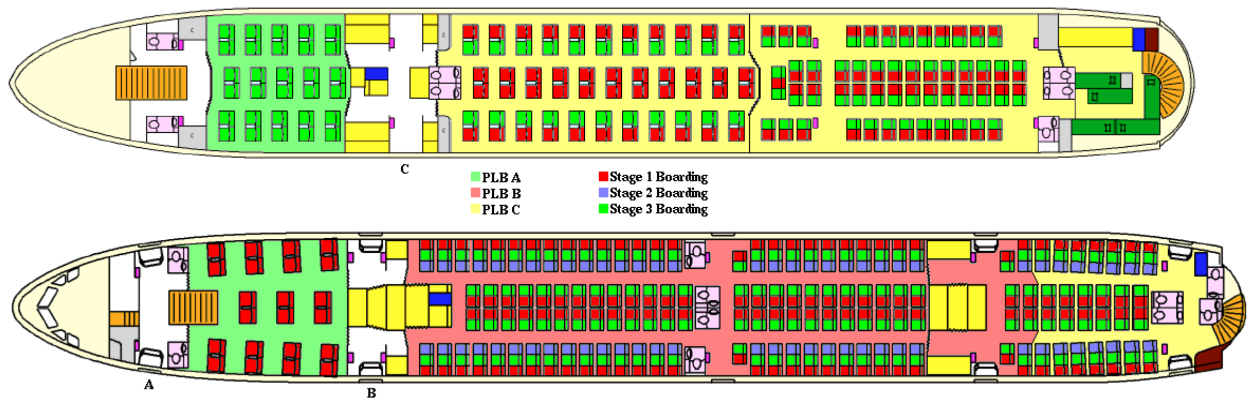


Figure 4: Method 1. For each stage of boarding we have as many people board as possible maintaining the WilMA method. This results in very few people boarding in stage 3 or "Call 3."

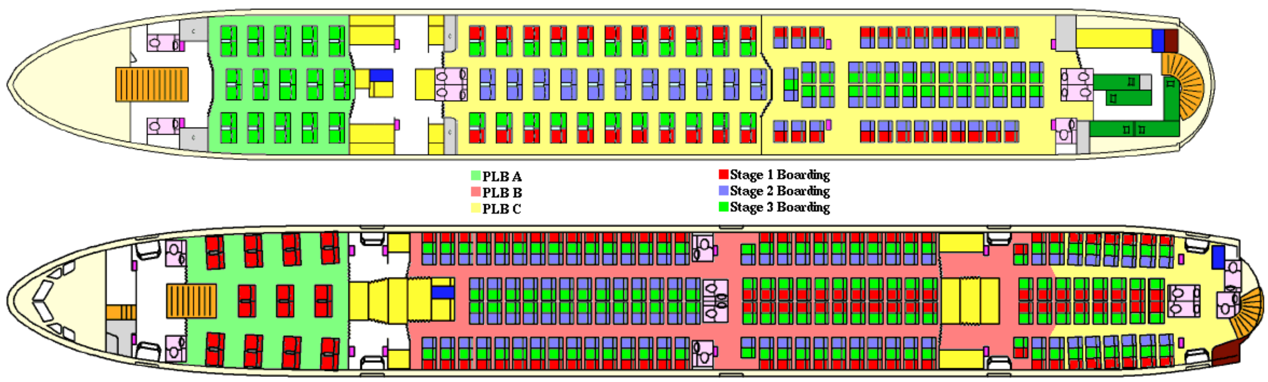
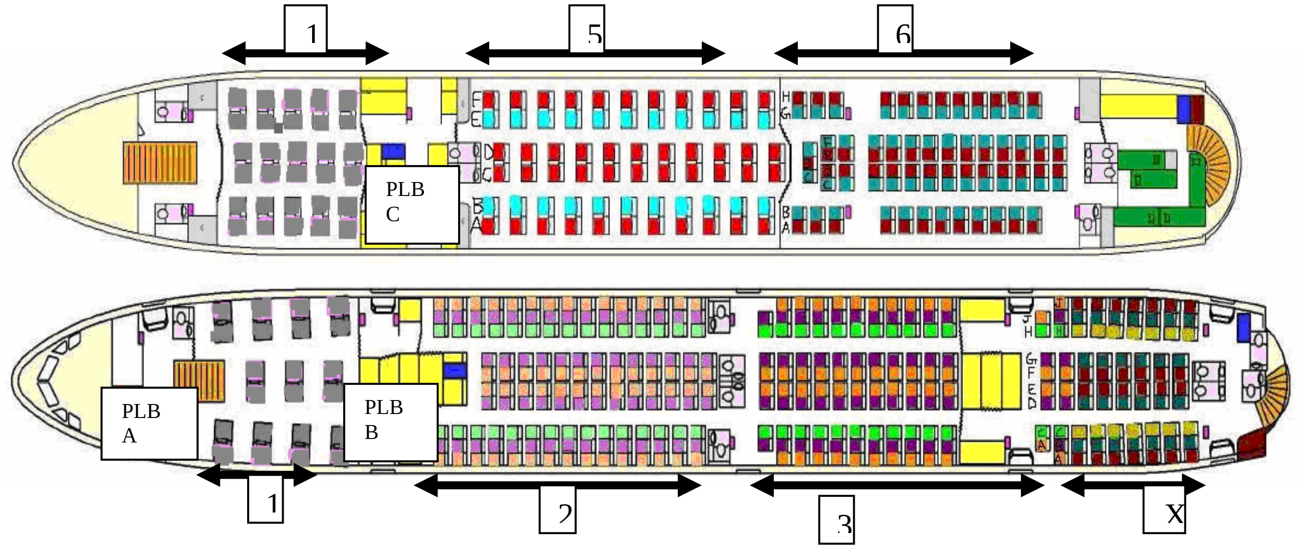


Figure 5: Method 2. In this method, we have more people boarding in the back of the plane during stage 1 and more boarding in the front of the plane in stage 2 and 3, while maintaining the WilMA method.

The best case of WilMA would be if we could get all the passengers to board in the "back to front" order where the passengers whose seats are the farthest down an aisle are in the front of the boarding line. Getting all the passengers to line up in the WilMA order as well as in decreasing seat number order would be a challenging and most likely an impractical task to be undertaken in the limited amount of space available at the waiting area outside the PLBs and also because this process would require a lot more time to get the passengers organized. Although theoretically the best, this would be the most impractical and inconvenient method both for the airline employees as well as the passengers. Having passengers board in the WilMA order and the decreasing seat number order is impractical but the next best practical method of using WilMA would be to not to board the passengers according to their seat number but according to their section, i.e. passengers whose seats are in the section that is in the back most part of the plane should go first, followed by the middle section and then followed by the front section. This is the method illustrated on the next page.



At each Passenger Loading Bridge (PLB), gate agents will make three calls as follows:

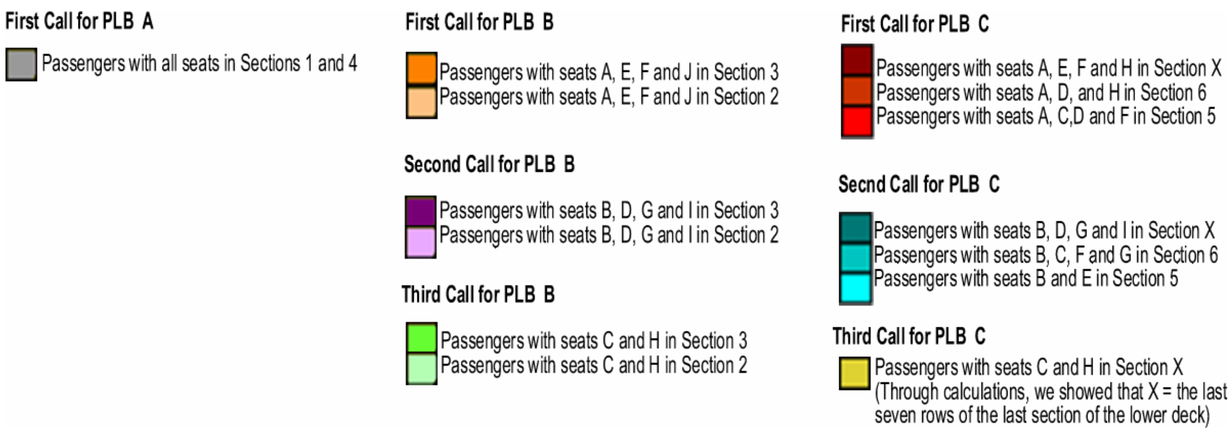


Figure 6: Method 3: Passengers are called in WilMA order but in each call, the passengers whose seats are in the back are called first followed by passengers whose seats are in the middle regions and finally passengers whose seats are in the front. Theoretically, this should be the ideal way of doing the WilMA method because this will minimize the amount of aisle interference and congestion. However, this may not be the most practical approach as it requires making upto seven calls, as in the case of PLB C.

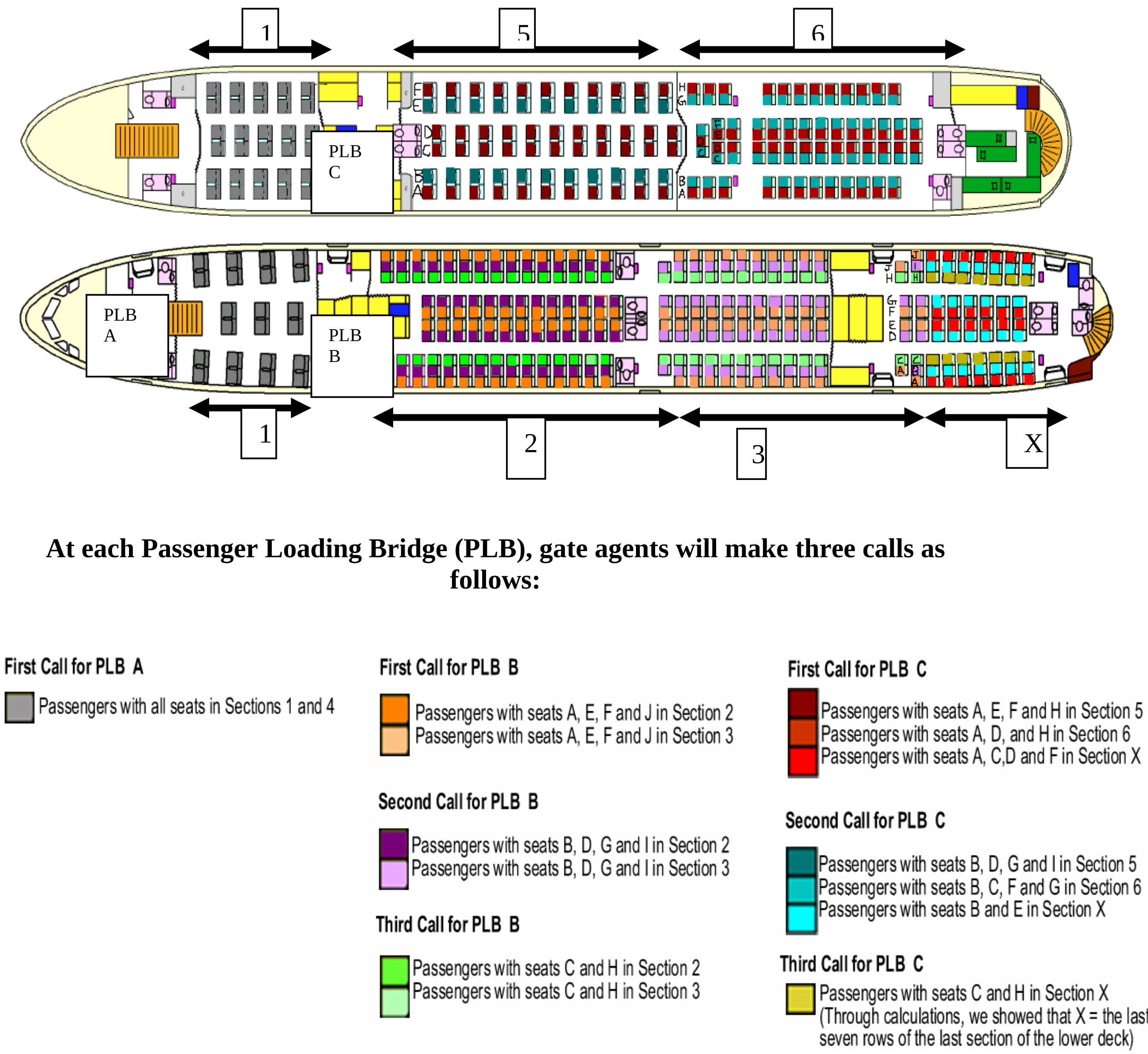


Figure 7: Method 4. Passengers are called in WilMA order but in each call, the passengers whose seats are in the front are called first followed by passengers whose seats are in the middle regions and finally passengers whose seats are in the back. This is the worst case scenario for using the WilMA method. We are using this method as a baseline for comparing how much better our other three methods are.

In order to properly analyze these methods of boarding, we needed to perform experimental trial runs. Not having an Airbus A380 at our disposal, we were forced to look for alternative means. We programmed a model of the A380 based on the seating diagrams that we had, and created functions allowing us to automate a passenger navigating the aisles of an airplane to reach his or her seat. Using a thousand trials for each method, we found the average amount of time that it took to fully board sections B and C. In addition, early tests of the simulation revealed that adding a row of seats to be boarded through PLB C and removing one row from PLB B boarding caused the difference in loading times between the two sections to become much closer to even. The psuedo-code describing the boarding algorithm used is as follows:

```
While there are fewer sitting passengers than total passengers{
    if the flight attendant is ready to let a passenger p through
        if there is nobody standing in the doorway to the entrance
            add p to the set B of passengers on the plane
        else
            add p to the set W of passengers that are waiting
        endif
    endif
    for all passengers p in set B
        if p is standing in the same row as the seat he has been assigned
            if P has luggage a nonzero luggage timer
                put luggage away, decrementing his luggage timer.
            else
                sit down, leaving the aisle
            endif
        else if p is standing on the aisle that his seat is on
            if there is somebody in front of p
                p does not move
            else
                p moves down the aisle one space
            endif
        else
            p moves up the column, hoping to get onto the aisle that his row
is on.
        endif
    endfor
endwhile
```

Note that this assumes the WilMA method is being used, and as such there is no time incurred by sitting into one's seat.

3. Boarding Results

Simulations(Minutes): 1000 Tests / entry

	Passenger Load	0 Sec. Int.		4.5 Sec. Int.		9 Sec. Int.	
Deck		**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
Method 1	**Large**	6.328	5.995	22.033	21.355	43.376	41.562
	Medium	3.977	4.275	12.770	13.680	24.880	26.231
	Small	1.843	2.307	4.351	5.018	8.052	8.926
Method 2	**Large**	6.192	5.947	22.018	21.324	43.386	41.560
	Medium	3.919	4.255	12.777	13.645	24.867	26.226
	Small	1.827	2.259	4.358	4.991	8.046	8.888
Method 3	**Large**	6.388	5.259	21.791	20.762	43.180	41.059
	Medium	3.689	3.481	12.544	13.092	24.680	25.725
	Small	1.459	1.765	4.128	4.429	7.849	8.392
Method 4	**Large**	7.587	6.971	22.144	21.431	43.529	41.715
	Medium	4.823	4.961	12.893	13.768	25.031	26.390
	Small	2.212	2.621	4.484	5.101	8.201	9.052

Large(555 Passengers), Medium(330 Passengers), Small(105 Passengers)

Here, upper deck is defined to be all the rows of the upper deck and the last eight rows of the last section of the lower deck.

When running our simulations of each method we realized that the mathematically calculated value of X, which tells us how many of the last rows of the last section of the lower deck should be boarded through PLB C, was not the most efficient value. We ran the simulations with X = 7 but found that our results caused a smaller difference between the load times of PLBs B and C if we made X = 8. Thus, adding one more row from the last section of the lower deck to the boarding through PLB C and removing one row from the load of PLB B proved to be the most time efficient way to model the problem. Since, we had decided that the best method would provide the boarding times for PLB B and PLB C to be as close to being equal as possible, we decided to run all our simulation using X = 8.

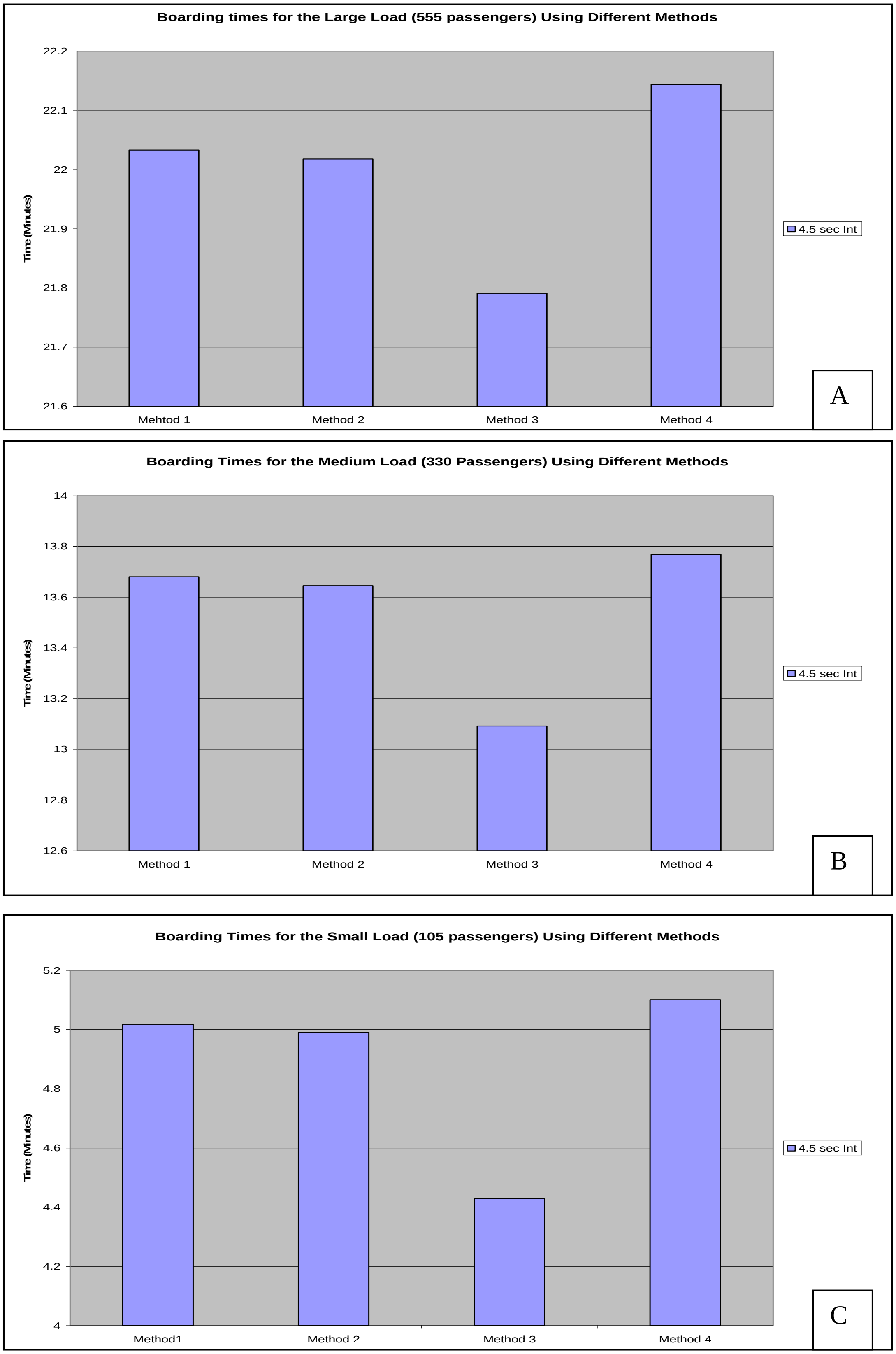


Figure 8: Boarding times found by simulations for Methods 1, 2, 3 and 4 for A. Large passenger load, B. Medium Passenger Load, and C. Small Passenger Load.

Our second realization was that the intervals of passengers boarding the plane had a lot to do with the efficiency of boarding the A380. We had expected that the time to store baggage would be a main factor in the models but upon increasing it by a considerable amount we found it had little effect on the total time to board. We adjusted the models to be most optimal by doubling the flow of passengers boarding from PLBs B and C which meant that we needed to add another flight attendant to check tickets at each of these PLBs adjusting the total flight attendants needed in our method from three to five. The rate of boarding measured for single aisle planes by researchers at Arizona State University is 9 seconds/person.[2] In our simulations, we made the passengers boarding through each PLB at a rate of 4.5 seconds per passenger. This cut the total boarding time by a little under 2 fold. This was expected as the A380 has two aisles and thus should be able to board twice the number of people as a regular single aisle plane through each PLB with only congestion near the front of each PLB affecting each aisle's flow.

To see how much time it would take if we removed the constraint of checking tickets (0 second interval), we were able to see that Method 2 had the lowest congestion of all the methods at the largest passenger load. However, with the interval of 4.5 seconds which our methods are primarily modeling, Method 3 was 13 seconds faster than Method 2 which took 22.018 minutes to board. However, due to the fact that Method 3 is more complex in managing the ticket checking and announcements for the flight attendants, we justified choosing Method 2 over Method 3 because Method 2 is more practical. Although every simulation was run for a value inside each interval assigned we focused primarily on the 555 seat results due to the fact many airlines are intending to use the A380 for traditionally high occupancy flights. Our conclusion from our results is that Method 2 will result in the most efficient as well as practical way for airlines to board the A380 in comparison to all our other methods.

4. A380 Deboarding Efficiency

The other factor in a planes turn around time that has to do directly with passengers is the deboarding of the plane once it reaches the terminal. Unlike boarding the deboarding of a plane is traditionally done in a first come first serve basis in meaning that those closest to the exits get off first and those furthest are last to leave the aircraft. The A380 will have three PLBs in which staff can use to deboard the aircraft.

Assumptions:

- The A380 plane will have three PLBs to deboard passengers.
- Each PLB of the A380 will flow at the same rate as the others as passengers deboard the plane.
- Passengers will not slow or obstruct the flow of each PLB.

[2] A research team at Arizona State University led by by Menkes H. L. van Den Briel obtained videotapes of actual airplane boarding and measured the passenger arrival rate, the row speed of the passengers and the luggage speed. This information was found in Mathew Pan's paper found at http://www.public.asu.edu/~dbvan1/papers/MatthewPanEssay.pdf

- Passengers will generally follow the predicted flow for each PLB and not take erratic routes in order to exit the plane.

Considerations:

- Disabled passengers will exit the plane last, this is due to the fact the allotted time needed for a disabled passenger to exit is generally expected to be much greater than a non-disabled passenger.
- First class passengers will exit first, again this is expected by the passengers and is to be done to maintain consistency in what passengers expect from the airlines.

Statistics: A380 (555 seats) Full

- For maximum efficiency all 3 PLBs will allow for deboarding passengers in a way that all three begin and end the deboarding process ideally at the same time.
- PLB A will first deboard first class passengers then economy class passengers from the lower deck.
- PLB B will deboard only economy seat passengers from the lower deck.
- PLB C will deboard the business class passengers from the upper deck followed by the economy seat passengers from the upper deck.

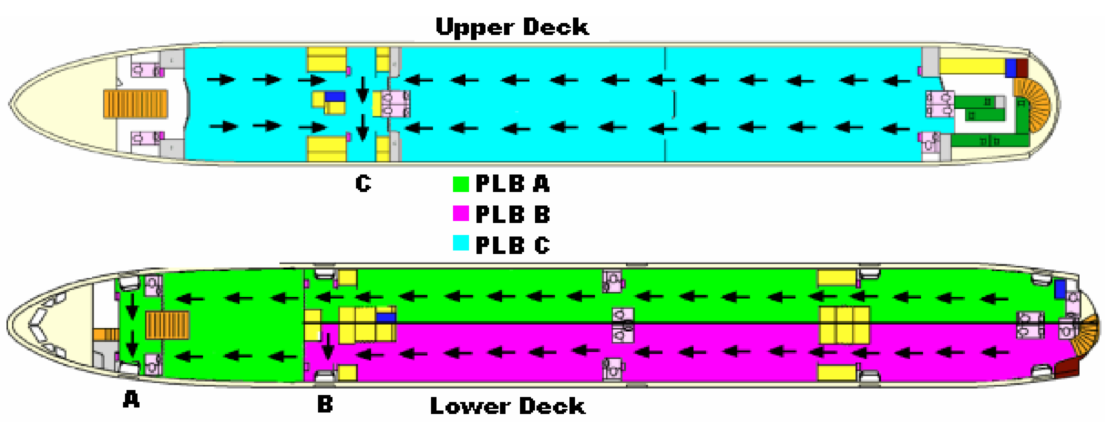


Figure 9: Deboarding Flow

Our objective is to get all of the passengers to exit the plane in such a way that comes closest to the optimal flow rate possible for the aircraft. If the aircraft is full with 555 passengers then the optimal amount of time to deboard the plane is 9.25 minutes. This was determined using the statistic from Boeing that the time it takes for a person to exit an aircraft is 3 seconds. Our team's strategy was to divide the plane up into 3 sections that were going to get us closest to the optimal value without having people take irregular routes that resulted in them walking further than they feel they should to exit the plane. For example someone in the back of the plane on the bottom deck will not appreciate walking up the stairs in the back of the plane in order to cross the entire plane to walk down the front stairs of the plane in order to exit through bridge A. With that in mind our team came up with a model that results in an expected time of 9.95 minutes to deboard the A380 airplane. The following explains the method:

PLB A: 22 first class passengers and 156 economy seat passengers from the lower deck for a total of 178 passengers exiting from bridge A.

PLB B: 178 economy seat passengers from the lower deck, total of 178 passengers exiting from bridge B.

PLB C: 96 business class passengers and 103 economy class passengers from the upper deck will exit through bridge C for a total of 199 passengers.

Figure 1 shows the flow that the passengers will take in order to exit the plane. In the image the upper deck is completely exiting through PLB C. This is to be the PLB that is expected to take the longest as it has 21 more people to have exit through it in comparison to the other two PLBs. The reasoning for having PLB C with more people exiting than PLBs A and C is due to the fact the method in which people will be exiting from PLBs A and B is not absolute. The lower decks have two aisles ideally we would want the starboard aisle flowing to exit to PLB A and the port aisle to flow to exit from PLB B. The ideal result for people exiting from PLBs A and B will be that they divide themselves evenly between each gate, but due to the fact people just want to leave the aircraft and getting a equal number exiting from each PLB A and B is unlikely so we have more passengers leaving through PLB C in order to have better control over how long it takes to deboard the aircraft. For example to meet optimal efficiency in deboarding we would need to have 14 business class passengers walk down the stairs of the front of the plane and exit through PLB A. The upper deck would then have 185 passengers exiting from PLB C, and the bottom deck would have 270 exiting between PLBs A and B with optimal value being that an equal number exit through both in which the value would be 185 units of time for each PLB. This is unrealistic however as we are relying on the passengers on the lower deck of dividing themselves into two equal groups in order to exit the plane. However with PLB C being our ideal constraint on the time to deboard the aircraft we allow for the discrepancy between the flows of PLBs A and B to differ by as much as 42 passengers. Given the unpredictability on the behavior of the passengers from the lower deck the method we have come up with we feel is the best for exiting the airplane, taking only 7.57% more time than optimal deboarding. Our deboarding method is 92.96% efficient and allows for a range of error that would be acceptable to assume that PLB C will be the constraint for the deboarding time of the aircraft.

5. Conclusion

Airlines constantly strive to save money by being more efficient in the methods they use. As our team set out to come up with a strategy on what would be the most efficient way to board and deboard the A380 aircraft we kept this in mind and based a lot of our methods on the research that we found relating to our objective. The first aspect that we took into major consideration was how many PLBs we were going to use for our models. Through our research we found that many large international airports that were going to be expecting the arrival and departure of many A380's per day were equipping their terminals with three PLBs to access the airplanes. Other important findings through research made it apparent that the standard for the A380 would be a three class seating structure with 555 seats. Although the problem wanted a method for an 800 seat A380 the existence of such was not found and thus we concluded that a more practical model would be for the 555 seat version. Other important things that we found while doing preliminary research were on methods of boarding airplanes, from block boarding to reverse pyramid diagrams, we decided upon WilMA as the best strategy for the A380 based on other people's statistics and research done on the different strategies.

With all these things in mind we started with coding a program to run tests on the most efficient way to board the A380. Through these tests we made an important discovery in that the rate of flow from the PLB to the aircraft played a very important part in maximizing efficiency. With the addition of an extra flight attendant at PLBs B and C to check tickets we were able to cut the time of each boarding method in half. Not only was the time cut in half but each boarding method proved to be fast enough to prove as efficient methods for boarding the A380. This gave us flexibility in choosing which method would be best. Keeping in mind that our method was to be as efficient and practical as possible we decided on Method 2 as the best choice. Method 3 was 13 seconds faster than Method 2 but also required twice the number of announcements for boarding and we justified choosing Method 2 over Method 3 because it would be simpler for the flight attendants to announce and manage the boarding while using Method 2.

For the deboarding of the aircraft we took into account that controlling the movement of the passengers would not be as simple as the boarding process. Traditionally passengers exit the plane in a way that they move towards the nearest exit. Our method took this into account and proved to be 92.96%[3] efficient of the minimum time needed to deboard the aircraft, while still remaining to be practical.

In conclusion our team is very certain that the methods we came up with in boarding and deboarding an A380 are efficient and practical in use and major airlines would easily be able to integrate such methods into their current practices. Keeping in mind that airlines want to be efficient and practical in the methods that they use we ended with results that were in agreement with these expectations.

[3] We arrived at the efficiency number by dividing the optimal time to deboard (9.25 minutes) by our expected time (9.95 minutes) and multiplying by 100.

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