Flying into the Future:

A Simulation on Boarding Airplanes

by

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## Introduction

In today’s world, people are moving between places more rapidly largely because of airplanes. Someone in Los Angeles right now could be on the other side of the United States in New York City in only a couple of hours. Being able to travel long distances in a very short amount of time is a fairly new concept for society, but it has greatly influenced how people live their lives. For example, these strides in technology have created new jobs. In the airline industry there are numerous jobs including pilots, mechanics, airplane designers, flight attendants, TSA security, etc. This new technology also improves connectivity between people. For example, business partners can meet face-to-face even when they live across the country from each other. But air travel is not always perfect as delays and cancelled flights can disrupt the equilibrium. These delays and cancellations can be caused by inclement weather, holiday seasons/high traffic times of the year, mechanical issues, and airplane ground time.

## Explanation of the Problem

Former Air Transport Association of America economist and president of the aviation consulting company AeroEcon, David Swierenga, states that “an airplane only generates revenue when it is in the air” (Demerjian, 2006). More specifically, an airline accrues a cost of $30 per minute on the ground (Nyquist & McFadden, 2008). If an airline can fit more flights in the day, then more customers can use their services and thus more money comes into the airlines (assuming people buy tickets for those flights). There are many events that can cause increased ground time for a plane, including the deplanation process (unloading passengers), aircraft cleaning, refueling, cargo loading and unloading, and passenger boarding (Ferrari, 2005). It has been argued that of these requirements, boarding passengers takes the most time even though it is one of the easiest to control (Marelli, Mattocks, & Merry, 1998). Most previous simulations related to boarding airplanes have focused mostly on the order passengers are boarded, including boarding the plane from back to front and from the outside in. However, even with these suggestions for improvement, there has been a growing problem with boarding airplanes and that is passengers bringing more carry-on luggage with them.

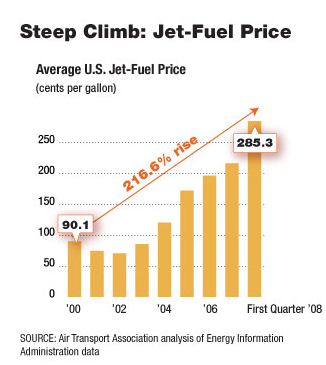
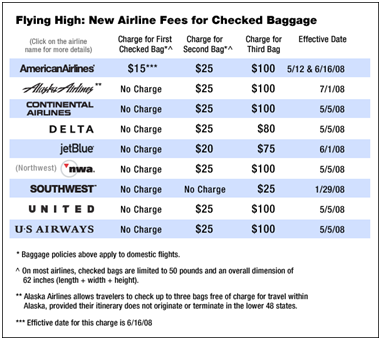
This increase in carry-on luggage, like many other causes of increased boarding time, centers on the climbing costs of jet fuel. As can be seen in Figure 1, from the year 2000 to the beginning of 2008 there was a 216.6% increase in jet fuel price. The airlines need to combat this higher price in order to make a profit and stay in business. Airlines have solved this with a few different plans of action. At the beginning of 2008, American Airlines stated they would cut about 12 % of their flights (Gutierrez, 2008; Brockman, 2008). If there are fewer flights, then less fuel is used and thus the airline combats some of the high cost of jet fuel. By having fewer flights however, the remaining flights will have more passengers on board which will lengthen the passenger loading time (Andrews, 2010).

Figure 1: Rising Fuel Costs From “Steep Climb: Jet-Fuel Price” by Lindsay Mangum, 2008, National Public Radio.

Besides reducing the number of flights, American Airlines at the same time in 2008 decided to begin charging passengers for their checked baggage. This was a difficult decision for an airline to make, but when the plane weighs less, it does not need as much fuel to get to the desired location (Andrews, 2010). It seems to be a logical decision for the airline to make. Not only will it lighten the load, but the airline will also gain income from the bags which can help pay for the rising cost of jet fuel. Table 1 depicts the fees the major airlines charged for checked baggage when American Airlines began charging for the first checked bag in the middle of 2008. As can be seen only American Airlines was charging for the first checked bag at this time.

By July 1, 2010, two years later, it was a completely different story. As shown in Table 2, most of the airlines followed American Airlines lead. Even though some stipulations exist on these fees, including Alaska Airlines not charging for the first three bags if the passenger is traveling within Alaska, United Airlines offering a $249 annual fee so the passenger can take up to two checked bags for free per flight, or some airlines offering deals if the passenger books his flight online, we see that the fees changed dramatically (United States Government Accountability Office [GAO], 2010). In the less than two-year span since American Airlines started charging passengers for checked bags, almost every other major airline had started charging for the first checked bag, as well as increased prices for multiple checked bags.

**Table 1: Checked baggage Fees as of Summer 2010 From “Flying High: New Airline Fees for Checked Baggage” by Alice Kreit, 2008, National Public Radio.**

|  |  |  |  |
| --- | --- | --- | --- |
| Airline | Charge for First Checked Bag | Charge for Second Checked Bag | Charge for more than 3 Checked Bags |
| American Airlines | $25 | $35 | 3-5: $100  6+: $200 |
| Alaska Airlines | $20 | $20 | 3: $20  4: $50 |
| Continental Airlines | $25 | $35 | 3-5: $100  6+: $200 |
| Delta Airlines | $25 | $35 | 3: $125  4-10: $200 |
| JetBlue Airline | $0 | $30 | 3+: $75 |
| Northwest Airlines | Merged with Delta Airlines on January 31, 2010 | | |
| Southwest Airlines | $0 | $0 | 3-9: $50  10+: $110 |
| United Airlines | $25 | $35 | 3+: $100 |
| US Airways | $25 | $35 | 3-9:$100 |
| Table 2: Data as of July 1, 2010 Adopted from “Commercial aviation - Consumers could benefit from better information about airline-imposed fees and refundability of government-imposed taxes and fees” by the United States Government Accountability Office (GAO) | | | |

This increase in prices for checked bags has caused many flyers to resort to their own cost-saving methods, such as carrying on more bags than technically allowed. This solution to bring only carry-on luggage on flights has been presented to the public though media such as MSNBC (Elliott, 2008). The combination of airlines offering fewer flights causing fuller flights, and charging for checked bags, thus causing more passengers to bring more carry-on bags is lengthening the boarding process. This could hurt the airlines more than it benefits them. With this background on the causes of the current issues at the core of boarding airplanes, it is important to look on what previous models focused their efforts to improve the boarding process.

## Previous Studies

### The Boeing Study

The Boeing Company led one of the first research efforts into boarding airplanes faster. Boeing began their simulation process by acknowledging that “since 1970, the actual speed at which passengers boarded an airplane (enplane rate) had slowed by more than 50 percent, down to as low as 9 passengers per minute” (Marelli et al., 1998). From this fact, Boeing believed the trend would continue if the problems causing the slowdown were not found. In order to try to uncover the problems, they created a simulation entitled PEDS (Passenger Enplane/Deplane Simulation). This model took into account interior configuration changes and variations in the passenger boarding process and procedures (Marelli et al., 1998). Boeing also conducted an experiment where they invited people to board a plane while the company videotaped the boarding process to analyze patterns in behavior. In doing so, their model could more accurately assign each passenger a walking speed, type of carry-on luggage, luggage put-away time, and relationship with other passengers (Marelli et al., 1998). Boeing was cautious about adding too many variables about people in the simulation because it is difficult to accurately predict human behavior and adding more variables increases the chance of error. The results of their simulation were that using two doors as opposed to one on a Boeing 757 (approximately 215 passengers) could reduce the boarding time by up to five minutes while using two doors and using an “outside-in” boarding policy could save up to 17 minutes (Marelli et al., 1998). The outside-in boarding policy seats all of the passengers in the window seats first, the middle seats next and the aisle seats last. A visual representation of an outside-in boarding policy can be found in Appendix A.

### Ghent University Study

Van Landeghem and Beuselinck started their research with interviews and observation and found that the average airplane turn time is between 30 and 60 minutes including deplanation, cleaning, and reboarding, and determined the minimum, median, and maximum time it took passengers to pass one row and exit from a seat into an aisle (2002). Their simulation focused on the assumption that carry-on luggage causes the most congestion thus making the turn time longer (Nyquist & McFadden, 2008). Because of their emphasis on luggage, their simulation is based on a bin occupancy model. Put simply, the bin occupancy model states that the fuller an overhead bin, the longer it takes a passenger to store his luggage. Van Landeghem and Beuselinck’s (2002) model plane has 132 seats which is equivalent to a Boeing 737 or an Airbus A320. Their simulation accounted for many scenarios including longer storage time for passengers with multiple pieces of luggage, a passenger blocking another passenger’s seat, and handling passengers who sit in the wrong seat. Since their model is based on the overhead bins, their model tested a 60%/30%/10% policy meaning 60% of the passengers were assigned one bag, 30% assigned two bags, and 10% assigned three bags (Van Landeghem, n.d.). A 20%/60%/20% policy was also tested.

After testing many boarding policies including random, block (a group of adjacent full rows), half block (a group of adjacent rows on one side of an aisle), row, half row, and by seat, Van Landeghem and Beuselinck (2002) found that only 9 of the 46 policies they tested yielded better results than the random method. A visual depiction of some of the more popular policies can be found in Appendix A. The best policies for passenger boarding involved calling off individual passengers by their row and seat number which can be a very complicated procedure (Van Landeghem & Beuselinck, 2002). Even other more practical policies tested led to problems when real human issues such as families being separated when boarding in different groups were taken into account (Van Landeghem, n.d.).

### Ferrari and Nagel

Ferrari and Nagel (2005) based their simulation on the work of Van Landeghem and Beuselinck (2002), but modified some aspects. While Van Landeghem and Beuselinck (2002) found the minimum, median, and maximum times for moving to the next seat, etc., Ferrari and Nagel (2005) used a deterministic process in which each passenger can only move one step forward per time increment if the desired cell is free. Their simulation included seat interference, which is when a passenger already seated is blocking the seat another passenger needs to get to. Their simulation also included the same 60%/30%/10% model for amount of carry-on luggage that Van Landeghem and Beuselinck (2002) used, but Ferrari and Nagel (2005) also included other disturbances including early and late passengers, different aircraft dimensions, and different airplane occupancy levels. They tested the same classes of boarding policies as Van Landeghem and Beuselinck (2002) and also added a pyramid policy which can also be seen in Appendix A. Ferrari and Nagel (2005) found that “boarding strategies that have good average performance also have good average worst-case performance” (50). Ferrari and Nagel (2005), just like Van Landeghem and Beuselinck (2002), found that the by-seat policies performed the best although Ferrari and Nagel also found that the outside-in strategy was fairly efficient. One other strategy Ferrari and Nagel modeled was the free seat choice that Southwest Airlines offers, but stated that because this model is based on human behavior, trying to simulate this method is difficult and only based on their own assumptions. In conclusion, Ferrari and Nagel (2002) stated that “restricting amount of carry-on luggage will accelerate the boarding process” (54).

### Arizona State University

The Arizona State University study focused its simulation around the idea of interferences. This includes the seat interference mentioned earlier and aisle interference when a passenger has stopped to stow bags while another passenger behind them is seated in a row further back in the plane. Van den Briel, Villalobos, Hogg, Linmann, and Mulé (2005) claim that minimizing these interferences can produce faster turnaround times for planes. They looked at all possible combinations of how the passengers in one half of an aisle could board, including boarding in the same group, boarding in different groups, and whether the window seat or the aisle seat is seated first. They determined the expected number of interferences for each one of these scenarios so they could design the best boarding policy. They also collected “walking speed, interference time, and time to store luggage in the overhead bins…from videotaping actual aircraft procedures” (van den Briel et al., n.d., 5). They found that the outside-in and reverse pyramid strategies performed the best and that the optimal number of boarding zones was four (Nyquist, McFadden, 2008). Van den Briel et al. (2005) also found that using an outside in boarding policy and adding an extra gate agent per flight scanning tickets, an airline could cut boarding times by up to 37 percent.

### Summary of Previous Research

These previous studies recognizing that the best way to board a plane is to maximize the number of passengers moving at the same time while minimizing interferences. While all of these simulations stressed different factors related to airplane boarding such as airplane design, bin occupancy, or interferences, they all provided solutions to the same question: Which boarding policy minimizes the amount of time to board an airplane? These studies overall found that an outside-in model of boarding the airplane with the window, middle, aisle pattern showed the best improvements and also that the by-seat policy although difficult to organize, provides an “optimal” decrease in boarding time. One main issue found was that these policies tend to fall apart when passengers are late, or people are traveling in groups like a family with small children that cannot be split up into different boarding classes. These issues make a boarding policy less efficient.

## The Model

My model takes a different approach than that of previous research. I do not focus my efforts on what boarding policy minimizes boarding time. This is because previous research showed that different models yielded consistent results on which policies perform the best. My model tries to explore other issues that may be present within the boarding process. The focus of my model is to analyze different baggage policies to see if there are ways airlines could alter current baggage policy to be more conducive to minimizing boarding time. Just like Marelli et al. (1998) and Ferrari and Nagel (2005) my simulation will be discrete. What this means is that a passenger moves from one cell to another cell at each step of the simulation. You can think of this as a piece of graph paper where a person is standing on one square and on the next step in the simulation, the person has moved over to an adjacent square. This is different than a continuous simulation where a passenger’s movement is more fluid and each passenger can move at a different speed than other passengers.

### Aircraft

The airplane in my model is based on airplanes in the Boeing 737 family and the Airbus A320 family. The Boeing 737 family is said to have “won orders for more than 6,000 airplanes, which is more airplanes than The Boeing Company's biggest competitor has won for its entire product line since it began business” (The Boeing Company, n.d.). The 737 airplanes are considered to be short to medium ranged and can hold between 75 and 215 passengers depending on the model with most ranging between 120 and 150 passengers (The Boeing Company, n.d.). The A320 family is the Airbus equivalent of the Boeing 737 family. The Airbus A320 family has had over 4,600 aircraft delivered as of March of 2011, which makes the A320 family another popular group of aircraft in the sky (Airbus, n.d.). Within the family, the A320 accommodates 180 passengers, the A319 accommodates up to 150 passengers, and the Airbus A318 seats close to 132 passengers (Airbus, n.d.). Figure 2 illustrates the seating charts for specific models of airplanes within the Boeing 737 family and the Airbus A320 family.

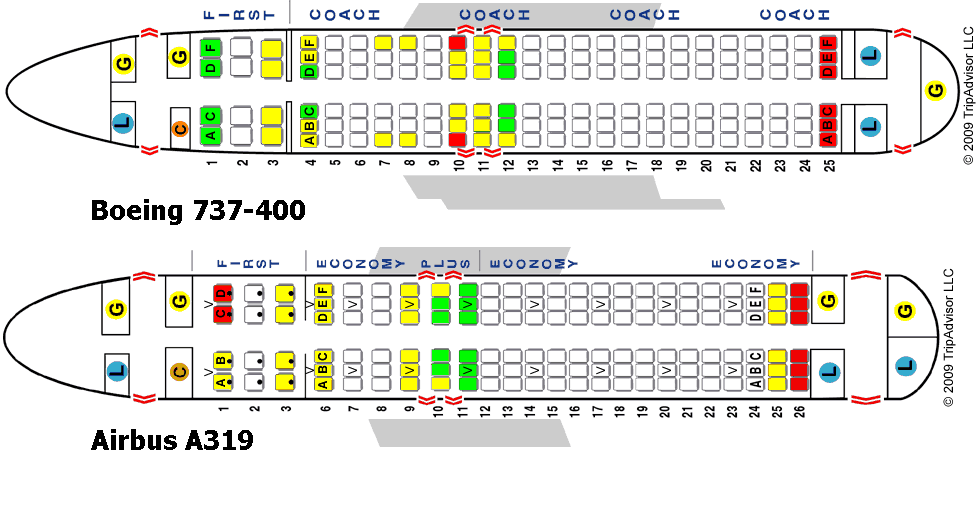


Figure 2: Seating Chart for the Boeing 737 and Airbus A320 Adopted from "US Airways Boeing 737(400)” and “Delta Airlines Airbus A319”by Seatguru.com by TripAdvisor

An airplane with a lower capacity of passengers was chosen because these aircraft make more flights in the day, meaning the process of unloading and reloading passengers occurs more often. These aircraft have the most to gain from an improvement in boarding time. Also, all of the previous research except Marelli et al. (1998) used an aircraft similar to one found in the Boeing 737 family or Airbus A320 family. The airplane used in my model contains 20 rows with six people in each row, three people on each side of a single aisle. My airplane model is representative of economy/coach class but ignores first class. This is because the coach section of the plane is larger than first class, so more of the boarding issues will occur in this section. By focusing my efforts on the coach section, I am able to analyze the part of the boarding process where the most issues occur. With my model all of the passengers enter the plane through one door located at the front.

### Overhead Bin and Bin Occupancy

The overhead bins of the plane in my model are crucial to the accuracy of my results. I was provided overhead bin dimension data by the Heath Tecna Aircraft Interior Solutions company whose work includes modifying currently existing bins to better fit bags and designing new types of bins. From the information they provided, found in Appendix B, I compared the properties of the overhead bins of each airplane in the Boeing 737 or Airbus A320 families. Note that in Appendix B I only included the planes that met this criterion. The resulting bin used in my model has a 60 inch wide bin length. This is equivalent to one bin per two rows on the plane (**Mayerowitz, 2010). The volume of the overhead bin in my model is 9.5 cubic feet (16,416 cubic inches). This overhead bin can fit five bags with dimensions 24 x 14 x 9.5, i.e. 47.5 linear inches. This bag size** falls within the range of accepted carry-on bag sizes for the 17 airlines I looked at (45 linear inches to 56 linear inches) (The Travel Insider, n.d.).

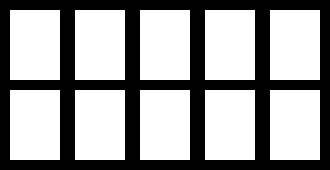
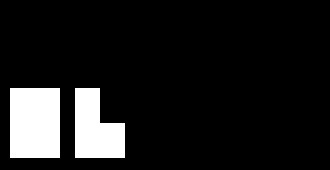
Since the graphics of my simulation are in 2-d and the overhead bins on real planes are above the rows of seats, I had to find an appropriate method of representing the bins. My simulation presents an overhead bin as a rectangle on the outside of each side of the rows. The image changes as the bin fills. Figure 3a is a representation of an overhead bin that is completely full. This bin contains 10 red rectangles where two rectangles signify a piece of luggage 47.5 linear inches in size. Since I want passengers to bring different sized bags that will correspond to more realistic patterns of carry-on luggage, the bin model is more complex than 10 red rectangles. Each one of these 10 rectangles is divided into four smaller rectangles for a total of 40 rectangles. From here forward, when referring to rectangles in the overhead bin I will be referring to the number of rectangles out of 40. This increased granularity allows a passenger to bring a bag that ranges from one rectangle, representing luggage the size of a laptop bag, all the way up to eight rectangles, representing the maximum size of a carry-on bag. These rectangles are based on each holding approximately 410 cubic inches rather than the number of linear inches. Figure 3b depicts a bin filled with seven rectangles representing a bag that is smaller than the maximum size (two large rectangles).

Figure 3a: An overhead bin that is completely full. Each rectangle is equivalent to a bag of 37 linear inches which is close to what many airlines consider the max size of a personal bag

Figure 3b: A partially filled overhead bin. This figure illustrates how each big rectangle is actually divided into smaller pieces.

With my bin model, the concept of bin occupancy is important. Bin occupancy as used by the Ghent University study (2002) and Ferrari and Nagel (2005) is the idea that as an overhead bin fills up, it takes more time for a passenger to stow his luggage. This makes sense, because when a bin is fuller, a passenger may have to shuffle around other passengers’ luggage before he can create enough space to place his luggage. I handle this issue by adding a time delay for the passenger trying to store his luggage. When the bin is half full, the passenger has to wait an extra three simulation steps to store the current piece of luggage and if the bin if three fourths full, the passenger has to wait an extra six simulation steps to store the current piece of luggage. If the passenger has multiple pieces of luggage to store, a time delay may be added to both pieces of luggage depending on how full the overhead bin is when the passenger begins storing each bag.

### Boarding Policy

As mentioned earlier, I chose to analyze different baggage policies, not different boarding policies. Because of this, I chose to use a random boarding policy. Ghent University found that only 9 of the 46 policies they tested performed better than random (Van Landeghem and Beuselinck, 2002). Therefore, a random boarding policy is not a poor overall choice and is easier for airlines to implement. Airlines also do not have to worry about late arriving passengers ruining the efficiency of more complex boarding policies since the boarding policy is already random. The random policy my model utilizes is that of “truly random” meaning that each passenger has an equal chance of sitting in any open seat.

Part of a boarding policy is how passengers inside the terminal are called off to enter in the plane. I have chosen to follow what Van Landeghem and Beuselinck (2005) call a random call-off system where all of the passengers are called in one group. This is one call-off system they tested. This random call-off system is a reasonable method when compared to a call-off system involving multiple groups as a multiple group method in a way transforms into a single group. As one group is boarding the plane, the attendants in the terminal are checking tickets for people in the next group and allowing them to enter the plane. The distinction between these different boarding groups becomes blurred once on the plane because the passengers from one group are stopping to store luggage while passengers in the next group are starting to enter the plane.

### Passengers

The passengers are another crucial aspect of making my model more accurate. Each passenger comes with a set of information. All passengers are assigned a random seat, number of bags, and size of each bag. The number of bags a passenger has depends on what baggage policy the user of the simulation decides. If the user of the simulation decides that he wants 100% of the passengers to have one bag then all of the passengers will have only one bag. If the user wants half of the passengers to have one bag and the other half to have two bags, then the simulation will make sure exactly half of the passengers have one bag and the other half exactly two bags. If a passenger has one bag, that would be representative of having a carry-on bag. A passenger having two bags would represent having a carry-on bag and a personal item and a passenger with three bags represents having a carry-on bag, a personal item, and a third bag that is probably not allowed by most airlines.

|  |  |  |
| --- | --- | --- |
| Bag # | Min Value | Max Value |
| 1 | 5 | 8 |
| 2 | 2 | 4 |
| 3 | 1 | 3 |

Once the number of bags has been set for the passenger, the size of the bags is also stored. Table 3 represents the range of sizes each bag could be. These numbers represent the number of rectangles out of 40 the bag will take in the overhead bin. The range of acceptable values for each bag exists because airlines have different restrictions for bringing a second and third bag. The maximum size of a carry-on bag is 47.5 linear inches, equivalent to eight rectangles, and for the personal item my model assumes the maximum size is 37 linear inches, equivalent to four rectangles in the overhead bin. Remember that each rectangle is related to a bag’s cubic inches, not its linear inches. My model will produce a random number for each bag a passenger has in accordance with the values in Table 3. This randomization of bag size allows a passenger to bring a bag smaller than the maximum size and allows for differences in the design of bags.

Table 3: Bag sizes used in model. The min and max values represent how many rectangles of space the bag will take in the overhead bin.

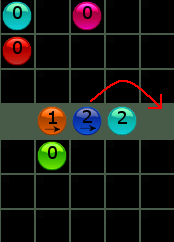
 When a passenger appears in the simulation, the user will only be able to see three aspects of the passenger; the first is the color. The passenger can be one of six different colors, but the colors do not hold any significance other than helping the user distinguish between different passengers. The next identifying feature is a number. This number represents the number of bags the passenger is holding. As the passenger places his bags in the overhead bins, this number will change. Lastly, the passenger will have an arrow. This arrow represents which direction the passenger is moving. Figure 4 is a depiction of passengers with their identifying characteristics.

Figure 4: The passengers’ identifying features include a color, a direction arrow, and number of bags

#### Passenger Movement

When a passenger enters the plane, his first goal is to continue walking until he reaches the row where his seat is located. The passenger takes two simulation steps to move one spot down the aisle in the airplane. Once the passenger has reached his row and all of his bags are packed, he will move up or down towards his seat. Crossing seats takes a passenger one simulation step. This behavior seems in line with how passengers on a plane would act. Problems occur when a passenger is trying to store a bag and there is no space in the overhead bin. In this situation, the passenger will look at the overhead bin on the other side of the aisle to see if there is space. If there is, then the passenger will place his luggage there. If there is no space, then the passenger will go to another row. The passenger will continue down the rows until he finds space in an overhead bin for his bag. Once the passenger is holding zero bags, he has to find his way back to his seat. This causes an issue because this passenger will be going against the flow of traffic. In natural settings, it is possible that the passenger will move back as far back as he can and if he runs into people he might temporarily jump into a row to let other passengers pass him or other passengers may back up if this passenger is close enough to his seat. Without doing extensive research on this behavior I cannot properly model this. Also, when dealing with human behavior it is very easy to make mistakes, because human behavior is often unpredictable. Because of these issues, the passengers in my model can only move one direction in the aisle. Therefore, once a passenger has finished stowing his bags, a time delay is used to account for how long it would take the passenger to walk back to his row if his path were clear. Then the simulation “teleports” the passenger back to his spot. It also adds a time delay if there are any seat interferences. These will be defined later. If a passenger reaches the last row in the plane and has not stowed all of his bags, the simulation in this case will also “teleport” him back to his seat with the same time delay system, but he will sit down with however many bags he has left.

#### Aisle interference

Within passenger movement aisle interferences need to be taken into account. This is one aspect that van den Briel et al. (2005) included in their model. Aisle interference is when a passenger is stopping to place a bag in an overhead bin and there is one or more passengers behind him waiting to move to rows further back in the plane. This kind of interference is shown in Figure 5. My model deals with this issue by forcing the passenger(s) behind the stalled passenger to wait until the passenger storing luggage has stored all of his bags before they are allowed to move again. In the simulation the waiting passengers will not be moving. I have assumed that a passenger with luggage occupies all of the space in the aisle so that other passengers cannot squeeze by him. This assumption was also made by Ferrari and Nagel (2005). 

#### Seat Interference

Figure 5: Aisle Interference

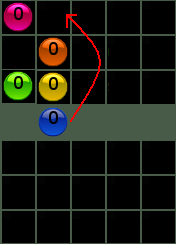
Seat interference is another aspect taken into account by van den Briel et al. (2005). Seat interference occurs when a passenger has finished storing his luggage and is ready to move into his seat, but there is a passenger or multiple passengers blocking the path. An image representation of this can be seen in Figure 6. Trying to create a solution to this problem runs again into how humans behave. The passengers may leave their seats and go into the aisle to allow the passenger by or the seated passengers may stand up and allow the other passenger to squeeze around them. Either way, it is hard to predict human behavior and without observation of such situations it is difficult to predict the outcome. To solve this problem, my model sets another time delay for the passenger trying to move into his seat. For every passenger blocking the passenger’s seat, a four simulation step wait time is added. In the example in Figure 6, the blue passenger waits an extra eight simulation steps before he moves to his spot. In the simulation, when this wait time is over, the passenger will appear to walk over the other passengers to get to his spot.

Figure 6: Seat Interference

#### Stowing Bags

When the passenger starts stowing his bags, a time delay is put in to represent the time it takes the passenger to find space to put his bag, lift his bag, and place it in the bin. The number of the bags a passenger is holding influences how many steps it takes the passenger to place a bag in the bin. If the passenger is holding one bag, it will take him four simulation steps to place his bag in the bin. If the passenger has two bags it will take six simulation steps to stow his first bag in the bin, and four steps to stow the next bag. For the person with three bags, it takes eight steps to stow the first bag, six steps to stow the second bag and four steps to stow the third bag. Since passengers have to juggle multiple bags when stowing their first bags, these time delays take into account the difficulties in trying to stow a bag while still holding other bags. These time delays could also be longer depending on how full the overhead bin is, as defined in the Overhead Bin/Bin Occupancy section.

### Other Assumptions about Passengers

My model ignores passengers who arrive early and passengers who arrive late. This is because having a model with one call-off group and random seating means that passengers arriving late or early do not influence the results. My model also does not take into account passengers who take the wrong seat because this again runs into the issue of a passenger moving against the flow of traffic on the plane and the difficulties of predicting human behavior.

My model assumes that a passenger will attempt to store all bags in the overhead bin, thus ignoring bags that are carried into a seat with a passenger. This issue can be controlled somewhat by the user, but it is not a perfect solution. If a user of the simulation wanted to test a policy where all passengers have two bags but will only put one bag in the overhead bin, the user could select a 100/0/0 policy. This workaround, however, violates the method used to compute the storage time for a bag being placed in the overhead bin as outlined in the Stowing Bags section.

## Other Design Choices

### Greenfoot

Greenfoot is a Java based integrated development environment (IDE) designed to provide a user-friendly graphical user interface (GUI). Greenfoot includes a class browser which displays the hierarchy of all of the classes used in the application, and execution control, allowing the user to control the speed of execution of the program. Greenfoot allows the user to physically add his own objects into the simulation without having to code the new objects in the source file. “While Greenfoot supports the full Java language, it is especially useful for programming exercises that have a visual element” (Greenfoot, n.d.). The main advantage of Greenfoot is the ability to easily create simple graphics. The graphics are in the form of a 2-d grid-like graph paper. The one disadvantage of graphics in the form of a grid for the simulation is that movement may not be fluid since the objects can only move from one block to the next.

### Java

Because of my decision to use Greenfoot, I had to use Java. Java does have some beneficial features for my simulation. First, it is an object oriented language (an object is a collection of data together with associated operations on that data). In my model I have person objects where each person has a seat location, current location, number of bags and bag sizes. As more and more people are created, they have their own characteristics, but they all use the same block of code to control their attributes. The collection of different variables and methods to change these variables are called an object class. Every person is an object in the person class. There are a number of other classes including a bin class, where every bin keeps track of how full it is, a seat class, and an aisle class.

Within Java another important feature is inheritance or “a mechanism by which one class acquires the properties – the data and operations – of another class” (Dale & Weems, 2010, 759). Greenfoot provides programmers with a base world (environment) class and actor class to build from. This hierarchy eliminates extra work for the programmer and makes programs much easier to understand. For example, my person class is a subclass of the Greenfoot actor class. This gives the person class access to functions such as finding the person’s current location. Likewise, my airplane class is a subclass of the world class which allows me to create the background used in my simulation without having to start from scratch.

Lastly, Java offers the ability to perform concurrent tasks through threading. Threading can be accomplished on either single or multi-core processors. Essentially, threading divides a task into multiple pieces (threads) and switches execution between them during the running of a program. This gives the appearance that different events are acting concurrently even though only one task is actually running at a time. Concurrency is conducive to simulating the boarding of an airplane because many different parts are working at the same time. There are people who are continually moving towards their assigned seats, there are seats that are either filled or empty, and there are overhead bins that could be anywhere between completely empty to completely filled. In real life, these events need to all happen simultaneously. Therefore, in my simulation, these events need to happen close to the same time.

### How to use Greenfoot

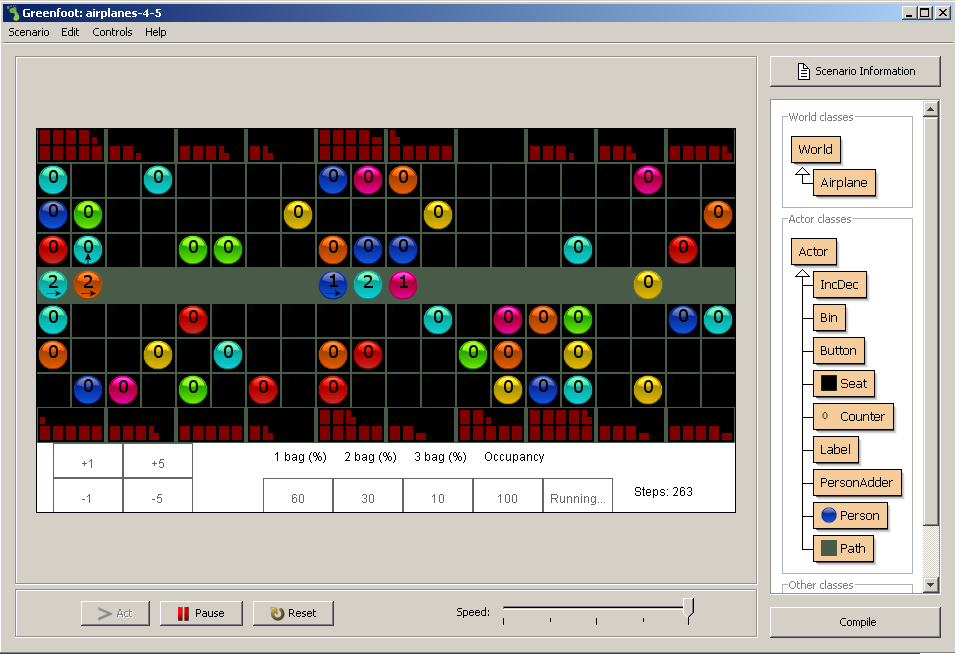
Greenfoot is a relatively easy environment to use if you are running a program. The most noticeable feature of the environment is the screen for the visualization. Figure 7 is a screenshot of my simulation. The passengers are in the process of loading the plane and some passengers are already seated. To the right of the screen containing the visualization is the class browser. This shows the programmer which classes are in the scenario and then inheritance structure/hierarchy. The most important feature of this environment for the user is the toolbar at the bottom. Figure 8 is a closer view of the toolbar itself.

Figure 7: Greenfoot IDE

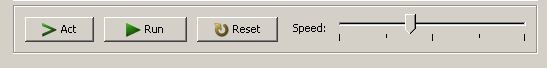


Figure 8: The Control Bar – Adopted from Greenfoot.org

The act button on the far left allows the user to step through each step of the simulation. This is useful if a user wants to see the difference between two consecutive steps in a simulation. The run button plays the visualization continuously. The execution speed can be controlled by the speed bar on the far right. When the run button is pressed, it turns into a pause button as can be seen in Figure 9. The pause button will stop the visualization on the current step. Once run is pressed, my simulation will continue running until all of the passengers are in their seats or until pause is pressed. The reset button clears the screen and a new simulation can then be run.

toolBarPause.bmp

Figure 9: The Control Bar while Running a Simulation – Adopted from Greenfoot.org

### How to Use my Simulation

Since the menu for my simulation is built into the actual program, a user needs to press run on the Greenfoot window as outlined above to begin. Once this button is pressed, it will appear as if the simulation is not running because no passengers are appearing. The used needs to first select the baggage policy and occupancy rate he would like to use from the menu located below the visual representation of the airplane. Figure 10 shows this menu.

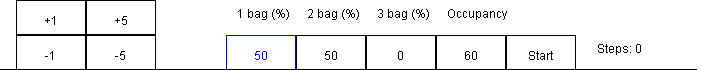


Figure 10: Menu for selecting a baggage policy and occupancy rate

On the far left side of this menu are boxes labeled +1,-1, +5, and -5. These boxes control the percentage to be added or subtracted from the value in the currently selected box. This box appears highlighted in blue. In the scenario in Figure 10, the user is changing the percentage of passengers who have one bag. The user has the option of changing the percentage of passengers who have one bag, the percentage of passengers who have two bags, the passengers who have three bags, and the occupancy level. If the user selects a bag policy that does not add up to 100%, the start button will not be enabled. Once the user has selected his desired baggage policy and occupancy rate, he can press start. The start button will then turn into a Running… button and all of the buttons on the menu will be disabled. This is illustrated by Figure 11. Once the simulation has started, the user will only be able to stop the simulation with the pause button in the Greenfoot IDE.

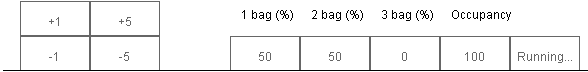
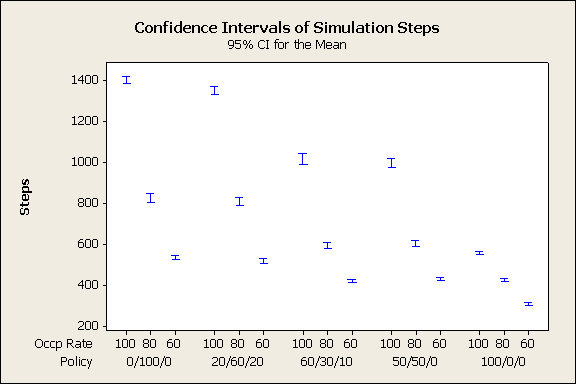


Figure 11: The menu when the user had started the simulation

## Simulation Tests

To test my simulation I selected five different policies. Two of these, a 60/30/10 and a 20/60/20, were tested in the Ghent University studies. I also selected a 0/100/0 policy which is representative of the current worst case policy allowed by airlines. Most airlines allow two bags: a carry-on and a personal item. Since it is highly unlikely that every single passenger on a plane would bring two bags, I decided to test a 50/50/0 policy which might be a more reasonable situation on a plane. With this policy, all the passengers follow the rules outlined by the airlines yet are not required to have two bags. I also tested a 100/0/0 policy which could be used as preliminary test for an airline that may want to change its policy to be more restrictive regarding the number of bags passengers are allowed to bring on the plane. With each of these five policies I tested three different occupancy levels: 100%, 80%, and 60%. The purpose of testing different occupancy rates was to demonstrate the effects of fuller planes, since more airlines have cut flights leading to fuller planes. I ran a total of 750 simulations, 50 simulations for each combination of baggage policy and occupancy rate. After collecting data I used confidence intervals to analyze my data over the population of all possible simulation runs. Since I only tested a few different options, using regression analysis did not seem to be appropriate and using confidence intervals allowed me to really concentrate on the means of the data.

### Results

The raw data from the simulations can be found in Appendix D. The results include the number of steps it took to complete the simulation as well as how many bags were left unstowed. After running the simulations, I calculated confidence intervals on the mean number of simulation steps. Figure 12 shows these intervals graphically and the values of these confidence intervals can be found in Appendix C. All of the lengths of the confidence intervals were under 50 simulation steps except the 60/30/10 policy at 100% occupancy where the interval length was 56. In Figure 12, the policies are ordered from the slowest policies to the fastest and a clear distinction between the different  policies can be seen. At 100% occupancy rate, both the 0/100/0 policy and the 20/60/20 policy averaged around 1400 simulation steps. The 60/30/10 policy and the 50/50/0 policy averaged around 1000 simulation steps and the 100/0/0 was the fastest at around 600 simulation steps. These three distinct groups appear at all three of the different occupancy levels. The fastest policy (100/0/0) performed on average 233.33% better than the slowest policy (0/100/0). This could have substantial effect on the amount of time airplanes spend on the ground. When looking at lower occupancy levels, the amount of time decreases for all policies, as fewer passengers on a plane equates to less time needed to board. However, significant gaps appear to exist at the different occupancy levels between the policies, as the fastest policy performs on average 200% better than the slowest policy at 80% occupancy and about a 175% better at 60% occupancy. It should be noted that policies involving more bags being brought on the airplane should take a longer amount of time. Since my model has all passengers attempting to store all of their bags in the overhead bins, more bags would equal longer boarding time since time is being taken to store these extra bags as well.

**Figure 12: Confidence Intervals for mean number of simulation steps**

Data for the number of bags left unstowed was also analyzed using confidence intervals. Figure 13 presents these results in a visual form and the numerical information on the confidence intervals can be found in Appendix C.

As the occupancies reach 60%, all of the policies have confidence intervals whose upper and lower bounds are close to (0,0). Of the policies that did not have this interval, the interval lengths were under half of a bag with a mean no greater than 0.18. Unlike the differences shown in the average number of simulation steps, the differences in unstowed bags disappear at 60%. Looking at the data closer does reveal some issues related to occupancy.

At 100% occupancy, the number of unstowed bags at the end of the simulation was on average 48.92 bags for the 0/100/0 policy and 43.04 bags for the 20/60/20 policy. By changing the occupancy to 80%, the average number of unstowed bags for the 0/100/0 policy was 7.54 bags and 5.18 bags for the 20/60/20 policy. This is a dramatic decrease in the number of unstowed bags from 100% occupancy to 80% occupancy. Dealing with five unstowed bags as opposed to 43 unstowed bags is much more manageable for a flight. Those five bags could go with the passengers in their seats or, if need be, it would be really easy to have those five bags go into the cargo, but having to deal with 43 bags could really slow down the process, this shows that the 0/100/0 and 20/60/20 policies are really inefficient when the plane is at full capacity.



Figure 13: Confidence Intervals for bags left unstowed

### The Queuing Effect

While running my simulations, I noticed patterns in data that do not show up in the raw data. These patterns fall under what I call The Queuing Effect. The Queuing Effect essentially is when all of the overhead bins are completely full, but there are still passengers trying to stow the bags they are carrying. Unfortunately for these passengers, they will not find space. Therefore these passengers continue to walk down the plane looking for spots. Eventually these passengers will reach the end of the plane where the time delay will begin so the passengers can be transported back to their seats. This process will continue until all of the passengers are placed in their seats. A visual depiction of The Queuing Effect can be seen in Figure 14. The presence of the Queuing Effect should be evidence for the airlines that the policy being tested is inefficient and could cause significant issues if that policy were implemented.

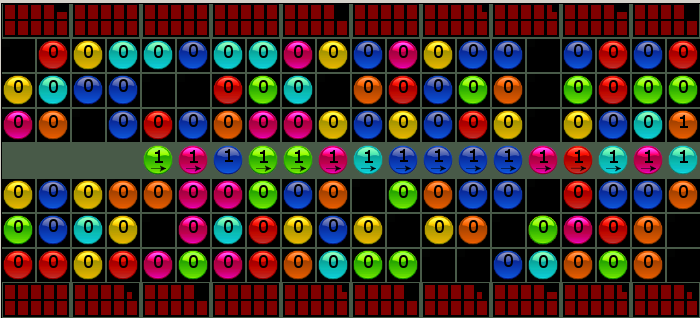


Figure 14: The Queuing Effect

### Suggestions to the Airlines

From my simulation results it is clear that baggage policy in conjunction with occupancy rate can have a significant influence not only on the amount of time it takes to board an airplane, but also on the number of bags left unstowed. Airlines will have to investigate the average occupancy rate of their current flights after the cut backs. This will be a huge determining factor in boarding efficiency in the future. Airlines will also have to analyze and predict the baggage policy that best represents the composition of their flights. While in the worst case all passengers could bring two bags, it is highly unlikely that this scenario would be the situation. The 50/50/0 policy which may be more representative of normal flights yields significantly different results at higher occupancy levels than the 0/100/0 policy according to my simulation results. However, with airlines charging for checked bags, this worst case scenario where every passenger brings two bags could become a reality.

Airlines should also look at these issues from a financial standpoint. They need to analyze the amount of money they save by cutting flights and how much money they earn from charging for checked bags to see if they are making enough money to eliminate the effects of money lost by increased ground time as a result of fuller flights and increased carry-on luggage. Airlines may find that the cost of jet fuel might be cheaper than spending extra time on the ground. Overall, it is hard to interpret the true effects of cutting flights and charging for checked baggage without airlines collecting data. But I suggest that if airlines consistently are having more and more flights at close to full capacity, and if airlines find that charging for checked bags has yielded more carry-on luggage, then it might be beneficial to change the baggage policy to the 100/0/0 policy where occupancy rate had almost no effect on the number of unstowed bags. Airlines could also more strictly enforce the policy that only one bag is allowed in the overhead bin, although this policy would be harder to enforce and also takes time.

## Strengths of the Model

The true strength of my model is that it focuses on the baggage policy and occupancy rate while holding all other variables constant. This is useful for analyzing data because a user can test different baggage policies and occupancy rates and know that the differences between two simulations are based exclusively on those two variables. With a more complex model, airlines may not be able to correlate their issues with one single factor.

My model has an additional advantage over fully computational programs. While computational programs would take an input, run the simulation internally and print out the results to the user, my simulation allows the user to view the simulation while it is running. This can expose issues with the boarding process such as The Queuing Effect that may not be found with raw data. A user can see where bottlenecks occur, notice differences between two iterations of the simulation, and from this, develop methods to try to fix the problems.

## Weaknesses of the Model

The weaknesses are associated with the human aspect of my model. Since I was not able to go out and observe the boarding of airplanes to analyze how long it takes passengers to move one row down an aisle, how long it takes passengers to move past seats, and how long it takes passengers to store their luggage, I had to select values based on educated guesses. This is why my model prints out the number of simulation steps the simulation takes rather than a time equivalent. I cannot make the assumption that one simulation step is equivalent to one second based on how values were selected for my model.

Likewise, my model does not take into account how humans behave on a plane. As outlined in the Passenger section, I used time delays and then “teleported” passengers back to their seat if they had to pass their seat to stow a bag, if they reached the end of the plane, or if other passengers were blocking their seat. This is not realistic of human behavior and most of the inconsistencies in the boarding process of my simulation can be equated to the issues I encountered in modeling human behavior.

My model also assumes that passengers try to store all luggage in the overhead bins, which is not the case in real life. Many passengers carry a bag with them to their seats. This could lead to skewed results since although a simulation run indicates 50 unstowed bags the actual number could be much smaller when the number of bags passengers take with them to their seats is accounted for. Lastly, adding a first class may change the results for unstowed bags since the first class only has four seats in a row as opposed to six which means there could be more space to place unstowed bags.

## Extensions

As with any modeling problem where there are so many factors and variables involved, there are essentially endless opportunities to make extensions to improve the model. Certain factors will become more important as technology advancements in airplanes and different policies, such as security laws, as well as airline fees and changes in boarding policy, make certain factors more important to boarding time.

### Overhead Bin

My model focused on creating a dynamic overhead bin, but there are many extensions that could be made to enhance the model of my bin. My bin model did not focus on a specific bin system, but there are numerous systems on planes such as outboard shelf, center pivot, outboard pivot, center translating, outboard shelf shallow, and outboard shelf deep just to name a few (Simmons & Worden, n.d.). Which bins are being used impacts the amount of luggage that can fit in a bin. The shape of the bin and how the door opens/closes restricts how much luggage can actually be fit into the bin. Therefore, testing different bins might be useful as different bin models on the same plane could make a significant difference in the amount of luggage that can be stored.

Different sized bins might also be tested. As can be seen in Appendix B, the airplanes I based my model on have different amounts of cubic space they hold and different bin lengths. This could also influence the boarding process, but is not accounted for in the current model.

### Bags

My model was based on a maximum carry-on bag of 47.5 linear inches, but in the future it is quite possible that the airlines could change the size of the maximum bag. Instead of allowing 47.5 linear inches maybe airlines will restrict passengers to bags of 40 linear inches maximum. This would have a significant impact not only on the passengers, but also on the process of packing overhead bins. The program could be altered to permit users to select different bag sizes. This would allow airlines to see the lasting effects of changing bag size before having to actually implement it. Also, since different airlines have a different maximum size for carry-on bags, it would be useful to provide a tool for airlines to run simulations with the bag sizes that they actually allow.

It would also be useful to have a more explicit method of handling bags that passengers carry with them to their seats. With my model passengers try to pack all of their bags in the overhead bins, but this is not necessarily true for all passengers. Adding this feature would require modifying the way bags are stored as well as modifying how passengers deal with seat interferences. It is more likely that a passenger carrying a bag to his seat would necessitate other passengers leaving their seats in order to create enough room for the passenger. It would also be useful to add passengers who do not try to pack any of their bags in the overhead bins.

### Human Behavior

One of the main features to expand my simulation would be a better method of handling human behavior. I had very limited data on how much time it takes a passenger to move down one row, pass a seat, and store luggage. It would be useful for me to go out into the field, not only to observe human behavior to get a grasp of how humans act and interact in the situation of boarding a plane, but also to video record boardings to analyze how long the entire boarding process takes as well as individual characteristics such as speed and stowing time.

One other feature of human behavior is how passenger navigates back to his seat if he has to find a new spot to place his luggage. As outlined in the Passenger Movement section, there are many ways people handle going against the flow of traffic including temporarily standing in rows, squeezing by other passengers, and other passengers backing up. Observing and recording many airplane boardings would allow me to notice patterns in human behavior that could be incorporated into my simulation. With any extension to the human behavior aspect of the simulation there will still be an issue of not being able to accurately predict human behavior.

### Generalizability

Lastly, it would be a nice extension if I could make my simulation more general so that it can be applied to a wide variety of planes. This would involve a number of changes to my simulation. It would have to allow the user of the simulation an opportunity to enter in how many passengers he would like to have in the simulation. It would also need to allow the user to add multiple aisles, multiple doors, and a first class. These additions would permit users to test almost any model airplane.

Most of the previous research focused on the boarding policies and call-off systems as already mentioned. It would be useful for me to add an option to test multiple boarding policies so that I would be better able to compare my data with that of previous research. I would also be able to see if policies such as outside-in and by seat are really efficient with my more overhead bin focused model.

## Obstacles

### Threading

Using Greenfoot made it very easy to create graphics, but with this advantage came many difficulties when trying to write code. The underlying threading structure of Greenfoot caused issues when dealing with collision avoidance with passengers. When trying to add a new passenger to the world, a check had to be made to make sure the spot was open. Every time the simulation tried to add a new passenger to the world, it was finding that there was a passenger blocking the first spot in the plane and waited until the next simulation step. This created a staggered pattern on the simulation screen because the passenger blocking the path did end up moving out of that spot during that simulation step just in a later thread. My problem was that even though I could organize the order in which different classes in the world acted (threads), the world class always acts first. Since my creation of a new person was executed in the world class, all I had to do was move the person adder to its own class and make sure its thread executed after the person class.

Even with this issue solved, there is some underlying Greenfoot threading structure that could possibly change the order the thread in the class executes. I could run into the same issue I had with adding new people with people already placed in the world. The first passenger added to the world does not necessarily have to move before the last person added in the world. The system can chose to move first whichever passenger it wants to causing more ordering issues.

### Slow Execution

At the height of my simulation, there can be over 300 objects in the world all trying to run pieces of code at the same time. This can really slow down program execution. In fact, if you watch my simulation, you will see that the simulation does slow down as more and more objects are added into the world. I developed a few coding methods to try to minimize this. At one point I redrew the picture for each passenger at every step of the execution. To try to speed up execution, I put in a check to redraw the picture only when it needs to be changed. Since there are up to 120 objects related to the passengers, I wrote in a check to see if a passenger is in his seat. If he is in his seat, then all of the checks related to trying to get him into his seat are bypassed. Greenfoot as a coding environment is not really intended to handle all of the objects I put in the world and if I were to make the program much more complex, I would have to switch to a different environment or a faster computer.

### Storing Luggage in the Same Bin at the Same Time

When I began testing my program I noticed that it was possible for two passengers to try to store luggage in the same bin at the same time. Since my overhead bin spans two rows, this is definitely a possibility. The way I had this process coded, a passenger would check to see if there was space in the bin and if there was, wait a time delay and place his bag in the bin. Now if there were two passengers doing this at the same time, it is likely that one would finish waiting before the other and place his bag in the bin. But now there is less space in the bin and possibly no space that the other passenger thought existed. This means that the second passenger could try to fit his bag in the bin when all of a sudden there was no space. This issue was hard to find because the debugging tool in Greenfoot, which is not very robust, made error checking difficult. To solve this problem I ended up changing the image of the bin before I performed the time delay. This means that the passenger’s bag appears in the bin before the time delay representing the stowing time is finished. This does not change the results of the simulation, just the order of how events occur.

### Menu

Lastly, trying to create a useful menu useful was not the easiest of tasks. I was trying to create a menu where the user could enter values for the percentage of passengers having 1, 2, or 3 bags. Since Greenfoot is a newer coding environment, most of the information related to it is found on the internet. The online Greenfoot community has an open source gallery where users post source code to make it available to other users. I was able to explore what other users had done to create menus and from that make my own. I resorted to a group of buttons on the screen that serves the same purpose although it takes a lot longer for a user to select the kind of simulation he would like to run.

## Conclusions

Much of the previous research an airplane boarding has looked into methods for minimizing the amount of time airplanes spend on the ground by focusing efforts on the boarding policy. They found that policies that minimize interferences between the passengers are the most efficient, but are hard to implement when real life issues such as families and late passengers come into the picture. My model takes a different approach to the airplane boarding problem since changing airline policies have shifted focus to the effects of baggage policies. My model provided results indicating that fuller airplanes and the likelihood of more carry-on luggage by passengers as a result of fighting high jet fuel costs might be causing airlines more trouble than good by increasing the boarding time and increasing the likelihood of unstowed bags. I suggest that airlines need to analyze their financial situation to see if cutting flights and charging for checked bags has greater advantages than the costs of increased boarding time. If need be, restricting the amount of luggage passengers may bring on the plane can help minimize boarding time and help airlines fly into the future with maximum profit.

## References

Airbus (n.d.). A320 Family. Retrieved from http://www.airbus.com/aircraftfamilies/passengeraircraft/a320family/

Andrews, L. (2010, November 16) How airlines cut costs [Web log post]. Retrieved from http://www.airlinetickets.org/blog/how-airlines-cut-costs/

The Boeing Company (n.d.). 737 Family. Retrieved from http://www.boeing.com/commercial/737family/index.html

Brockman, J. (2008, May 6). Ode to the second checked bag. *National Public Radio*. Retrieved from http://www.npr.org/templates/story/story.php?storyId=90714705&ft=1&f=1006

Dale, N. & Weems, C. (2010). Programming and Problem Solving with C++. Sudbury, Massachucetts: Jones and Bartlett.

Demerjian, D (2006, May 9). Airlines Try Smarter Boarding. *Wired News*. Retrieved from http://www.wired.com/science/discoveries/news/2006/05/70689

Elliott, C. (2008, June 12). Fee for all: Avoid new airline luggage charges – Strategies that can help you get around American, United first-bag fee. *Microsoft National Broadcasting Corporation*. Retrieved from http://www.msnbc.msn.com/id/24761262/

Ferrari, P. (2005). [Improving passenger boarding in airplanes using computer simulations](http://leeds-faculty.colorado.edu/vandenbr/papers/05sep05article.pdf). *International Airport Review*. Retrieved from http://leeds-faculty.colorado.edu/vandenbr/papers/05sep05article.pdf

Ferrari, K. & Nagel, K (2005). Robustness of efficient passenger boarding strategies for airplanes. *Transportation Research Record: Journal of the Transportation Research Board*, 1915, 44-54.

Greenfoot. (n.d.) What is Greenfoot?. Retrieved from http://www.greenfoot.org/about/whatis.html

Gutierrez, C. (2008, May 21). American Airline’s heavy baggage. *Forbes.com*. Retrieved from http://www.forbes.com/2008/05/21/amr-airlines-closer-markets-equity-cx\_cg\_0521markets37.html

HeathTecna Aircraft Interior Solutions. (2011). Airplane Overhead Bins [Data File] Retrieved from an email from Joe Frazier – Interiors Principal Engineer.

Kreit, A. (2008). Flying-high: New airline fees for checked baggage. *Microsoft National Broadcasting Corporation*. Retrieved from http://www.npr.org/news/graphics/2008/may/flying\_high.html

Nyquist, D.C., & McFadden, K.L. (2008). A study of the airline boarding problem. *Journal of Air Transport Management*, 14, 197-204. doi: 10.1016/j.jairtraman.2008.04.004

Mangum, L. (2008). Steep climb: Jet fuel price. *Microsoft National Broadcasting Corporation*. Retrieved from http://media.npr.org/news/graphics/2008/may/steep\_climb00.jpg?t=1248646712

Marelli, S., Mattocks, G., & Merry, R. (1998). [The role of computer simulation in reducing airplane turn time](http://www.boeing.com/commercial/aeromagazine/aero_01/t/t01/index.html). Retrieved from http://www.boeing.com/commercial/aeromagazine/aero\_01/textonly/t01txt.html

Mayerowitz, S. (2010, September 14). Meet the world’s most-cramped airline seat – The proposed SkyRider reduces coach legroom even more. *ABC News.* Retrieved from http://abcnews.go.com/Travel/skyrider-worlds-cramped-airplane-seat/story?id=11633822

Seat Guru. (n.d.). Delta Airlines Aribus A319 (319). Retrieved from http://www.seatguru.com/airlines/Delta\_Airlines/Delta\_Airlines\_Airbus\_A319.php

Seat Guru. (n.d.). Guide to Airline Boarding Procedures. Retrieved from http://www.seatguru.com/articles/boarding\_procedures.php

Seat Guru. (n.d.). US Airways Boeing 737-400 (734). Retrieved from http://www.seatguru.com/airlines/US\_Airways/US\_Airways\_Boeing\_737-400.php

Simmons, G., & Worden, L. (n.d.). Advancements in overhead stowage bin article retention. Retrieved from http://www.smartcockpit.com/data/pdfs/flightops/safety/Advancements\_In\_Overhead\_Stowage\_Bin\_Article\_Retention.pdf

The Travel insider (n.d.). Airline Carry On Luggage Allowance. *The Travel Insider*. Retrieved from http://thetravelinsider.info/travelaccessories/airlinecarryonluggageallowances.htm

United States Government Accountability Office. (2010, July). Commerical aviation - Consumers could benefit from better information about airline-imposed fees and refundability of government-imposed taxes and fees. (GAO-10-785). Retrieved from http://www.gao.gov/new.items/d10785.pdf

Van den Briel, M.H.L., Villalobos, J.R., & Hogg, G.L. (n.d.). The aircraft boarding problem. *Arizona State University*. Retrieved from http://leeds-faculty.colorado.edu/vandenbr/papers/IERC2003MvandenBriel.pdf

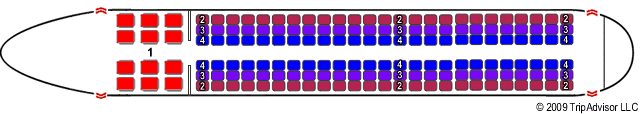
Van den Briel, M.H.L., Villalobos, J.R., Hogg, G.L., Lindemann, T., & Mulé, A.V. (2005). America West Airlines develops efficient boarding strategies. *Interfaces,* 35(3), 191-201. doi: 10.1287/inte.1050.0135

Van Landeghem, H. (n.d.) A simulation study of passenger boarding times in airplanes. *University of Pittsburgh.* Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.19.2106&rep=rep1&type=pdf

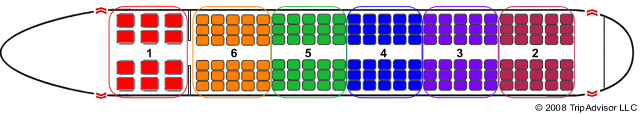
Van Landeghem, H., & Beuselinck (2002). Reducing passenger boarding time in airplanes: A simulation based approach. *European Journal of Operational Research*, 142, 294-308.

## Appendix A: Boarding Policies

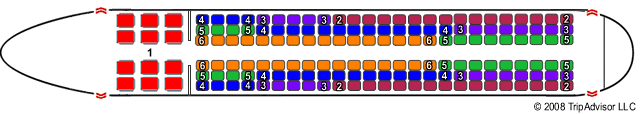
**Images from seatguru.com by Trip Advisor**

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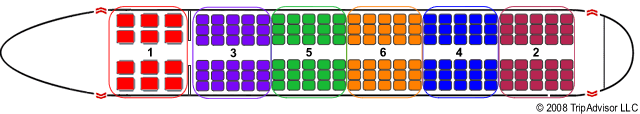
Outside-in Boarding Policy

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Back to Front Boarding Policy

****

Reverse Pyramid Boarding Policy

****

Rotating Zone Boarding Policy

## Appendix B: Overhead Bin Models

**Information provided by Heath Tecna**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Interior Type** | **Aircraft Type** | **Volume per bin door** | **Shelf Width** | **Placard Weight per door** | **Length of Interior down and back** | **Bin Length/ weight** |
| CARRY-ALL (BOEING) | 737-200 | 9.1 | 22.3 | 180 | 1280 | 60"/ |
| QUIKBIN | 737-200 | 8.7 | 24 | 100 | 1275 | 60"/ |
| SPACEMAKER I | 737-200 | 9.1 | 23 | 180 | 1240 | 60"/ |
| SPACEMAKER II | 737-200 | 9.2 | 23 | 180 | 1260 | 60"/ |
| ATI (BOEING) | 737-300 | 9.8 | 25.25 | 180 | 1500 | 60" / 27lbs |
| ATIX (concept I) | 737-300 |  |  | 165 | 1500 | 60"/ |
| ATIX (concept II) | 737-300 | 10.2 | 28.2 | 175 | 1500 | 60"/ |
| ATI (BOEING) | 737-400 | 9.8 | 25.25 | 180 | 1700 | 60" / 27lbs |
| ATIX (concept II) | 737-400 | 10.2 | 28.2 | 175 | 1700 | 60"/ |
| ATI (BOEING) | 737-500 | 9.8 | 25.25 | 180 | 1300 | 60" / 27lbs |
| ATIX (concept I) | 737-500 |  |  | 165 | 1300 | 60"/ |
| ATIX (concept II) | 737-500 | 10.2 | 28.2 | 175 | 1300 | 60"/ |
| NG (BOEING) | 737-600 | 13.3 |  | 80 | 1290 | 80"/ 43lbs |
| NG (BOEING) | 737-700 | 13.3 |  | 80 | 1420 | 80"/ 43lbs |
| NG (BOEING) | 737-800 | 13.3 |  | 80 | 1960 | 80"/ 43lbs |
| A320 (AIRBUS) | A320 | 7.7 | 28.6 | 84 | 1686 | 88” |

## Appendix C: Confidence Intervals

**Mean number of Steps Confidence Intervals**

|  |  |  |  |
| --- | --- | --- | --- |
| **Policy** | **Occupancy Rate** | **Mean # of Steps** | **Confidence Interval** |
| 0/100/0 | 100 | 1403.82 | (1387.32, 1420.41) |
| 0/100/0 | 80 | 824.48 | (803.899, 845.061) |
| 0/100/0 | 60 | 532.44 | (523.031, 541.849) |
| 20/60/20 | 100 | 1351.24 | (1332.66, 1369.82) |
| 20/60/20 | 80 | 806.26 | (786.634, 825.886) |
| 20/60/20 | 60 | 517.68 | (506.7, 528.66) |
| 60/30/10 | 100 | 1016.58 | (988.494, 1044.67) |
| 60/30/10 | 80 | 593.2 | (580.808, 605.592) |
| 60/30/10 | 60 | 418.5 | (410.746, 426.254) |
| 50/50/0 | 100 | 996.32 | (972.35, 1020.29) |
| 50/50/0 | 80 | 602.32 | (587.265, 617.375) |
| 50/50/0 | 60 | 429.66 | (421.522, 437.798) |
| 100/0/0 | 100 | 555.5 | (547.324, 563.676) |
| 100/0/0 | 80 | 424.28 | (417.271, 431.289) |
| 100/0/0 | 60 | 306.96 | (301.297, 312.623) |

**Mean number of Unpacked Bags Confidence Intervals**

|  |  |  |  |
| --- | --- | --- | --- |
| **Policy** | **Occupancy Rate** | **Mean # of Bags Unpacked** | **Confidence Interval** |
| 0/100/0 | 100 | 48.92 | (48.2314, 49.6086) |
| 0/100/0 | 80 | 7.54 | (6.82469, 8.25531) |
| 0/100/0 | 60 | 0.18 | (0.003149, 0.032851) |
| 20/60/20 | 100 | 43.04 | (42.2528, 43.8272) |
| 20/60/20 | 80 | 5.18 | (4.48935, 5.87065) |
| 20/60/20 | 60 | 0.14 | (0.01148, 0.2685) |
| 60/30/10 | 100 | 15.94 | (15.3971, 16.4829) |
| 60/30/10 | 80 | 0.54 | (0.2405, 0.8395) |
| 60/30/10 | 60 | 0.02 | (-0.0202, 0.0602) |
| 50/50/0 | 100 | 15.58 | (15.0381, 16.1219) |
| 50/50/0 | 80 | 0.38 | (0.137148, 0.62285) |
| 50/50/0 | 60 | 0 | (0, 0) |
| 100/0/0 | 100 | 0.04 | (-0.01626, 0.096256) |
| 100/0/0 | 80 | 0 | (0, 0) |
| 100/0/0 | 60 | 0 | (0, 0) |

**\*95% confidence interval, two tail**

## 

## Appendix D: Raw Data

| Policy | Occupancy Rate | Steps | Bags |
| --- | --- | --- | --- |
| 0/100/0 | 100 | 1389 | 50 |
| 0/100/0 | 100 | 1451 | 50 |
| 0/100/0 | 100 | 1295 | 48 |
| 0/100/0 | 100 | 1407 | 45 |
| 0/100/0 | 100 | 1317 | 48 |
| 0/100/0 | 100 | 1415 | 53 |
| 0/100/0 | 100 | 1342 | 47 |
| 0/100/0 | 100 | 1420 | 48 |
| 0/100/0 | 100 | 1388 | 49 |
| 0/100/0 | 100 | 1342 | 52 |
| 0/100/0 | 100 | 1468 | 52 |
| 0/100/0 | 100 | 1401 | 48 |
| 0/100/0 | 100 | 1386 | 50 |
| 0/100/0 | 100 | 1372 | 49 |
| 0/100/0 | 100 | 1327 | 46 |
| 0/100/0 | 100 | 1433 | 51 |
| 0/100/0 | 100 | 1410 | 47 |
| 0/100/0 | 100 | 1419 | 46 |
| 0/100/0 | 100 | 1357 | 48 |
| 0/100/0 | 100 | 1381 | 52 |
| 0/100/0 | 100 | 1490 | 51 |
| 0/100/0 | 100 | 1374 | 47 |
| 0/100/0 | 100 | 1489 | 44 |
| 0/100/0 | 100 | 1402 | 49 |
| 0/100/0 | 100 | 1480 | 47 |
| 0/100/0 | 100 | 1321 | 51 |
| 0/100/0 | 100 | 1457 | 51 |
| 0/100/0 | 100 | 1483 | 52 |
| 0/100/0 | 100 | 1347 | 49 |
| 0/100/0 | 100 | 1338 | 44 |
| 0/100/0 | 100 | 1394 | 48 |
| 0/100/0 | 100 | 1443 | 49 |
| 0/100/0 | 100 | 1415 | 53 |
| 0/100/0 | 100 | 1391 | 45 |
| 0/100/0 | 100 | 1563 | 51 |
| 0/100/0 | 100 | 1392 | 49 |
| 0/100/0 | 100 | 1436 | 51 |
| 0/100/0 | 100 | 1372 | 48 |
| 0/100/0 | 100 | 1479 | 52 |
| 0/100/0 | 100 | 1380 | 48 |
| 0/100/0 | 100 | 1385 | 49 |
| 0/100/0 | 100 | 1527 | 52 |
| 0/100/0 | 100 | 1443 | 47 |
| 0/100/0 | 100 | 1357 | 50 |
| 0/100/0 | 100 | 1294 | 47 |
| 0/100/0 | 100 | 1483 | 51 |
| 0/100/0 | 100 | 1386 | 43 |
| 0/100/0 | 100 | 1383 | 50 |
| 0/100/0 | 100 | 1415 | 49 |
| 0/100/0 | 100 | 1352 | 50 |
| 0/100/0 | 80 | 906 | 8 |
| 0/100/0 | 80 | 763 | 9 |
| 0/100/0 | 80 | 867 | 7 |
| 0/100/0 | 80 | 720 | 12 |
| 0/100/0 | 80 | 890 | 8 |
| 0/100/0 | 80 | 810 | 4 |
| 0/100/0 | 80 | 773 | 13 |
| 0/100/0 | 80 | 778 | 8 |
| 0/100/0 | 80 | 903 | 5 |
| 0/100/0 | 80 | 1027 | 4 |
| 0/100/0 | 80 | 882 | 6 |
| 0/100/0 | 80 | 858 | 6 |
| 0/100/0 | 80 | 845 | 7 |
| 0/100/0 | 80 | 806 | 8 |
| 0/100/0 | 80 | 834 | 6 |
| 0/100/0 | 80 | 888 | 6 |
| 0/100/0 | 80 | 843 | 6 |
| 0/100/0 | 80 | 711 | 8 |
| 0/100/0 | 80 | 926 | 6 |
| 0/100/0 | 80 | 894 | 6 |
| 0/100/0 | 80 | 842 | 8 |
| 0/100/0 | 80 | 817 | 9 |
| 0/100/0 | 80 | 850 | 5 |
| 0/100/0 | 80 | 796 | 9 |
| 0/100/0 | 80 | 834 | 9 |
| 0/100/0 | 80 | 936 | 7 |
| 0/100/0 | 80 | 896 | 9 |
| 0/100/0 | 80 | 888 | 6 |
| 0/100/0 | 80 | 798 | 10 |
| 0/100/0 | 80 | 895 | 5 |
| 0/100/0 | 80 | 815 | 6 |
| 0/100/0 | 80 | 725 | 7 |
| 0/100/0 | 80 | 854 | 4 |
| 0/100/0 | 80 | 901 | 11 |
| 0/100/0 | 80 | 785 | 7 |
| 0/100/0 | 80 | 705 | 11 |
| 0/100/0 | 80 | 782 | 5 |
| 0/100/0 | 80 | 780 | 8 |
| 0/100/0 | 80 | 729 | 10 |
| 0/100/0 | 80 | 786 | 7 |
| 0/100/0 | 80 | 781 | 6 |
| 0/100/0 | 80 | 854 | 4 |
| 0/100/0 | 80 | 925 | 5 |
| 0/100/0 | 80 | 782 | 6 |
| 0/100/0 | 80 | 735 | 8 |
| 0/100/0 | 80 | 756 | 10 |
| 0/100/0 | 80 | 647 | 13 |
| 0/100/0 | 80 | 844 | 11 |
| 0/100/0 | 80 | 797 | 14 |
| 0/100/0 | 80 | 765 | 4 |
| 0/100/0 | 60 | 571 | 0 |
| 0/100/0 | 60 | 520 | 0 |
| 0/100/0 | 60 | 539 | 0 |
| 0/100/0 | 60 | 537 | 1 |
| 0/100/0 | 60 | 546 | 2 |
| 0/100/0 | 60 | 513 | 0 |
| 0/100/0 | 60 | 501 | 1 |
| 0/100/0 | 60 | 564 | 0 |
| 0/100/0 | 60 | 571 | 0 |
| 0/100/0 | 60 | 521 | 0 |
| 0/100/0 | 60 | 575 | 2 |
| 0/100/0 | 60 | 552 | 0 |
| 0/100/0 | 60 | 516 | 0 |
| 0/100/0 | 60 | 497 | 0 |
| 0/100/0 | 60 | 525 | 0 |
| 0/100/0 | 60 | 547 | 0 |
| 0/100/0 | 60 | 474 | 0 |
| 0/100/0 | 60 | 550 | 0 |
| 0/100/0 | 60 | 564 | 0 |
| 0/100/0 | 60 | 557 | 0 |
| 0/100/0 | 60 | 554 | 0 |
| 0/100/0 | 60 | 550 | 0 |
| 0/100/0 | 60 | 599 | 0 |
| 0/100/0 | 60 | 476 | 2 |
| 0/100/0 | 60 | 559 | 0 |
| 0/100/0 | 60 | 509 | 0 |
| 0/100/0 | 60 | 576 | 0 |
| 0/100/0 | 60 | 528 | 0 |
| 0/100/0 | 60 | 499 | 0 |
| 0/100/0 | 60 | 500 | 0 |
| 0/100/0 | 60 | 507 | 0 |
| 0/100/0 | 60 | 583 | 0 |
| 0/100/0 | 60 | 532 | 0 |
| 0/100/0 | 60 | 525 | 0 |
| 0/100/0 | 60 | 539 | 0 |
| 0/100/0 | 60 | 549 | 0 |
| 0/100/0 | 60 | 464 | 0 |
| 0/100/0 | 60 | 495 | 0 |
| 0/100/0 | 60 | 566 | 0 |
| 0/100/0 | 60 | 618 | 0 |
| 0/100/0 | 60 | 500 | 0 |
| 0/100/0 | 60 | 506 | 0 |
| 0/100/0 | 60 | 539 | 1 |
| 0/100/0 | 60 | 524 | 0 |
| 0/100/0 | 60 | 498 | 0 |
| 0/100/0 | 60 | 522 | 0 |
| 0/100/0 | 60 | 482 | 0 |
| 0/100/0 | 60 | 509 | 0 |
| 0/100/0 | 60 | 551 | 0 |
| 0/100/0 | 60 | 523 | 0 |
| 20/60/20 | 100 | 1261 | 44 |
| 20/60/20 | 100 | 1368 | 45 |
| 20/60/20 | 100 | 1361 | 46 |
| 20/60/20 | 100 | 1331 | 42 |
| 20/60/20 | 100 | 1338 | 45 |
| 20/60/20 | 100 | 1414 | 44 |
| 20/60/20 | 100 | 1372 | 45 |
| 20/60/20 | 100 | 1352 | 48 |
| 20/60/20 | 100 | 1293 | 39 |
| 20/60/20 | 100 | 1427 | 43 |
| 20/60/20 | 100 | 1380 | 42 |
| 20/60/20 | 100 | 1424 | 43 |
| 20/60/20 | 100 | 1427 | 44 |
| 20/60/20 | 100 | 1267 | 40 |
| 20/60/20 | 100 | 1422 | 45 |
| 20/60/20 | 100 | 1286 | 48 |
| 20/60/20 | 100 | 1279 | 42 |
| 20/60/20 | 100 | 1367 | 42 |
| 20/60/20 | 100 | 1406 | 47 |
| 20/60/20 | 100 | 1193 | 39 |
| 20/60/20 | 100 | 1377 | 44 |
| 20/60/20 | 100 | 1334 | 43 |
| 20/60/20 | 100 | 1439 | 40 |
| 20/60/20 | 100 | 1430 | 48 |
| 20/60/20 | 100 | 1261 | 42 |
| 20/60/20 | 100 | 1289 | 41 |
| 20/60/20 | 100 | 1355 | 42 |
| 20/60/20 | 100 | 1352 | 42 |
| 20/60/20 | 100 | 1378 | 46 |
| 20/60/20 | 100 | 1375 | 36 |
| 20/60/20 | 100 | 1382 | 43 |
| 20/60/20 | 100 | 1428 | 41 |
| 20/60/20 | 100 | 1455 | 44 |
| 20/60/20 | 100 | 1309 | 41 |
| 20/60/20 | 100 | 1319 | 42 |
| 20/60/20 | 100 | 1290 | 44 |
| 20/60/20 | 100 | 1323 | 42 |
| 20/60/20 | 100 | 1334 | 44 |
| 20/60/20 | 100 | 1477 | 47 |
| 20/60/20 | 100 | 1365 | 37 |
| 20/60/20 | 100 | 1327 | 45 |
| 20/60/20 | 100 | 1288 | 40 |
| 20/60/20 | 100 | 1320 | 38 |
| 20/60/20 | 100 | 1296 | 43 |
| 20/60/20 | 100 | 1400 | 41 |
| 20/60/20 | 100 | 1228 | 45 |
| 20/60/20 | 100 | 1256 | 44 |
| 20/60/20 | 100 | 1316 | 43 |
| 20/60/20 | 100 | 1472 | 48 |
| 20/60/20 | 100 | 1419 | 43 |
| 20/60/20 | 80 | 786 | 6 |
| 20/60/20 | 80 | 771 | 11 |
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| 20/60/20 | 80 | 850 | 5 |
| 20/60/20 | 80 | 755 | 3 |
| 20/60/20 | 80 | 814 | 7 |
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| 20/60/20 | 80 | 785 | 4 |
| 20/60/20 | 80 | 815 | 8 |
| 20/60/20 | 80 | 898 | 7 |
| 20/60/20 | 80 | 901 | 5 |
| 20/60/20 | 80 | 903 | 0 |
| 20/60/20 | 80 | 880 | 1 |
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| 20/60/20 | 80 | 788 | 4 |
| 20/60/20 | 80 | 781 | 4 |
| 20/60/20 | 80 | 788 | 0 |
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| 20/60/20 | 80 | 749 | 4 |
| 20/60/20 | 80 | 840 | 4 |
| 20/60/20 | 80 | 803 | 5 |
| 20/60/20 | 80 | 811 | 5 |
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| 20/60/20 | 80 | 708 | 5 |
| 20/60/20 | 80 | 918 | 6 |
| 20/60/20 | 80 | 836 | 3 |
| 20/60/20 | 80 | 732 | 8 |
| 20/60/20 | 80 | 857 | 7 |
| 20/60/20 | 80 | 837 | 3 |
| 20/60/20 | 80 | 837 | 7 |
| 20/60/20 | 80 | 866 | 10 |
| 20/60/20 | 80 | 789 | 5 |
| 20/60/20 | 80 | 829 | 3 |
| 20/60/20 | 80 | 732 | 9 |
| 20/60/20 | 80 | 801 | 4 |
| 20/60/20 | 80 | 755 | 4 |
| 20/60/20 | 80 | 873 | 6 |
| 20/60/20 | 80 | 823 | 7 |
| 20/60/20 | 80 | 721 | 6 |
| 20/60/20 | 80 | 798 | 4 |
| 20/60/20 | 80 | 881 | 7 |
| 20/60/20 | 80 | 651 | 7 |
| 20/60/20 | 80 | 700 | 5 |
| 20/60/20 | 80 | 829 | 3 |
| 20/60/20 | 80 | 983 | 2 |
| 20/60/20 | 80 | 713 | 6 |
| 20/60/20 | 80 | 867 | 1 |
| 20/60/20 | 60 | 539 | 0 |
| 20/60/20 | 60 | 542 | 0 |
| 20/60/20 | 60 | 525 | 0 |
| 20/60/20 | 60 | 585 | 2 |
| 20/60/20 | 60 | 539 | 2 |
| 20/60/20 | 60 | 486 | 0 |
| 20/60/20 | 60 | 509 | 0 |
| 20/60/20 | 60 | 519 | 1 |
| 20/60/20 | 60 | 556 | 0 |
| 20/60/20 | 60 | 451 | 0 |
| 20/60/20 | 60 | 541 | 0 |
| 20/60/20 | 60 | 573 | 0 |
| 20/60/20 | 60 | 426 | 0 |
| 20/60/20 | 60 | 571 | 0 |
| 20/60/20 | 60 | 526 | 0 |
| 20/60/20 | 60 | 559 | 0 |
| 20/60/20 | 60 | 558 | 0 |
| 20/60/20 | 60 | 557 | 0 |
| 20/60/20 | 60 | 531 | 0 |
| 20/60/20 | 60 | 469 | 0 |
| 20/60/20 | 60 | 483 | 0 |
| 20/60/20 | 60 | 524 | 0 |
| 20/60/20 | 60 | 585 | 0 |
| 20/60/20 | 60 | 516 | 0 |
| 20/60/20 | 60 | 540 | 0 |
| 20/60/20 | 60 | 460 | 0 |
| 20/60/20 | 60 | 516 | 0 |
| 20/60/20 | 60 | 528 | 0 |
| 20/60/20 | 60 | 586 | 0 |
| 20/60/20 | 60 | 548 | 1 |
| 20/60/20 | 60 | 533 | 0 |
| 20/60/20 | 60 | 508 | 0 |
| 20/60/20 | 60 | 486 | 0 |
| 20/60/20 | 60 | 496 | 1 |
| 20/60/20 | 60 | 492 | 0 |
| 20/60/20 | 60 | 463 | 0 |
| 20/60/20 | 60 | 528 | 0 |
| 20/60/20 | 60 | 533 | 0 |
| 20/60/20 | 60 | 549 | 0 |
| 20/60/20 | 60 | 564 | 0 |
| 20/60/20 | 60 | 510 | 0 |
| 20/60/20 | 60 | 438 | 0 |
| 20/60/20 | 60 | 490 | 0 |
| 20/60/20 | 60 | 517 | 0 |
| 20/60/20 | 60 | 491 | 0 |
| 20/60/20 | 60 | 464 | 0 |
| 20/60/20 | 60 | 487 | 0 |
| 20/60/20 | 60 | 505 | 0 |
| 20/60/20 | 60 | 481 | 0 |
| 20/60/20 | 60 | 501 | 0 |
| 60/30/10 | 100 | 906 | 17 |
| 60/30/10 | 100 | 1046 | 16 |
| 60/30/10 | 100 | 993 | 17 |
| 60/30/10 | 100 | 1090 | 17 |
| 60/30/10 | 100 | 1069 | 17 |
| 60/30/10 | 100 | 1091 | 17 |
| 60/30/10 | 100 | 949 | 18 |
| 60/30/10 | 100 | 1143 | 21 |
| 60/30/10 | 100 | 1118 | 18 |
| 60/30/10 | 100 | 1013 | 15 |
| 60/30/10 | 100 | 1232 | 18 |
| 60/30/10 | 100 | 973 | 19 |
| 60/30/10 | 100 | 824 | 14 |
| 60/30/10 | 100 | 994 | 16 |
| 60/30/10 | 100 | 941 | 13 |
| 60/30/10 | 100 | 1016 | 16 |
| 60/30/10 | 100 | 928 | 18 |
| 60/30/10 | 100 | 1216 | 17 |
| 60/30/10 | 100 | 1124 | 15 |
| 60/30/10 | 100 | 874 | 13 |
| 60/30/10 | 100 | 965 | 13 |
| 60/30/10 | 100 | 921 | 13 |
| 60/30/10 | 100 | 1014 | 16 |
| 60/30/10 | 100 | 794 | 12 |
| 60/30/10 | 100 | 938 | 17 |
| 60/30/10 | 100 | 1098 | 17 |
| 60/30/10 | 100 | 1002 | 14 |
| 60/30/10 | 100 | 1067 | 18 |
| 60/30/10 | 100 | 1067 | 16 |
| 60/30/10 | 100 | 960 | 14 |
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| 60/30/10 | 100 | 1213 | 18 |
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| 60/30/10 | 100 | 1093 | 16 |
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| 60/30/10 | 100 | 1010 | 15 |
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| 60/30/10 | 80 | 567 | 2 |
| 60/30/10 | 80 | 577 | 0 |
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| 60/30/10 | 80 | 651 | 0 |
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| 60/30/10 | 80 | 692 | 0 |
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| 60/30/10 | 80 | 547 | 0 |
| 60/30/10 | 80 | 518 | 0 |
| 60/30/10 | 60 | 422 | 0 |
| 60/30/10 | 60 | 414 | 0 |
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| 60/30/10 | 60 | 391 | 0 |
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| 60/30/10 | 60 | 406 | 0 |
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| 60/30/10 | 60 | 449 | 0 |
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| 60/30/10 | 60 | 409 | 0 |
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| 60/30/10 | 60 | 417 | 0 |
| 60/30/10 | 60 | 436 | 0 |
| 60/30/10 | 60 | 414 | 0 |
| 60/30/10 | 60 | 392 | 0 |
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| 60/30/10 | 60 | 409 | 0 |
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| 60/30/10 | 60 | 421 | 0 |
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| 60/30/10 | 60 | 424 | 0 |
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| 50/50/0 | 100 | 1146 | 13 |
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| 50/50/0 | 100 | 919 | 14 |
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| 50/50/0 | 80 | 576 | 0 |
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| 50/50/0 | 80 | 569 | 1 |
| 50/50/0 | 80 | 573 | 0 |
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| 50/50/0 | 80 | 572 | 0 |
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| 50/50/0 | 80 | 574 | 0 |
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| 50/50/0 | 80 | 658 | 0 |
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| 50/50/0 | 80 | 653 | 0 |
| 50/50/0 | 80 | 602 | 2 |
| 50/50/0 | 80 | 558 | 0 |
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| 50/50/0 | 60 | 451 | 0 |
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| 100/0/0 | 100 | 568 | 0 |
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| 100/0/0 | 100 | 574 | 0 |
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| 100/0/0 | 100 | 612 | 0 |
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| 100/0/0 | 80 | 406 | 0 |
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| 100/0/0 | 80 | 413 | 0 |
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| 100/0/0 | 60 | 314 | 0 |
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| 100/0/0 | 60 | 284 | 0 |
| 100/0/0 | 60 | 328 | 0 |
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| 100/0/0 | 60 | 293 | 0 |
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| 100/0/0 | 60 | 327 | 0 |
| 100/0/0 | 60 | 301 | 0 |
| 100/0/0 | 60 | 298 | 0 |
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