Bus Seating in Arlington, Virginia: ART Passenger Demographics, Seating Preferences and Dwell Time Efficiency

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ABSTRACT

Boarding, alighting and seating maneuvers were monitored on selected Arlington Transit (ART) bus routes in order to determine the link between passenger demographics, seating preferences and boarding and alighting times within the system. The data collection methodology employed digital stopwatch timings of boardings and alightings in conjunction with a coordinate-based spreadsheet seating chart tracking system in order to document passenger movements and seating occupancies. Passengers were visually profiled according to their ethnicity, sex, general age group and bulkiness. Multiple linear regression analysis was used to develop boarding and alighting models, and t-tests were used to isolate statistically significant differences between profiled groups in terms of their seating preferences and inter-group separation distances aboard the buses. It was observed that female passengers tend to sit closer to other passengers than males do, and that older female passengers have a preference for sitting in aisle seats and towards the lower level front of the bus – each of these preferences is linked with shorter boarding times. Males, in general, tend to prefer window seating to aisle seating, and this preference is linked with longer boarding and alighting times. It was also observed that younger passengers prefer less efficient upper level seating to lower level seating and that white passengers, on average, tend to sit closer to other white passengers on routes where whites are a minority in terms of passenger composition. Monetary fare payment was observed to contribute to longer boarding times than the use of a swipe card (e.g., SmarTrip® card).

DEDICATION

I would like to dedicate this work to my late professor and friend Dr. Shinya Kikuchi, whose passion for public transit and technical mastery of the science of transportation were unmatched. I continue to be motivated by Dr. Kikuchi's dogged insistence that his students and colleagues develop innovative solutions to urban transportation problems.

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I would also like to specifically thank Blanche Buergler, Kelly MacKinnon and Steve Yaffe from Arlington Transit for their feedback as well as their eagerness to learn more about the system they so skillfully administer.

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CHAPTER 1: INTRODUCTION

1.1 Problem Definition

The commercial speed of a public bus is dependent not only on the portion of its operational time spent in motion but also on the portion of functional time during which it is stopped. Standing time, or dwell time, as defined formally in the Highway Capacity Manual [1], is “the time a transit unit (vehicle or train) spends at a station or a stop, measured from stopping to starting,” principally in order to accommodate boarding and/or alighting passengers. Dwell time can often account for more than 25% of the effective travel time of public transportation vehicles [2], and during the dwell time period, queuing, fare collection, seat selection, crowding adjustments, entering movement and exiting movement can occur, sometimes concurrently.

Bus system operators with the objective of maximizing or increasing fixed route capacity in order to increase potential payload are faced with the task of increasing the number of buses, increasing the maximum passenger capacity of each bus and/or increasing the operational frequency of the specific route. In situations where the fleet size and physical characteristics of each bus are constants, the operational frequency on the bus route becomes the critical parameter which must be modified. Decreasing dwell time may lead to increased operating frequency and a resulting increase in fixed route capacity.

Passenger seating is closely related to bus dwell time. Although the selection of a seat (or standing space) is fundamentally and directly part of the boarding process, the location and orientation of the selected seat (or standing space) as well as other environmental factors can have significant impacts on the alighting process. Vuchic [3] formally developed an equation which expresses dwell time in transit vehicles with distinct exit and entry portals as the sum of a lost time period and the maximum value of either its boarding time or its alighting time (for transit vehicles using the same portal for entry and exit, boarding and alighting times are summed together). While Vuchic's equation treats the respective boarding and alighting terms as average rates to be applied to a given number of boarding or alighting passengers, these rates may vary greatly depending on the actions and preferences of the passengers. The passengers themselves may also vary in terms of their personal characteristics which may directly affect their boarding and alighting times as well as their predisposition towards selecting seats of a certain type, location or surrounding condition.

The primary problem to be addressed in this study is to determine how the characteristics, seating preferences and dwell time activity of passengers affect the boarding and alighting efficiency of buses within a specific system (Arlington Transit).

1.2 Research Objectives

In this study, a greater and more comprehensive understanding of the dynamics of the seating behavior component of dwell time for a particular transit system has been acquired. While a greater knowledge of seating dynamics is a worthy objective in its own right because it increases our understanding of passenger-based transportation systems, it may also directly lead to policies than can improve the operational efficiency of specific public transportation modes. Objectives addressed in this study included (1) identifying visual passenger characteristics that lead to different seating selections and (2) identifying the seating preferences and passenger profiles that impact boarding and alighting times. This study has developed models which link seating preferences and passenger profiles with boarding and alighting time, and it has employed hypothesis testing to confirm significant differences in seating behavior among passenger groups with differing demographic profiles.

1.3 Scope of Research

This thesis presents observations and analyses of the seating choices and boarding and alighting times of passengers using public bus transportation in the Arlington County system. Seating behavior was monitored on Arlington County's ART (Arlington Transit) buses. The Arlington Transit bus network features a collection of routes that each cater to riderships of varying levels of heterogeneity. In addition, ART vehicles feature distinctive seating geometries, exit placements, overall configurations, and a choice of fare payment methods that may reveal sharp differences in observed seating preferences among passenger groups.

1.4 Significance of Thesis

This thesis explores the link between passenger demographics, seating preferences and boarding and alighting times. No existing study uncovered during the literature review attempts to link demographics with boarding and alighting efficiency, and no significant study of any kind has ever been conducted on the seating preferences of ART bus passengers. The findings of this thesis may lead to practical improvements in the operation of a functioning bus system (ART).

1.5 Thesis Organization

This thesis is comprised of six chapters with additional appendices. After this chapter, Chapter 2 is devoted to a literature review, which is essentially divided into two parts. The first focuses on the social and psychological motivations behind passenger seating behavior. The second part is devoted to papers which focus on the technical aspects of transit, which includes relevant work on public transportation as well as pedestrian movement. The literature review underscores the research gap which this thesis fills. Chapter 3 presents background data on the Arlington Transit system which, along with some key findings described in the literature review, provide a basis for formulating hypotheses which will be evaluated and discussed in the results chapter. Chapter 4 offers a detailed description of the methodology employed in order to collect data and subsequently analyze the derived results. Chapter 5 is the results section of this thesis. A detailed analysis and discussion of the results is included in this chapter, and Chapter 6 is the conclusion section which summarizes the main findings of this thesis.

CHAPTER 2: REVIEW OF LITERATURE

Even though passenger seating is ultimately a public transportation issue, the mechanics of passenger movement are related to pedestrian traffic flow dynamics. Moreover, the motivations behind seating choices may have social, psychological and/or anthropological roots. The selection of relevant literature reviewed reflects these influences. This review divides the surveyed literature into two groups: (a) social literature (primarily focusing on psychological motivations behind seating behavior) and (b) technical transportation papers (primarily based on public transportation and pedestrian traffic studies).

2.1 Social Literature

Bus seating in the United States has not always been an unrestricted choice among all passengers as ethnic minorities (blacks in particular) in many localities were often compelled to sit in reserved areas and to relinquish seats to white passengers whenever deemed "necessary." The American Civil Rights movement was notably sparked by the refusal of Rosa Parks, a black female passenger, to relinquish her seat on a bus in Montgomery, Alabama. While the legal restriction of seating may have compelled specific ethnic/racial groups of passengers to sit more closely together, other factors, including socially influenced feelings of "racial identity" which begin to intensify during adolescence [4] may induce individuals of similar backgrounds to sit together [5], whether in an academic setting, a general social setting, or specifically on public transit vehicles.

A relatively new academic discipline known as "environmental psychology" [6] focuses specifically on human spatial behavior and its motivations. In everyday living (including time spent in transit), individuals function within spatial spheres that separate themselves from other individuals, and the magnitude of the separation space may be based on the individuals in contact with each other, the activity being performed and the environmental setting. Major motivators that have been cited as influential factors affecting the magnitude of separation space include the desires for safety, privacy [7], comfort [8], the level of desire for social interaction [9] and functional utility (the practical space needed to accomplish tasks) [10].

Many of these motivations are theorized to be rooted in the human evolutionary process [11]. An instinctual perceived need for space may be linked with territorial behavior, for example, which provided evolutionary advantages to human beings by regulating a safe amount of survival space and limited competition for resources. In his studies of behavior, Calhoun [12][13] noted that when "perceived" densities surpass a certain point, the "crowding" effect begins and human beings, like other animals, may fall into a "behavioral sink" where there is a perceived loss of control and behavior becomes more erratic. This erratic behavior has been shown to range from aggression, which is rare, to fleeing or withdrawal [14][15], which may affect separation distance if regulation space exists.

Whatever the motivations are, individuals attempt to regulate the space that surrounds them at work, at home and in transit. In a study directly monitoring seating behavior on Greyhound buses, Kim [16] observed that once passengers acquire a seat (there is a general preference for seats that are next to other unoccupied seats), passengers engage in certain unspoken rules of "social disengagement" that discourage other passengers from selecting a neighboring seat. If it is impossible or at the very least, impractical, to avoid sitting next to another passenger, passengers may have preferences for the types of passengers they would prefer to sit next to or avoid. It is not inconceivable that ethnic stereotypes, perceptions relating to gender roles, and comparative differences in age may influence the formation of these preferences.

Age, gender and culture seem to have some effect on the magnitude of personal space. Hayduk [17] has observed that this space increases with age, and Gifford [18] is among the researchers who have observed that male/male pairs keep the largest distance between them followed by female/female pairs and then male/female pairs. There are also cultural factors that are apparently influential. Sommer [19] notes that in comparable social situations, French and South Americans have been observed to interact at closer distances than English – it remains to be seen whether there is an observable difference in transit seating distances between members of different (or the same) ethnic groups.

Arlington County's transit population is diverse in terms of the cultural backgrounds of its passengers. This and other social factors are likely to define a unique transportation culture with distinctive seating preferences.

2.2 Technical Transportation Literature

The literature on bus seating preferences is severely limited. The amount of available literature focusing on the broader issue of transit dwell times is also limited, although some notable studies have been conducted by Levinson [20], Kraft and Bergen [21] and Lin and Wilson [22], among others. Levinson's study has been used to develop general guidelines for transit boarding and alighting time models in traffic manuals such as the ITE Transportation and Traffic Engineering Handbook [23] based on factors such as the number of passengers, fare collection method, and platform elevation levels. Dueker et al. [24] cite these studies and comment that the limited amount of literature on bus dwell times is due to the cost and time required for manual data collection. They conclude in their study that key factors such as lift operations and low floor buses can most significantly impact bus dwell times.

Qi et al. [25] developed a cellular boarding and alighting micro-simulation model for a population of Beijing metro-rail passengers that closely examined the correlation between group sizes and boarding times. The motivation for passenger movement between target cells was based on a calculation of probable perceived utility as affected by “pressure” from surrounding passengers and individual preferences. They found that average alighting time increased with a higher ratio of boarding to alighting passengers, and that average boarding time seemed to decrease (with a low statistical correlation coefficient) with increasing ratios of boarding to alighting passengers. While this model did account for the desire of passengers to select cells within a train based largely on the maximization of empty surrounding space, ethnicity was not considered as a motivator for spatial decision making, and pedestrians were classified as “aggressive”, “standard”, and “conservative” based on their desire to compete for space, with an emphasis on standing room only space as opposed to sub-capacity seat selection decision-making.

The Helbing social force model is an influential pedestrian traffic model that simulates the movement of individuals and groups of pedestrians toward destinations that may or may not be related to public transportation. Pedestrians in this model may move toward a target and either accelerate or decelerate based on “attractions” and “repulsions,” where the summation of social attractions and repulsions modify the movement of a pedestrian who would otherwise move in an uninhibited fashion with an intended velocity toward its destination. In Helbing's model, pedestrian behavior is usually motivated by utility maximization whereby an optimal path is sought to minimize delays and to walk with the minimal velocity necessary to reach a destination "at a certain time." Helbing accounted for deviations from ideal, predictable behavior which could occur in irregular situations, due to insufficient knowledge of optimal strategies by the pedestrian and the possibility of "emotional" behavior by incorporating the possibility for stochastic fluctuations in his model. While this model also considers group dynamics (including the tendency of opposing platoons to form bottlenecks through a single opening and change the direction of prevailing movement after a point of equilibrium "pressure" is reached), individual movement is based largely on traveling at maximum (uninhibited) intended speed, the minimization of travel time to an objective location and the maximization of practical space between pedestrians within a visual radius [26]. Hoogendoorn [27] developed a gas-kinetic model of pedestrian flow with three types of interactions described: one-sided, two-sided and passive. Speed-density relationships for pedestrian traffic flows are presented, and from this there were derived travel time and walking speeds for different pedestrian situations.

The boarding and alighting processes on commercial airplanes may be at least somewhat instructive when considering the problem of public bus dwell time efficiency. An airplane boarding study conducted by Tang et al. compared passenger seating based on (i) random boarding, (ii) seat number ordered boarding, and (iii) the combination of seat number groupings and so-called "individual properties" (including personalized maximum movement speed and the effects of carrying luggage) in determining seat boarding order. Using a numerical simulation technique that incorporates the probable travel speed of individual passengers and the effects of conflicts and carrying baggage, Tang et al. found that randomized seating was the least efficient in terms of timing and the number of seating conflicts, and that seating orders based on numbered groupings and individual passenger properties was the most efficient [28]. The study underscored the importance of limiting conflicts between passengers but its value is somewhat limited when comparing it to the proposed public transportation study because the two modes are not completely comparable for a variety of reasons including: (a) luggage is not carried and handled exactly the same way on buses and metro-rail trains as it is on commercial aircrafts, (b) air passengers are more likely than bus passengers to have the same origin and destination, (c) the entry and exit geometries tend to differ as public transportation vehicles tend to have more than one exit portal, and critically, (d) seat selection is resolved differently on commercial air flights than it is on public transit.

Alam and Werth [29] created an agent-based seat preference model of a public bus in Manchester, England that factored in the age grouping, ethnicity, size ("heavy" or "not heavy") and sex of each passenger. Each stop of the bus route was a separate time step, and seating preference rules were developed as part of a clustering probability model. Clustering probability is defined as the "fraction of points that are part of a cluster" and a node is part of a cluster if "its four nearest neighbors (von Neumann neighborhood) all share its characteristic" [29a]. The presented rules were based on a combination of observation and "intuition", however, the authors stressed the fact that the rules were only "for demonstration", and that any "racial and gender implications" implied by such rules were "unintended" [29b]. One typical set of sample rules that is part of the model is the following: "Non-Asian female passengers prefer sitting with a female passenger at the front if they have to take an aisle seat. If that is not possible, they avoid sitting with young males or those who are heavy in size…" [29c]. With the given rules, and with an input of specific passenger agent types at various stops along the Manchester route, the model's output could be used to determine clustering probabilities along the routes based on ethnicity, sex and age factors.

Berkovich et al. studied seating (and standing) behaviors on New York City subway cars, using a grid to mark spaces for passengers. Gender, "bulk" (baggage and passenger size) and age group (adult or child) were the primary visually observed demographic factors noted when observing seating preferences. Using data collected between subway stops, Berkovich et al. derived "probability snapshots" of various occupancy load factors, indicating relative preferences for seat types and seating arrangements. It was concluded that 90% seat utilization was only achieved at 120% load factors (there is nearly always a certain small percentage of passengers who prefer to stand), passengers have a preference for seats near doors as well as window seats, and it was observed that fewer women rode in near empty cars [30]. Much of the focus of the study was on seating configuration, and the conclusion of the study featured a new layout design for subway cars that took into account some of the observed preferences.

2.3 Research Gap

There are few studies that link bus seating preferences to dwell time efficiency, and fewer studies still that consider these effects along with passenger demographics. No papers discovered during the literature review have focused their attention on the seating behavior of the unique Arlington, Virginia bus system. This thesis aims to provide quantifiable rules to describe seating preferences observed among visually identified agent groups defined by ethnicity, age category, size, and/or gender parameters, and this study attempts to determine how these observed preferences affect the operational efficiency (primarily as measured by their effect(s) on standing time) of the Arlington Transit bus system.

CHAPTER 3: HYPOTHESES AND DATA

The seating choices of transit passengers traveling in or through Arlington County has not been substantially covered by accessible literature. While unofficially, some individuals familiar with the system contend that teenagers using ART buses tend to select seats in the back of the bus, few, if any, other observations have been made on record.

3.1 ART Survey & Collected Data

A 2008 Arlington Transit rider study conducted by LDA Consulting and the Southeastern Institute of Research [31] is the latest accessible literature regarding ART's ridership. It reported the following statistics and observations regarding ART users at the time of the survey:

- 55% of ART users, based on survey responders, were female [31a]
- the mean age of users was 36 yet the average ART user was marginally younger than the average Arlington citizen [31b]
- 84% of ART users lived in Arlington [31c]
- The majority of riders were ethnic of ethnic minority backgrounds (31% Hispanic, 28% African American, 27% White Non-Hispanic, 9% Asian, 5% Other) [31d]
- 13% of users were not employed and 21% were students [31e]
- 63% of riders worked in Arlington [31f]
- 70% of riders had household incomes below $60,000 [31g]
- 58% of riders used ART at least 5 days a week [31h]
- ART had an estimated 7,000 unique riders per month [31i]
- Older riders were more likely to have been riding ART for a longer period of time [31j]
- 65% of riders lived less than 3 blocks from an ART stop [31k]
- Roughly ¾ of riders used the bus to get to work [31l]
- The most heavily used route was Route 41 (Columbia Pike-Ballston-Courthouse) [31m]
- Nearly a third of the survey respondents chose to complete the survey in Spanish; those who took the survey were slightly more likely to be satisfied with ART's service than other riders [31n]
- 13% of ART riders were "choice" riders; 48% were "bus dependent"; 39% were described as "other – non choice" [31o]

• 78% of riders were inclined to believe that the driver/operator was "courteous" [31p]
• 89% of riders were inclined to believe that the bus was "safe" [31q]

The riders directly observed during this study in 2013 were visually identified according to a methodology described in the next chapter. The sample breakdown is as tabulated in Table 1 and Table 2:

Total	254	Total Males	134	Total Females	120
Younger	53	Younger Males	33	Younger Females	20
Middle	140	Middle Males	70	Middle Females	70
Older	61	Older Males	31	Older Females	30
Asian	24	Asian Males	8	Asian Females	16
Black	52	Black Males	23	Black Females	29
Hispanic	85	Hispanic Males	53	Hispanic Females	32
Other	16	Other Males	5	Other Females	11
White	77	White Males	45	White Females	32

Table 1: Riders Observed in This Study, 2013

Total	100.00%	Total Males	52.76%	Total Females	47.24%
Younger	20.87%	Younger Males	12.99%	Younger Females	7.87%
Middle	55.12%	Middle Males	27.56%	Middle Females	27.56%
Older	24.02%	Older Males	12.20%	Older Females	11.81%
Asian	9.45%	Asian Males	3.15%	Asian Females	6.30%
Black	20.47%	Black Males	9.06%	Black Females	11.42%
Hispanic	33.46%	Hispanic Males	20.87%	Hispanic Females	12.60%
Other	6.30%	Other Males	1.97%	Other Females	4.33%
White	30.31%	White Males	17.72%	White Females	12.60%

Table 2: Riders Observed in This Study by Percentage of Total, 2013

A comparison of the 2013 sample and the estimates derived from the 2008 survey indicate that the 2008 sample was comprised of a greater percentage of female riders, 55%, compared to roughly 47% in 2013. The ethnic composition (by percentage) of the 2013 and 2008 samples, respectively, were roughly comparable for Asians, Whites and

Hispanics, although the 2008 survey reported a greater percentage of Blacks (28%) than the 2013 sample (roughly 20%). The reported median age of 36 for ART riders in 2008 cannot be directly compared to the 2013 sample, although the majority of riders observed were in the "Middle" age category, and roughly equal numbers were in the "Younger" age category (approximately age 19 or younger) as in the "Older" age category (approximately age 60 or older).

The authors of the 2008 rider study indicated in their report that their samples may have been biased due to their quota-based survey sampling methods [31r], and this may account for some of the difference between the 2008 and 2013 rider compositions. Another factor which may account for some of the discrepancy is the date each sample was taken, as the passenger demographics in Arlington may have changed significantly over the course of five years. Yet another factor to be considered is that the 2008 sample was based on a survey of all existing routes during peak and off-peak periods, including routes which accounted for less than 5% of the total estimated ridership. The 2013 study observed key routes during peak and off-peak times, however, a greater emphasis was placed on peak period samples and only routes which accounted for at least 5% of the total ridership as estimated in the 2008 survey were part of the 2013 study. Route selection differences as well as differences in the respective distributions of peak and off-peak samples may each account for significant differences in the demographic splits (including the gender splits) of passenger groups observed in the 2008 and 2013 studies.

3.2 Hypotheses

Based on the given survey results, anecdotal information regarding Arlington's transportation culture, results from studies of other systems, and social observations presented during the literature review, the following hypotheses were developed:

- Passengers in general will have a detectable preference for window seats over aisle seats (this was observed by Berkovich et al. [30] on New York City subways).
- Younger passengers are more likely to select upper level seating than passengers of other age groups (based on anecdotal information). Many Arlington Transit buses have a slightly elevated back section which is two steps higher than the front section of the bus.
- Older passengers are more likely to sit near the bus driver (possibly due to the fact that there is priority seating near the front of the bus and also because senior passengers may be less inclined to walk longer distances to occupy seats near the back of the bus on the upper level).
- Separation distances with respect to “heavy” or bulky/oversized passengers will be greater than that of all previously boarded passengers as a whole.
- Female seat selecting passengers are more likely to sit closer to another female passenger than to a male passenger. Gifford [18] noted this when examining spatial relationships in different contexts.
- Hispanic passengers are more likely to select seats with a shorter separation distance from other passengers of any ethnicity. Sommer [19] noted that Latin Americans have smaller personal spheres than do other cultures – it is therefore likely that this may extend to public transit seating in Arlington, particularly if there is a large immigrant Hispanic/Latino component of the ridership.
- White and Asian boarding passengers are more likely to maintain a greater separation distance from passengers of ethnic groups other than their own. This

hypothesis is based on a general impression of intercultural dynamics in the United States.

These hypotheses were tested in Chapter 5. T-testing was employed in order to determine if statistically significant conclusions could be drawn from the observed results.

CHAPTER 4: METHODOLOGY

Two primary forms of data were collected in this study: (a) seating chart data, and (b) timing data. Seating charts were used to track the positions of each passenger on a bus between stops, and digital stopwatch timing measurements were used to measure the boarding and alighting times of the respective platoons of entering and exiting passengers at each stop along a particular route. The first section of this chapter describes the ART routes selected for analysis. The next section presents an illustration of the modeling of an ART bus. The final two sections of this chapter respectively describe the data collection and data analysis methodologies of this study in detail.

4.1 Analysis Routes

The ART routes selected for analysis were chosen based on their proportion of officially estimated aggregate ridership. A "5% Rule" was applied to determine which routes were major components of the system: if, according to the latest accessible demographic passenger survey [31s], a previously and currently existing route accounted for at least 5% of the system's estimated total ridership, it was considered to be a significant route for analytical purposes. The routes selected for analysis were ART 41, ART 51, ART 52, ART 53 and ART 75, and links to route maps are provided on the official Arlington Transit website [32]. Data was collected during weekday AM and PM peak and off-peak periods over the course of a month, between the final week of May and the final week of June 2013.

ART 41

ART 41 runs through portions of Columbia Pike, Glebe Road, Wilson Boulevard and Clarendon Boulevard. It is a route whose major stops include Courthouse Plaza (located near the Courthouse Metro Station) and locations along Randolph Street near a side entrance of the Ballston Commons Mall. The Columbia Heights West residential area directly serviced by this route had a 2011 median household income that was roughly 25% lower than the median income for Arlington County as a whole, and the neighborhood racial composition is slightly more than 50% Hispanic and less than 25% White, with combined Asian and Black compositions jointly accounting for less than 25% [33].

ART 51

ART 51 runs through portions of George Mason Drive, Harrison Street, Lee Highway, Washington Boulevard and Fairfax Drive. It is a route whose major stops include the Ballston Metro Station and the Virginia Hospital Center, which was Arlington County's 2nd largest private employer as of January 2010 [34]. The Tara-Leeway Heights neighborhood directly serviced by this route has a population that is roughly 85% White with a 2011 median household income approximately 30% greater than the median for Arlington County as a whole [35], while the Langston-Brown neighborhood directly serviced by this route has a population that was roughly 40% Black, 30% White and 20% Hispanic, with a 2011 median household income which was also approximately 30% greater than the median for Arlington County as a whole [36].

ART 52

ART 52 runs through portions of Washington Boulevard, George Mason Drive, Yorktown Boulevard, Trinidad Street and Sycamore Street. It is a route whose major stops include the Ballston Metro Station, East Falls Church Metro Station, and the

Virginia Hospital Center. The Yorktown neighborhood directly serviced by this route had a racial composition that was roughly 85% White with a 2011 median income roughly 60% greater than that of Arlington County as a whole [37], and the Williamsburg neighborhood directly serviced by this route had a racial composition that was roughly 85% White with a 2011 median income approximately 75% greater than that of Arlington County as a whole [38].

ART 53

ART 53 runs through portions of Quincy Street, Military Road, and Williamsburg Boulevard as well as through two Lee Highway intersections, at Cherrydale and Sycamore Street, respectively. It is a route whose major stops include the East Falls Church Metro Station, the Ballston Metro Station and Arlington's Central Library Branch. In addition to directly servicing the Williamsburg neighborhood, it services the Bellevue Forest and Gulf Branch neighborhoods along Military Road as well as the Rock Spring neighborhood along Old Dominion Drive and Williamsburg Boulevard. Each of these neighborhoods had 2011 median household incomes that were roughly double that of Arlington County as a whole and populations that were approximately 90% White [39][40][41].

ART 75

ART 75 runs through portions of Wilson Boulevard, Carlin Springs Road, Frederick Street, Walter Reed Drive and Four Mile Run Drive. Its major stop locations include Shirlington Station, the Ballston Metro Station, and the Virginia Square Metro Station. Neighborhoods directly serviced by the route include Bluemont, a neighborhood with a racial composition comprised of roughly 75% Whites and 15% Hispanics, with a 2011 median income that was roughly 10% greater than the median for Arlington County as a whole [42], Glencarlyn, a neighborhood with a racial composition comprised of roughly 65% Whites, 15% Asians and 10% Hispanics, with a 2011 median income that was roughly 10% lower than the median for Arlington County as a whole [43], and Shirlington, a neighborhood with a racial composition comprised of roughly 55% Whites, 25% Blacks and 15% Hispanics, with a 2011 median income that was roughly 8% lower than the median for Arlington County as a whole [44].

4.2 Modeling the ART Bus

There are some variations in the seating plans of the buses deployed in the Arlington Transit system even though the buses generally use similar seating configurations. Each ART bus was modeled using a spreadsheet grid (Figure 1) in order to provide a convenient means of tracking the location of each passenger.

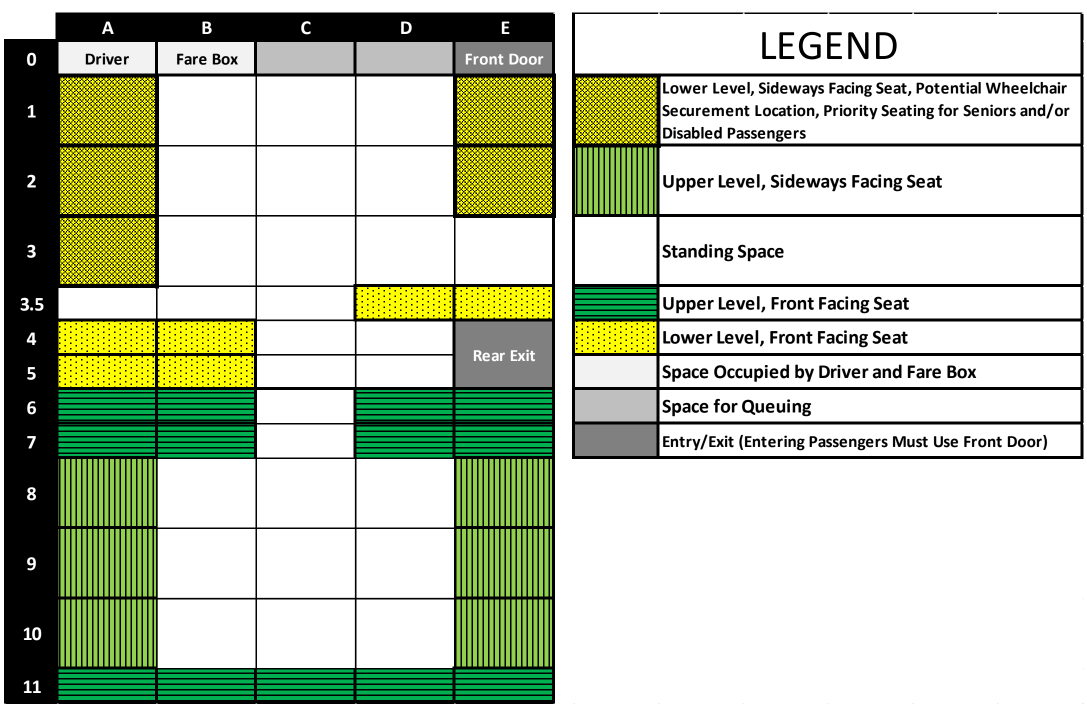


Figure 1: Spreadsheet Representation of an ART Bus interior

A three-dimensional coordinate system was employed in order to track passenger occupancies of unique and specific locations within each ART bus. Separation distances between agents occupying any two spaces can be derived by calculating the differences in location in each direction. In the spreadsheet representation of an ART bus above, the slightly elevated upper level begins at Row 6. Seats in rows 1 through 5 are “lower level” seats while seats in rows 6 through 11 are “upper level” seats. Columns A through E represent the discrete “lateral” (X-Direction) spacing while rows 0-11 mark the “longitudinal” (Y-Direction) spacing. Note that on the given representation of an ART bus, seats in Row 3.5 are located between seating rows 3 and 4 to indicate that there is not a full seat space of longitudinal (Y-Direction) separation between the seats in Row 3.5 and those in either Row 3 or Row 4. Lower level seats were given a Z-direction coordinate value of 0 while upper level seats were given a Z-direction coordinate value of 1. The legend provided gives a brief description of the illustrated seat types.

4.3 Data Collection Methodology

A single observer equipped with a laptop computer and a digital cell phone stopwatch rode selected ART buses (predetermined routes and time periods) in order to (a) document the seating positions of demographically profiled passengers aboard the bus at each stop, and to simultaneously (b) collect timing measurements of entering and exiting passenger platoons at these stops. The information gathered from the seating charts was used to calculate separation distances between passenger types as well as seating preferences and positional indicators for each boarding passenger. The timing data gathered for boarding and alighting movements was combined with the demographic profiles and seating information of the respective boarding and alighting passengers in order to determine which factors and passenger characteristics most significantly contribute to boarding and alighting time. The collection methodologies for each set of data (seating chart data and timing data) are described in this section. Data analysis methodologies are described later in this chapter.

4.3.1 Seating Charts

The seating positions of entering and previously seated passengers were noted on Excel spreadsheet seating charts. At each consecutive stop, a seating chart grid was pasted into a different part of the sheet and modified to reflect changes. Because there were some minor variations in the vehicle models used by ART, the use of a spreadsheet was convenient because it was able to be rapidly modified in order to accurately reflect the seating arrangement. A data point occurred whenever one or more passengers entered the vehicle at a stop and selected a space to occupy (either seating or standing). The choices made by each passenger formulated a separate set of data points. The entering passenger(s) as well as the passenger(s) already in the vehicle were assigned a code reflecting their profile (age, sex, ethnicity, spatial occupancy/heaviness). These code letters were typed into the cells corresponding to the vehicle spaces occupied by the passengers.

The passenger coding was as depicted in Table 3:

Digit	Coding
1st	**Ethnicity**: A=Asian, B=Black, H=Hispanic/Latino, W=White, O=Other
2nd	**Sex**: F=Female M=Male
3rd	**Age**: Y=Younger (Child/Teen), M=Middle Aged (Adult), O=Older Adult (Senior)
(4th)	**Heavy/Bulky**: h=Heavy/Bulky, otherwise no code letter

Table 3: Passenger Agent Coding for Seating Chart Data

The data points from an hypothetical ART bus stop were tabulated as follows in the hypothetical ART bus diagram below (Figure 2): the visually identified boarding passengers, "seat selectors (SS)" are an elderly white female, WFO (Seat 5A), and a heavyset teenage male who vaguely appears to be of Middle Eastern origin OMY (Seat 11C), both coded in bold italics on the ART bus grid. Passengers remaining on board from the previous stop, "previously boarded passengers (PBP)", are a heavyset adult White male WMMh (Seat 2A), a senior Hispanic male HMO (Seat 2E), an adult White female WFM (Seat 5B), and a bulky adult White male collecting the data, WMMh (Seat 6D).

Separation distances are all positive values measured relative to the location of the object agent. For the senior white female sitting in seat 5A, WFO, sample calculations are provided below. Distances are reported as {Lateral, Longitudinal, Vertical} or {X, Y, Z}.

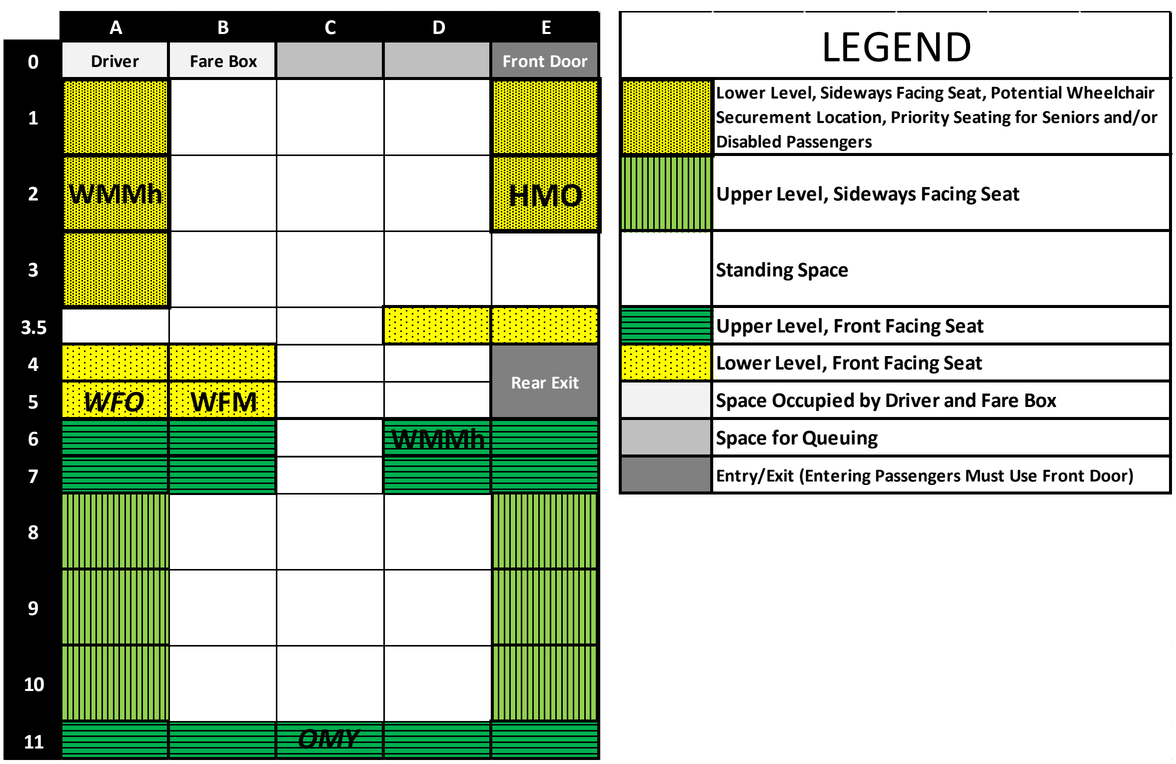


Figure 2: Hypothetical Seating Chart

Indexed Distance to passenger agent WFM in 5B is {0.33, 0, 0}; Absolute = 0.33

Lateral: 1 space of separation out of a maximum possible of 3 = 1/3 = 0.33

Because the agent WFM in seat 5B is located in Column B, the maximum possible X-Direction separation from her would be attained by occupying a space in Column E, which is three lateral spaces away. ***WFO*** *is located only one space away from her, laterally.*

Longitudinal: 0 spaces of separation out of a maximum possible of 6 = 0/6 = 0

Because the agent WFM in seat 5B is located in Row 5, the maximum possible Y-Direction separation from her would be attained by occupying a space in Row 11, which is 6 longitudinal spaces away. ***WFO*** *is seated in the same row and is therefore located 0 spaces away from her, longitudinally.*

Vertical: 0 spaces of separation out of a maximum possible of 1 = 0/1 = 0

Because the agent WFM in seat 5B is located in the lower level, the maximum possible Z-Direction separation from her would be attained by occupying a space in the upper level (Rows 6 through 11). All upper level seats are 1 vertical space above lower level seats. ***WFO*** *is seated in the lower level along with WFM, and is therefore located 0 spaces away from her, vertically.*

Combined Distance Calculation = $(0.33^2 + 0^2 + 0^2)^{0.5} = 0.33$

The combined (total) distance calculation takes the square root of the sum of the squares of the X, Y and Z directional distances calculated previously. This is a form of the standard three-dimensional distance equation used to calculate absolute distances between any two points given their coordinates (or relative distances in each direction).

Similar calculations for entering passenger ***WFO*** in 5A are performed relative to all other passenger agents, with the exception of those passengers who also entered at the same stop (in this case, ***OMY***, the heavyset teenage male "other" agent). Passengers in seats 2A and 6D are similar agent types (WMMh: heavyset/bulky adult white males) so the distances to the reference passenger ***WFO*** (the senior white female who boarded at this stop) are averaged for this data point.

Other indexed distances {X, Y, Z} which serve as positional indicators for agent ***WFO***:

Indexed Distance to Driver calculated to be {0, 0.45, 0}; Absolute = 0.45

Indexed Distance to Front Door calculated to be {1, 0.45, 0}; Absolute = 1.10

Indexed Distance to Rear Exit calculated to be {1, 0, 0}; Absolute = 1

Tabulating the distance data collected for the senior female passenger ***WFO*** would yield the following partial set of seating charts (Figure 3). Ellipses '…' represent additional passenger agent types whose calculations have been excluded from this example:

Lateral (X)	WFM	…	…	Front Door	Rear Exit	Driver
WFO	0.33	…	…	1.00	1.00	0.00

Longitudinal (Y)	WFM	…	…	Front Door	Rear Exit	Driver
WFO	0.00	…	…	0.45	0.00	0.45

Vertical (Z)	WFM	…	…	Front Door	Rear Exit	Driver
WFO	0.00	…	…	0.00	0.00	0.00

|Combined|	WFM	…	…	Front Door	Rear Exit	Driver
WFO	0.33	…	…	1.10	1.00	0.45

Figure 3: Hypothetical Seating Table Segments (X, Y, Z and Combined)

Seating Preference Indicators

For preference indicators, (i) seated-standing, (ii) seating type and (iii) window-aisle-other, indexed scores are reported and compared between agent groups. The scores were derived based on the selection and relative proportion of available seating choices in the bus seating diagram illustrated previously. Unselected seating types were given a preference index value of 0.

*For determining the **Seat or Stand** preference indicator: When the senior white female sitting in seat 5A, **WFO**, selected a seat instead of standing, there were 26 total seats and 28 standing spaces. Her seat preference index is 1/(26/54) = 2.08. Her standing preference index was 0. Similar calculations were performed in order to determine preference index values for "Window-Aisle-Other" and "Front-Side" facing seats as displayed in the chart in Table 4.*

	Seat	Stand	Window	Aisle	Other	Front	Side
WFO	2.08	0.00	2.89	0.00	0.00	1.53	0.00

Table 4: Hypothetical Seating Preference Table for agent WFO

4.3.2 Timings

Boarding and alighting timings were often collected at alternating stops due to the logistical difficulty of collecting the measurements simultaneously. At some stops, alighting was completed before boarding began and the two processes were able to be recorded more easily. In order to be able to capture the timing of boarding and alighting platoon movements (Figure 4), the observer was seated in a position where both the front and rear doors were within the same line of sight.

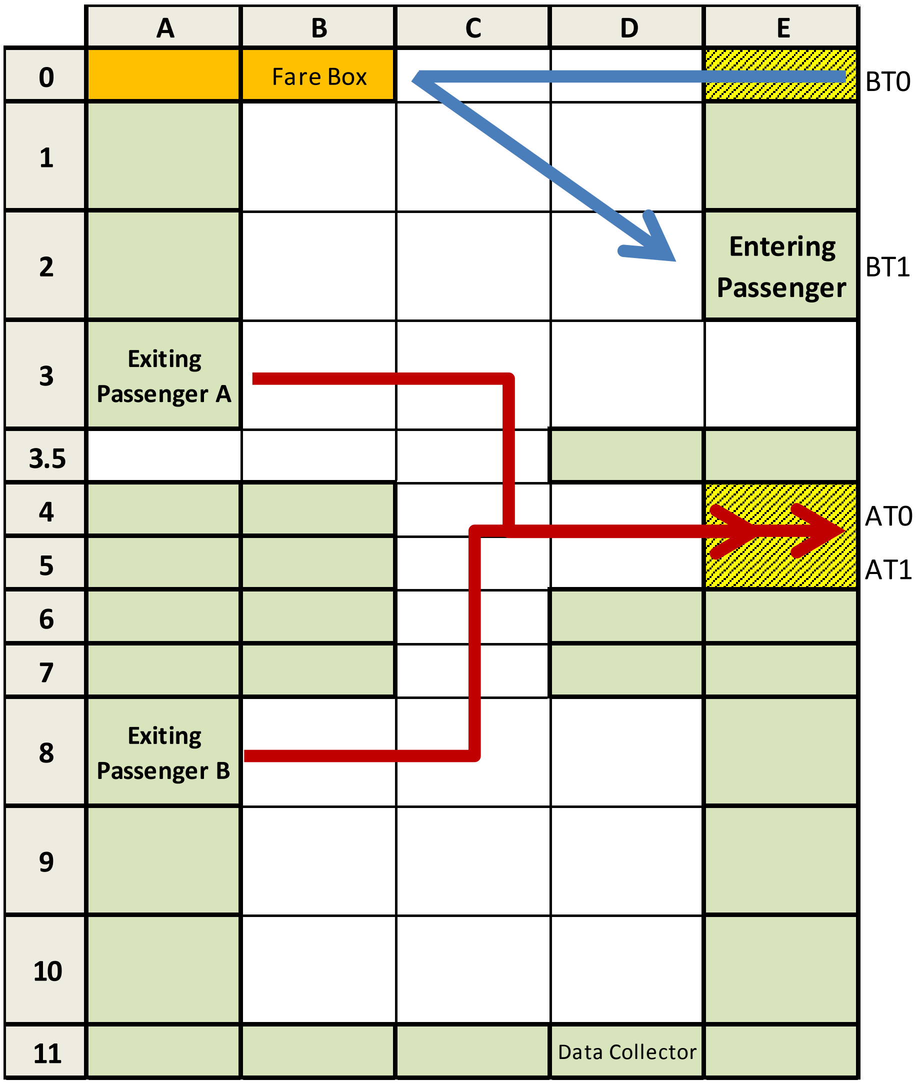


Figure 4: Illustration of Timing Measurement Procedure

Boarding timings commenced when the first passenger at an ART bus stopping point crossed the threshold of the front door (BT0 in Figure 4), and the timings ended once the final entering passenger occupied a seat or final standing space (BT1 in Figure 4). The timings focused on the main initial platoon of exiting and entering passengers in order to limit the distortion caused by late arriving passengers boarding during time checks or other prolonged bus stoppages. Late boarding passengers not part of the initial platoon were excluded from the initial boarding data point measurement and considered separately. As boarding time was measured, the number of entering passengers, the number of entering passengers using cash fare payment, and the profile of the entering passengers (which were coded on the spreadsheet seating charts) were noted along with the profile and occupancy information of previously seated and/or standing passengers on the bus.

Alighting timings commenced with the opening of the exit vehicle door(s) (AT0 in Figure 4) and terminated the moment the last alighting passenger walked past the threshold of his or her chosen exit portal (AT1 in Figure 4). The rear exit of the bus was usually used as the sole exit portal during an alighting movement, however, the front door was sometimes used as an exit by some alighting passengers. The number and profile of the alighting passengers as well as the pre-alighting occupancy of the bus were noted.

4.4 Data Analysis Methodology

4.4.1 Seating Charts

Average values for each passenger agent type were collected and tabulated. This data was used to fill seating charts illustrating (a) seating preferences, (b) positional indicators (seating positions relative to the Driver, Front Door and Rear Exit in all directions as well as total distance), and (c) separation distances between passenger agent groups, all as described in the previous section on data collection.

Hypothesis testing was employed in order to determine if statistically significant differences between the mean values of compared passenger agent groups were observed. Using Microsoft Excel's Version 2010 Data Analysis package, an "F-Test Two Sample for Variances" was performed, assuming a hypothetical difference of 0 between the sample variances with $\alpha = 0.05$. If the calculated F-Value statistic exceeded the F-

Critical value, the variances were "unequal" and a t-test assuming unequal variances was performed for the means (otherwise a t-test assuming equal variances was performed). In either case, a default α value of 0.05 and hypothetical difference of 0 were assumed in the t-test unless stated otherwise. A t-value exceeding the t-critical value was interpreted to indicate a statistically significant difference in means. One-tailed and two-tailed t-tests were used depending on the hypothetical propositions declared previously in Chapter 3.

4.4.2 Timings & Regression Analysis

Multiple regression analysis was used to link passenger agent types and behaviors with timing measurements, as respective boarding and alighting time models were derived iteratively. Initial models incorporating all regressors (as listed below, for each model in Table 5 and Table 6, respectively) were subsequently refined in order to obtain relationships which explained much of the variation in timing values collectively while being comprised of individual explanatory variables that were statistically and logically significant.

	Boarding
y	total boarding time
x1	pre-boarding seating occupancy (proportion)
x2	pre-boarding non-Asian minority occupancy (proportion)
x3	total number of boarding passengers
x4	total number of boarding passengers paying fare with cash
x5	total number of senior boarding passengers
x6	total number of female boarding passengers
x7	total number of boarding passengers selecting a standing position
x8	total number of window seat boarding passengers
x9	total number of white boarding passengers
x10	total number of boarding passengers selecting an upper level seat or space
x11	total number of window aisle conflicts (boarding passengers sitting in window when adjacent aisle seat is occupied)
x12	total number of disabled boarding passengers (requiring lift operation)
x13	total number of aisle seat boarding passengers

Table 5: Initial Boarding Time Regressors

	Alighting
y	total alighting time
x1	pre-alighting seating occupancy (proportion)
x2	total number of alighting passengers
x3	total number of senior boarding passengers
x4	total number of upper level alighting passengers
x5	total number of window aisle conflicts (window seat passenger alights when adjacent aisle seat is occupied)
x6	total number of alighting window seated passengers
x7	total number of alighting disabled passengers (requiring lift operation)
x8	proportion of alighting passengers getting up first to approach exit before bus has stopped

Table 6: Initial Alighting Time Regressors

Linear boarding and alighting models of the form $y = b + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 \ldots a_nx_n$ were derived with the collected data using Microsoft Excel's Version 2010 Regression Data Analysis application. The dependent variable *y* corresponded to either the boarding time or alighting time, in seconds, for an ART system stop. Each *x* value represented a particular regressor with a corresponding *a* coefficient, and the value of *b* represented the intercept. Assuming a 95% statistical significance level, statistically significant regressors attained p-values of 0.05 or lower. Each model was refined by sequentially eliminating a statistically insignificant variable during each regression trial until all included model variables were individually significant. Additional regression trials included interaction terms when the potential for statistical significance appeared likely (based in part on observed results from the seating chart data), and in some cases, variables that did not meet the desired level of individual statistical significance were included in subsequent trial models if they were deemed to be of practical and logical significance. Final preferred models were selected based on comparatively high model F-test values and the statistical, logical and practical significance of all included variables.

CHAPTER 5: RESULTS

5.1 Seating Chart Results

Notable and statistically significant seating chart results are presented and commented on in this subchapter. Complete tables are provided in the Appendices section for reference.

5.1.1 Seating Type Preferences

All groups were observed to strongly prefer seating to standing. During the data collection process, the few boarding passengers who opted to occupy a standing space were invariably observed to alight within four or five stops. The variations in seating/standing preference index values are essentially a reflection of the average occupancies observed for each passenger group at boarding points. Seating preferences are tabulated (Tables 7-11).

In terms of average values, Female passengers were observed to have a greater average preference for aisle seats than Male passengers had, however, subsequent t-testing indicated that this difference was not significant, nor was the Female passenger preference for aisle seating over window seating. The general preference for window seating over aisle seating by Males was observed with 95% statistical significance. Younger passengers exhibited a stronger preference for window seating over aisle seating with 95% statistical significance.

	Seat	Stand	Window	Aisle	Other	Front	Side
Female	2.00	0.02	1.03	1.26	0.79	0.96	1.00
Male	2.06	0.01	1.50	0.98	0.74	1.05	0.84

Table 7: General Seating Preference Tables by Sex Group (Sample Sizes: Nfemales = 120, Nmales = 134)

	Seat	Stand	Window	Aisle	Other	Front	Side
Younger	1.99	0.00	1.45	0.42	1.03	0.91	1.11
Middle	2.06	0.03	1.32	1.23	0.65	1.05	0.83
Older	2.01	0.00	1.04	1.43	0.79	1.00	0.94

Table 8: General Seating Preference Tables by Age Group (Sample Sizes: Nyounger=53, Nmiddle=140, Nolder=61)

	Seat	Stand	Window	Aisle	Other	Front	Side
Asian	1.90	0.00	1.34	1.31	0.66	1.17	0.71
Black	1.94	0.04	1.51	0.97	0.80	1.03	0.93
Hispanic	2.14	0.02	1.39	1.07	0.69	1.03	0.85
Other	1.93	0.00	1.09	0.57	1.14	0.52	1.73
White	2.05	0.02	1.02	1.30	0.77	1.02	0.88

Table 9: General Seating Preference Tables by Ethnic Category
(Sample Sizes: Nasian=24, Nblack=52, Nhispanic=85, Nother=16, Nwhite=77)

White passengers were the only ethnic category to prefer aisle seating to window seating in terms of average index scores, but this preference was not statistically significant. Black and Hispanic passengers were observed to prefer window seating, however, neither group's preference for window seating met the 95% statistical significance threshold. Subsequent hypothesis testing of this notable trend was able to confirm both groups' preference for window seating with 90% statistical significance.

	Seat	Stand	Window	Aisle	Other	Front	Side
Younger Females	1.98	0.00	1.05	0.63	1.10	0.75	1.35
Middle Females	2.00	0.04	1.11	1.29	0.70	1.03	0.87
Older Females	2.01	0.00	0.81	1.60	0.80	0.92	1.05

Table 10: Age-Sex Group Seating Preference Tables for Females
Sample Sizes (Nyf = 20, Nmf = 70, Nof = 30)

T-testing results indicated that Younger Females and Middle Females did not have a statistically significant preference for a particular seating type. Older Females were observed to prefer aisle seating, however, this group's preference for aisle seating did not meet the 95% statistical significance threshold. Subsequent hypothesis testing of this notable trend was able to confirm the Older Female group preference for aisle seating with 90% statistical significance.

	Seat	Stand	Window	Aisle	Other	Front	Side
Younger Males	1.99	0.00	1.69	0.29	0.99	1.00	0.97
Middle Males	2.12	0.03	1.52	1.17	0.60	1.07	0.79
Older Males	2.00	0.00	1.26	1.27	0.78	1.07	0.82

Table 11: Age-Sex Group Seating Preference Tables for Males
Sample Sizes (Nym = 33, Nmm= 70, Nom= 31)

All Males collectively were observed to prefer window seats to aisle seats with 95% statistical significance although Older Males were not observed to have this preference.

5.1.2 Group Spacing Comparisons: Positional Indicators

There is an article section in the Appendices which explains the format and interpretation of separation seating charts. The positional indicator charts (Tables 12-15) suggest that in the X-direction, all passenger groups appear to be more inclined to sit closer to the left side of the bus (which includes the driver) than the side which includes both exits. Notably, there are a few more left side seats available on the lower level of the typical ART bus than there are right side seats. Younger and Middle Females are most evenly spaced between the left and right sides of the bus.

X	DRIVER	FrontDr	RearDr
Younger Females	0.49	0.51	0.51
Middle Females	0.48	0.53	0.53
Older Females	0.39	0.61	0.61

X	DRIVER	FrontDr	RearDr
Younger Males	0.37	0.63	0.63
Middle Males	0.40	0.60	0.60
Older Males	0.37	0.63	0.63

Table 12: X-Direction Distance Positional Indicators for Age-Sex Groups
Sample Sizes (Nyf = 20, Nmf = 70, Nof = 30, Nym = 33, Nmm= 70, Nom= 31)

Y	DRIVER	FrontDr	RearDr
Younger Females	0.50	0.50	0.42
Middle Females	0.47	0.47	0.35
Older Females	0.37	0.37	0.30

Y	DRIVER	FrontDr	RearDr
Younger Males	0.54	0.54	0.53
Middle Males	0.55	0.55	0.40
Older Males	0.56	0.56	0.42

Table 13: Y-Direction Distance Positional Indicators for Age-Sex Groups
Sample Sizes (Nyf = 20, Nmf = 70, Nof = 30, Nym = 33, Nmm= 70, Nom= 31)

Z	DRIVER	FrontDr	RearDr
Younger Females	0.55	0.55	0.55
Middle Females	0.44	0.44	0.44
Older Females	0.27	0.27	0.27

Z	DRIVER	FrontDr	RearDr
Younger Males	0.55	0.55	0.55
Middle Males	0.61	0.61	0.61
Older Males	0.58	0.58	0.58

Table 14: Z-Direction Distance Positional Indicators for Age-Sex Groups
Sample Sizes (Nyf = 20, Nmf = 70, Nof = 30, Nym = 33, Nmm= 70, Nom= 31)

TOTAL	DRIVER	FrontDr	RearDr
Younger Females	1.02	1.09	1.06
Middle Females	0.94	0.99	0.96
Older Females	0.76	0.89	0.90

TOTAL	DRIVER	FrontDr	RearDr
Younger Males	0.97	1.18	1.17
Middle Males	1.06	1.15	1.13
Older Males	1.02	1.16	1.12

Table 15: Total Distance Positional Indicators for Age-Sex Groups
Sample Sizes (Nyf = 20, Nmf = 70, Nof = 30, Nym = 33, Nmm= 70, Nom= 31)

Higher values in the Y-Direction and Z-Direction positional indicator charts (particularly those corresponding to separations from the Driver and Front Door) suggest a preference for sitting towards the elevated back half of a bus. T-testing indicates that with 95% statistical significance, Older Females have lower positional indicator values (with respect to the Driver and Front Door) in the Y and Z directions than do the remaining agent types considered jointly, suggesting a relative preference for lower level seating. Middle Females exhibited a trend towards lower positional indicator values (with respect to the Driver and Front Door) in the Y and Z directions relative to the remainder of agent types considered jointly (all other groups excluding Older Females), but with only 90% statistical significance. Younger Females did not exhibit a statistically significant difference from Males collectively in terms of Y and Z values for positional indicators.

5.1.3 General Group Spacing Comparisons

Separation charts are presented here along with tables indicating the number of observations (Tables 16-24 and Tables 26-32). The number of observations for separation distance tables is based on the number of *interactions* between seat selecting (SS) passenger groups and previously boarded passenger (PBP) groups. Complete separation charts are provided in the Appendices section – they show the indexed values between all passenger agent types in all directions as well as a total combined distance tally.

With 95% statistical significance, Males tended to separate themselves from other agents by greater distances than Females did. With 95% statistical significance, both Female and

Male seat selectors respectively tended to separate themselves from passengers of the opposite sex by a greater average distance than passengers of the same sex. With 95% statistical significance, Female seat selectors sat at closer distances from other Females than Male seat selectors did from previously boarded Male passengers.

TOTAL	Female	Male	All
Female	0.96	1.05	1.01
Male	1.1	1.05	1.07

# Obs	Female	Male	All
Female	214	282	496
Male	305	328	633

Table 16: Total Distance Separation between Gender Groups (left), Number of Observations/Interactions (right)

With 95% statistical significance, it was observed that seat selector groups of all age categories tended to seat themselves most closely to Older passengers and furthest from Younger passengers. For Younger and Middle aged seat selectors, average separation distances appeared to decrease as the age level of the previously boarded passenger groups increased. With 95% statistical significance, Younger seat selectors tended to separate themselves from each age group by greater distances than Middle and Older seat selectors.

TOTAL	Younger	Middle	Older
Younger	1.18	1.12	1.04
Middle	1.08	1.03	1.01
Older	1.00	1.06	0.93

# Obs	Younger	Middle	Older
Younger	31	112	54
Middle	119	407	147
Older	56	150	53

Table 17: Total Distance Separation between Age Groups (left), Number of Observations/Interactions (right)

TOTAL	Asian	Black	Hispanic	Other	White	All
Asian	0.86	0.93	1.01	0.82	1.13	1.03
Black	1.04	1.08	1.06	1.17	1.00	1.04
Hispanic	1.20	0.98	1.03	1.01	1.09	1.05
Other	1.09	0.88	1.16	NA	1.10	1.06
White	0.92	1.12	1.00	0.99	1.08	1.05
# Obs	Asian	Black	Hispanic	Other	White	All
Asian	6	12	16	2	30	66
Black	14	43	44	14	84	199
Hispanic	16	62	161	53	140	432
Other	8	12	11	0	23	54
White	47	70	65	31	172	385

Table 18: Total Distance Separation between Ethnic/Racial Groups (top), Number of Observations/Interactions (bottom)

The tabulated inter-ethnic group spacing differences are generally not statistically significant. Despite the fact that Asian seat selectors separated themselves from passengers of any ethnic group by the shortest tabulated distance (1.03) relative to other seat selecting groups, the difference was not statistically significant. In terms of White seat selection patterns, White seat selectors appeared to separate themselves the most from Black passengers (1.12), however, the difference in separation from Black passengers and other White passengers (1.08), was not statistically significant.

Seat Separations: Female Seat Selector Groups

TOTAL DISTANCE	Asian Males	Black Males	Hispanic Males	Other Males	White Males	All Males
All Females	0.98	1.01	1.08	0.78	1.08	1.05
Non-White Females	1.07	0.91	1.10	0.47	1.08	1.05
White Females	0.81	1.08	0.99	1.02	1.08	1.05
# Obs	Asian Males	Black Males	Hispanic Males	Other Males	White Males	All Males
All Females	17	32	56	16	161	282
Non-White Females	11	14	44	7	107	183
White Females	6	18	12	9	54	99

Table 19: Total Distance Separations – Ethnic Female Seat Selector Groups & Ethnic Male Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

TOTAL DISTANCE	Asian Males	Black Males	Hispanic Males	Other Males	White Males	All Males
All Females	0.98	1.01	1.08	0.78	1.08	1.05
Younger Females	NA	1.35	0.99	0.43	1.07	1.01
Mid-Aged Females	0.95	1.06	1.11	1.01	1.06	1.06
Older Females	1.05	0.83	1.02	0.61	1.14	1.04
# Obs	Asian Males	Black Males	Hispanic Males	Other Males	White Males	All Males
All Females	17	32	56	16	161	282
Younger Females	0	1	8	3	28	40
Mid-Aged Females	12	22	40	8	92	174
Older Females	5	9	8	5	41	68

Table 20: Total Distance Separations – Age Categorized Female Seat Selector Groups & Ethnic Male Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

TOTAL DISTANCE	Young Males	Mid -Aged Males	Old Males
All Females	1.17	1.07	0.90
Younger Females	1.59	1.02	0.79
Mid-Aged Females	1.21	1.06	0.95
Older Females	0.96	1.12	0.83
# Obs	Young Males	Mid-Aged Males	Older Males
All Females	50	168	64
Younger Females	4	24	12
Mid-Aged Females	32	102	40
Older Females	14	42	12

Table 21: Total Distance Separations – Age Categorized Female Seat Selector Groups & Age Categorized Male Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

With respect to Female seat selectors and previously boarded Male passengers, no clear pattern emerged in terms of separations. With 95% statistical significance, Female seat selectors of all age groups tended to sit farthest away from Younger Males and closest to Older Males. Differences in observed separation distances between Female seat selectors and particular ethnic groups of Male previously boarded passengers were, in general, not statistically significant.

TOTAL DISTANCE	Asian Females	Black Females	Hispanic Females	Other Females	White Females	All Females
All Females	0.86	1.03	0.94	1.03	0.93	0.96
Non-White Females	0.62	0.97	0.97	0.97	0.93	0.94
White Females	0.94	1.22	0.87	1.27	0.94	0.99
# Obs	Asian Females	Black Females	Hispanic Females	Other Females	White Females	All Females
All Females	22	47	63	28	58	218
Non-White Females	5	36	46	22	31	140
White Females	17	11	17	6	27	78

Table 22: Total Distance Separations – Ethnic Female Seat Selector Groups & Ethnic Female Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

TOTAL DISTANCE	Asian Females	Black Females	Hispanic Females	Other Females	White Females	All Females
All Females	0.86	1.03	0.94	1.03	0.93	0.96
Younger Females	0.66	1.25	1.04	1.17	0.97	1.03
Mid-Aged Females	0.85	1.01	0.88	1.02	0.93	0.94
Older Females	0.93	1.04	1.00	0.81	0.90	0.96
# Obs	**Asian Females**	**Black Females**	**Hispanic Females**	**Other Females**	**White Females**	**All Females**
All Females	22	47	63	28	58	218
Younger Females	2	1	11	7	11	32
Mid-Aged Females	12	32	35	17	33	129
Older Females	8	14	17	4	14	57

Table 23: Total Distance Separations – Age Categorized Female Seat Selector Groups & Ethnic Female Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

TOTAL DISTANCE	Young Females	Mid -Aged Females	Old Females
All Females	1.15	0.92	0.93
Younger Females	1.18	1.01	0.98
Mid-Aged Females	1.17	0.90	0.93
Older Females	1.12	0.94	0.85
# Obs	**Young Females**	**Mid-Aged Females**	**Older Females**
All Females	37	113	68
Younger Females	6	9	17
Mid-Aged Females	17	75	37
Older Females	14	29	14

Table 24: Total Distance Separations – Age Categorized Female Seat Selector Groups & Age Categorized Female Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

With respect to Female seat selectors and previously boarded Female passengers, with 95% statistical significance, Female seat selectors of all age categories tended to sit farther away from Younger and Middle Male passengers than from Older Male passengers. Female seat selectors collectively tended to sit closest to Asian females, however, the differences observed between the distances corresponding to Asian Female passengers and Female passengers as a whole were not statistically significant. With 95% statistical significance, Female seat selectors of all age groups tended to sit closer to Older Females than to Middle and Younger Female passengers.

With 95% statistical significance, t-testing results (Table 25) indicated that White Female seat selectors chose to sit farther away from Black Female passengers than from White

Female passengers while there was no significant difference in the separation distance between White Female seat selectors and previously boarded White Females or previously boarded non-Black Females.

F-Test Two-Sample for Variances		
White Female Seat Selectors	Black Female PBP	White Female PBP
Mean	1.22	0.94
Variance	0.12	0.18
Observations	11	27
df	10	26
F	0.63	
P(F<=f) one-tail	0.23	
F Critical one-tail	0.37	

t-Test: Two-Sample Assuming Unequal Variances α = 0.05		
White Female Seat Selectors	Black Female PBP	White Female PBP
Mean	1.22	0.94
Variance	0.12	0.18
Observations	11	27
Hypothesized Mean Difference	0	
df	23	
t Stat	2.12	
P(T<=t) one-tail	0.02	
t Critical one-tail	1.71	
P(T<=t) two-tail	0.04	
t Critical two-tail	2.07	

F-Test Two-Sample for Variances		
White Female Seat Selectors	White Female PBP	Rest Female PBP
Mean	0.94	0.96
Variance	0.18	0.14
Observations	27	38
df	26	37
F	1.29	
P(F<=f) one-tail	0.23	
F Critical one-tail	1.80	

t-Test: Two-Sample Assuming Equal Variances α = 0.05		
White Female Seat Selectors	White Female PBP	Rest Female PBP
Mean	0.94	0.96
Variance	0.18	0.14
Observations	27	38
Pooled Variance	0.16	
Hypothesized Mean Difference	0	
df	63	
t Stat	-0.19	
P(T<=t) one-tail	0.43	
t Critical one-tail	1.67	
P(T<=t) two-tail	0.85	
t Critical two-tail	2.00	

Table 25: White Female Seat Selection Hypothesis Testing Results, F-Test for Variances and t-Test for Black Female Previously Boarded Passengers (top), F-Test for Variances and t-Test for remaining Female Previously Boarded Passengers (bottom)

Seating Separations: Male Seat Selector Groups

With respect to Male seat selectors and previously boarded Male passengers, all Male seat selectors collectively were observed to sit closer to Asian Males than all Males in general, but this difference was observed with only 90% statistical significance. With 95% statistical significance, it was observed that all Male seat selectors collectively were observed to sit farther away from Middle and Older Males than from Younger Males.

TOTAL DISTANCE	Asian Males	Black Males	Hispanic Males	Other Males	White Males	All Males
All Males	0.90	1.03	1.02	1.01	1.09	1.05
Non-White Males	1.05	0.95	1.01	0.94	1.07	1.03
White Males	0.61	1.14	1.06	1.13	1.11	1.08

# Obs	Asian Males	Black Males	Hispanic Males	Other Males	White Males	All Males
All Males	20	49	80	16	164	329
Non-White Males	13	29	64	10	97	213
White Males	7	20	16	6	67	116

Table 26: Total Distance Separations – Ethnic Male Seat Selector Groups & Ethnic Male Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

TOTAL DISTANCE	Asian Males	Black Males	Hispanic Males	Other Males	White Males	All Males
All Males	0.90	1.03	1.02	1.01	1.09	1.05
Younger Males	0.96	0.98	1.16	NA	1.15	1.12
Mid-Aged Males	0.93	0.99	1.00	1.05	1.09	1.04
Older Males	0.74	1.17	0.94	0.77	1.03	1.02
# Obs	**Asian Males**	**Black Males**	**Hispanic Males**	**Other Males**	**White Males**	**All Males**
All Males	20	49	80	16	164	329
Younger Males	3	8	14	0	36	61
Mid-Aged Males	13	30	55	14	87	199
Older Males	4	11	11	2	41	69

Table 27: Total Distance Separations – Age Categorized Male Seat Selector Groups & Ethnic Male Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

TOTAL DISTANCE	Young Males	Mid -Aged Males	Older Males
All Males	0.97	1.07	1.07
Younger Males	0.99	1.13	1.16
Mid-Aged Males	1.01	1.05	1.03
Older Males	0.85	1.04	1.15
# Obs	**Young Males**	**Mid-Aged Males**	**Older Males**
All Males	67	213	49
Younger Males	9	47	5
Mid-Aged Males	42	125	32
Older Males	16	41	12

Table 28: Total Distance Separations – Age Categorized Male Seat Selector Groups & Age Categorized Male Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

TOTAL DISTANCE	Asian Females	Black Females	Hispanic Females	Other Females	White Females	All Females
All Males	1.16	1.08	1.07	1.12	1.13	1.10
Non-White Males	1.27	1.08	1.08	1.26	1.12	1.12
White Males	1.06	1.08	1.06	0.72	1.14	1.05
# Obs	**Asian Females**	**Black Females**	**Hispanic Females**	**Other Females**	**White Females**	**All Females**
All Males	32	71	98	40	65	306
Non-White Males	15	50	78	30	41	214
White Males	17	21	20	10	24	92

Table 29: Total Distance Separations – Ethnic Male Seat Selector Groups & Ethnic Female Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

TOTAL DISTANCE	Asian Females	Black Females	Hispanic Females	Other Females	White Females	All Females
All Males	1.16	1.08	1.07	1.12	1.13	1.10
Younger Males	1.43	1.09	1.12	1.47	1.20	1.20
Mid-Aged Males	1.23	1.06	1.04	1.04	1.11	1.08
Older Males	1.01	1.11	1.15	0.78	1.11	1.07
# Obs	**Asian Females**	**Black Females**	**Hispanic Females**	**Other Females**	**White Females**	**All Females**
All Males	32	71	98	40	65	306
Younger Males	3	19	21	12	10	65
Mid-Aged Males	16	35	58	21	44	174
Older Males	13	17	19	7	11	67

Table 30: Total Distance Separations – Age Categorized Male Seat Selector Groups & Ethnic Female Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

TOTAL DISTANCE	Young Females	Mid -Aged Females	Older Females
All Males	1.07	1.11	1.11
Younger Males	1.18	1.20	1.21
Mid-Aged Males	0.99	1.08	1.13
Older Males	1.12	1.10	0.92

# Obs	Young Females	Mid-Aged Females	Older Females
All Males	53	178	75
Younger Males	13	32	20
Mid-Aged Males	28	106	40
Older Males	12	40	15

Table 31: Total Distance Separations – Age Categorized Male Seat Selector Groups & Age Categorized Female Previously Boarded Passenger Groups (top), Number of Observations/Interactions (bottom)

With respect to Male seat selectors and previously boarded Female passengers, no definite and statistically significant seating pattern emerged between sub-groups.

Seating Separations by Route

Separations between ethnic groups were observed on the different analysis routes and tabulated averages are displayed in the Appendices section. Clear separation patterns between ethnic groups were not readily apparent, however, it was observed that on routes where White seat selectors formed the plurality of observed seat selecting passengers (ART 52, ART 53, ART 75), the separation distance between White seat selectors and White previously boarded passengers was greater than corresponding separation distances on routes where White seat selectors were observed to be in the minority of seat selecting passengers (ART 41, ART 51). This trend was observed with 90% statistical significance (Table 33).

Total Distance	Composition Status of White Passengers	Average Distance between White SS and White PBP
ART 41, ART 51	Minority	1.02
ART 52, ART 53, ART 75	Plurality	1.10

Table 32: Separation Distance between White Seat Selectors and White Previously Boarded Passengers by Route Composition

F-Test Two-Sample for Variances		
White Seat Selectors	ART 52,53,75 (White Plurality)	ART 41,51 (White Minority)
Mean	1.10	1.02
Variance	0.15	0.14
Observations	125	46
df	124	45
F	1.04	
P(F<=f) one-tail	0.46	
F Critical one-tail	1.54	

t-Test: Two-Sample Assuming Equal Variances α=0.10		
White Seat Selectors	ART 41,51 (White Minority)	ART 52,53,75 (White Plurality)
Mean	1.02	1.10
Variance	0.14	0.15
Observations	46	125
Pooled Variance	0.15	
Hypothesized Mean Difference	0	
df	169	
t Stat	-1.29	
P(T<=t) one-tail	0.10	
t Critical one-tail	1.29	
P(T<=t) two-tail	0.20	
t Critical two-tail	1.65	

Table 33: Significance Testing: White Seat Selectors – White Previously Boarded Passenger Separation Distances; White Minority Routes compared to White Plurality Routes, F-Test for Variances (top), t-Test assuming Equal Variances (bottom)

5.2 Timing Factors

5.2.1 Boarding Time Model

Boarding time was defined as the time between the instant the first boarding passenger of an entering platoon crossed the threshold of the front door until the instant the last boarding passenger sat (or stood) in his or her final seat or space. Applying multiple linear regression analysis to the acquired boarding time data yielded the following preferred model:

$$\mathbf{T_b = 7.95 + 5.26\, N_{bp} + 14.83\, N_{cfp} + 5.50\, N_{ul} + 69.92\, N_{dbp} - 8.57\, N_{bap}}$$

Where T_b = Boarding Time in seconds;
N_{bp} = Number of Boarding Passengers
N_{cfp} = Number of Boarding Passengers Paying Fare in Cash (No Card)
N_{ul} = Number of Boarding Passengers Selecting an Upper Level Seat
N_{dbp} = Number of Disabled Boarding Passengers
N_{bap} = Number of Boarding Passengers Selecting an Aisle Seat

This derived model is based on 122 ART system boarding measurements and accounts for much of the variability in the observed values (Table 34). Its adjusted R^2 value is 0.63

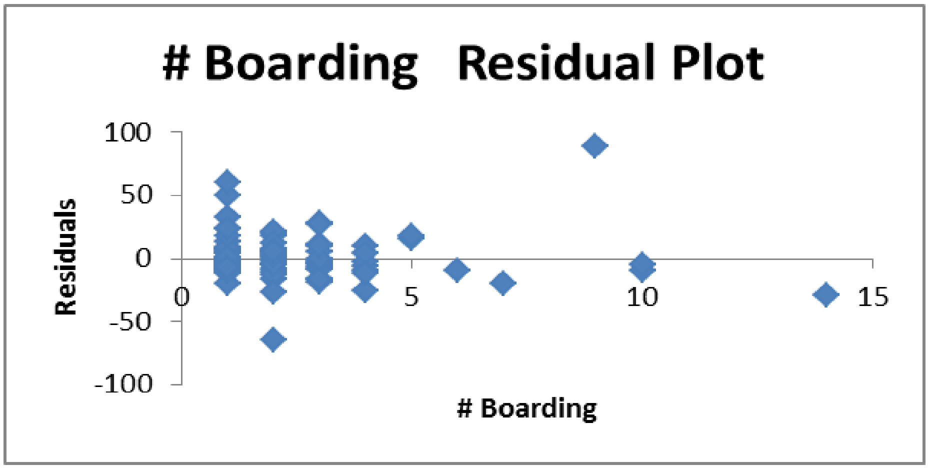
with an F value of 43 and F significance of < 0.001. All individual model parameters attained a 95% probability of statistical significance. This model reflects the general observation that the greatest contributors to boarding time were disabled boarding passengers followed by cash fare paying passengers and the total number of boarding passengers. While upper level seat selectors increase boarding time, aisle seat selectors marginally reduce boarding time in this system. In this preferred model, none of the predictors are directly related to demographics, even though it has been observed that certain demographic groups are more (or less) likely to select aisle seating and upper level seating. It should be noted that an alternate boarding time model (included in the Appendices) can be developed which incorporates an interaction between the number of female boarding passengers and the number of older boarding passengers.

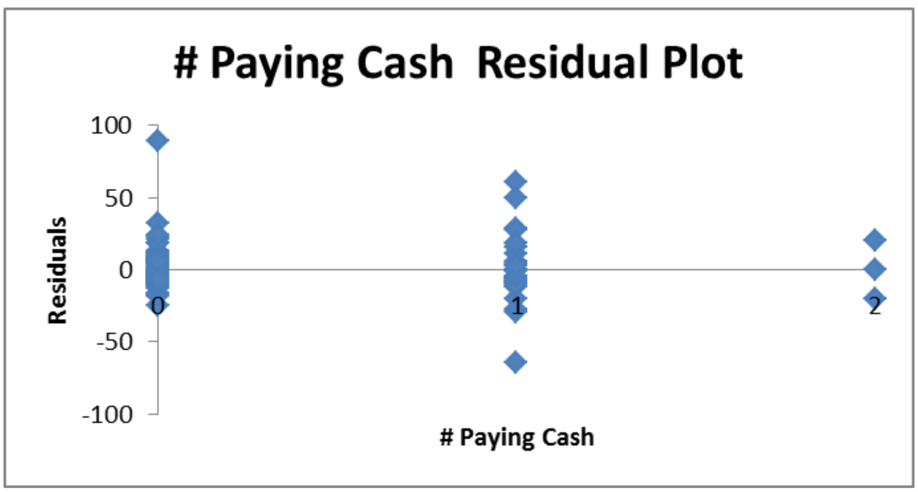
Regression Statistics	
Multiple R	0.81
R Square	0.65
Adjusted R Square	0.63
Standard Error	16.70
Observations	122
F	43.02
Significance F	6.93E-25
Regression df, SS	5, 60019
Residual df, SS	116, 32366

	Coefficients	Standard Error	t Stat	P-value
Intercept	7.95	2.26	3.52	6.17E-04
# Boarding Passengers	5.26	1.50	3.50	6.56E-04
# Paying Cash Passengers	14.83	3.21	4.62	1.01E-05
# Upper Level SS Passengers	5.50	2.00	2.75	6.98E-03
# Disabled Boarding Passengers	69.92	10.39	6.73	6.82E-10
# Aisle SS Passengers	-8.57	2.65	-3.24	1.58E-03

Table 34: Excel Output: Preferred Boarding Time Model

For each preferred model input variable, residual plots (Figure 5) as well as plots comparing observed and predicted boarding time values (Figure 6) are provided. The model appears to fit the data reasonably well. The vast majority of observations were of boardings with fewer than five passengers at a stop. The number of observations of disabled boarding passengers is very small, and this likely accounts for the wider differences between observed and predicted values.





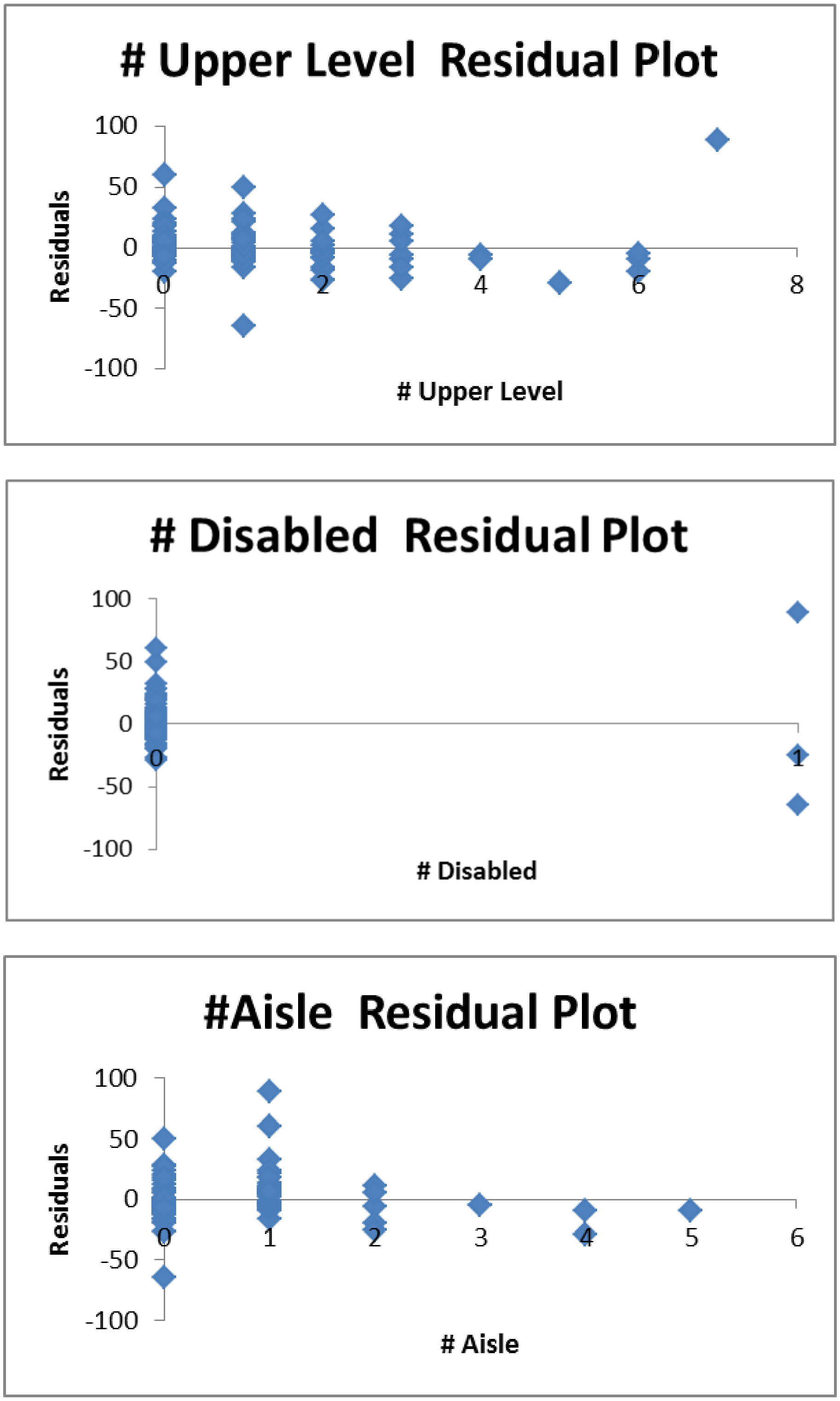
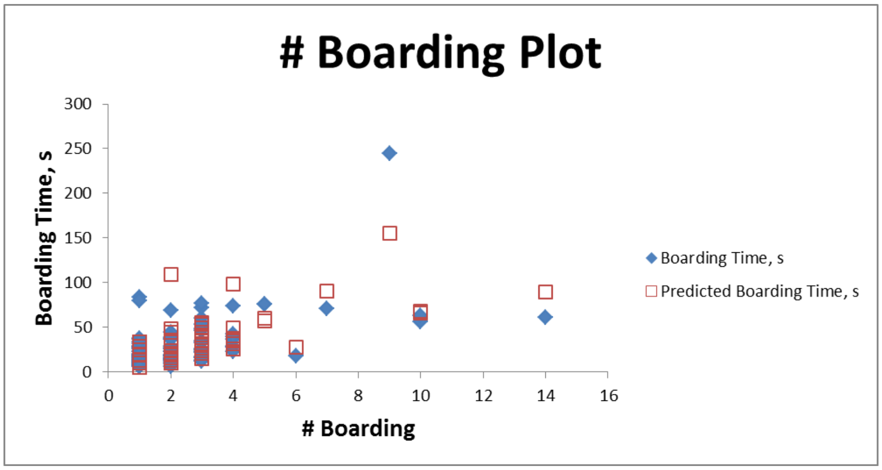
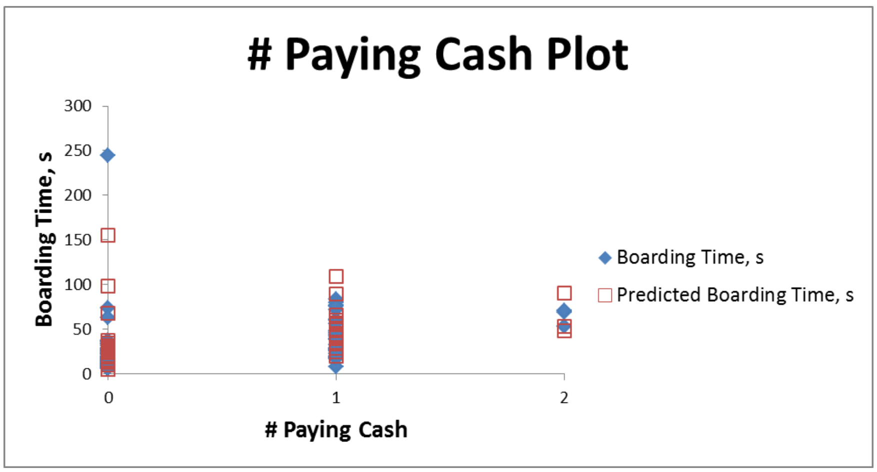


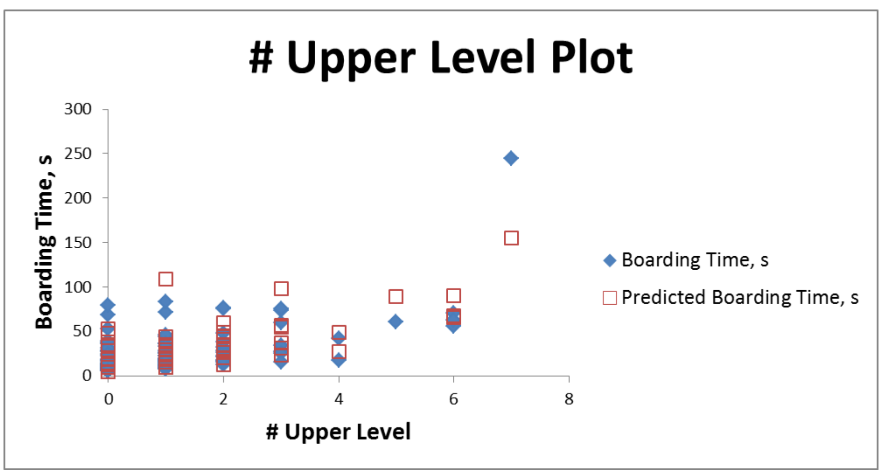
Figure 5: Residual Plots of Preferred Boarding Time Model Predictors



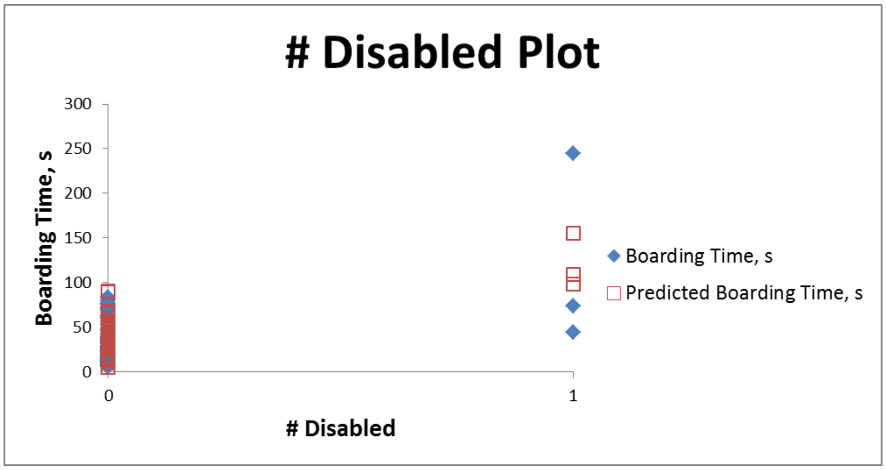
Boarding Plot
Boarding Time, s
Predicted Boarding Time, s
Boarding
0
2
4
6
8
10
12
14
16
300
250
200
150
100
50
0



Paying Cash Plot
Boarding Time, s
Predicted Boarding Time, s
Paying Cash
0
1
2
300
250
200
150
100
50
0



Upper Level Plot
Boarding Time, s
Predicted Boarding Time, s
Upper Level
0
2
4
6
8
300
250
200
150
100
50
0



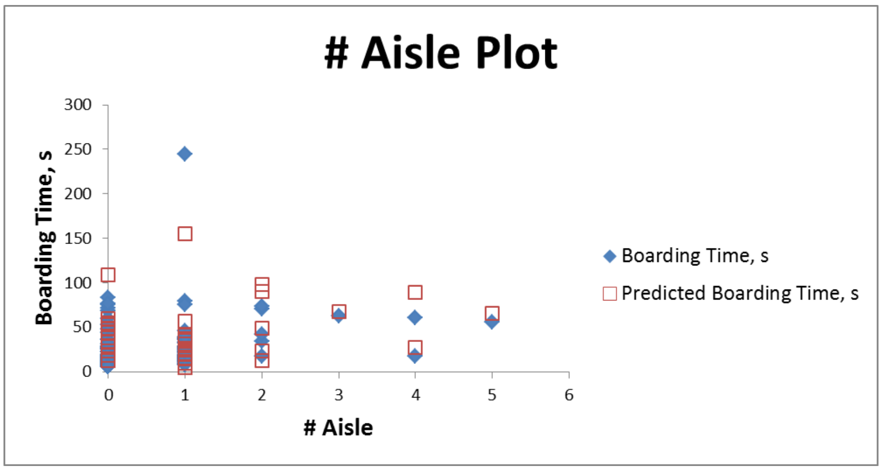


Figure 6: Plots of Preferred Boarding Time Model Predictors

5.2.2 Alighting Time Model

Alighting time was defined as the time between the instant the exit door was opened until the moment the last exiting passenger crossed the threshold of the exit. The following alighting time model was derived from multiple regression analysis.

$$\mathbf{T_a = 3.73 + 0.46\ N_{ap} + 1.97\ N_{sap} + 2.19\ N_{wp} + 59.92\ N_{dap} - 3.61\ P_{guf}}$$

Where T_a = Alighting Time in seconds
N_{ap} = Number of Alighting Passengers

N_{sap} = Number of Senior Alighting Passengers
N_{wp} = Number of Alighting Passengers Seated in Window Seats
N_{dap} = Number of Disabled Alighting Passengers
P_{guf} = Proportion of Passengers Getting Up First (before Exit)

This model was based on 82 ART system alighting observations and the model's adjusted R^2 value is 0.85 with an F value of 94.6 and F significance < 0.001 (Table 35). The number of alighting passengers, N_{ap}, was an individual factor that only attained a 73% probability of statistical significance within the model, but it was retained because of its logical significance with respect to alighting movement. All other parameters each attained a 95% probability of statistical significance within the model.

Regression Statistics	
Multiple R	0.93
R Square	0.86
Adjusted R Square	0.85
Standard Error	4.85
Observations	82
F	94.58
Significance F	3.49E-31
Regression df, SS	5, 11110
Residual df, SS	76, 1786

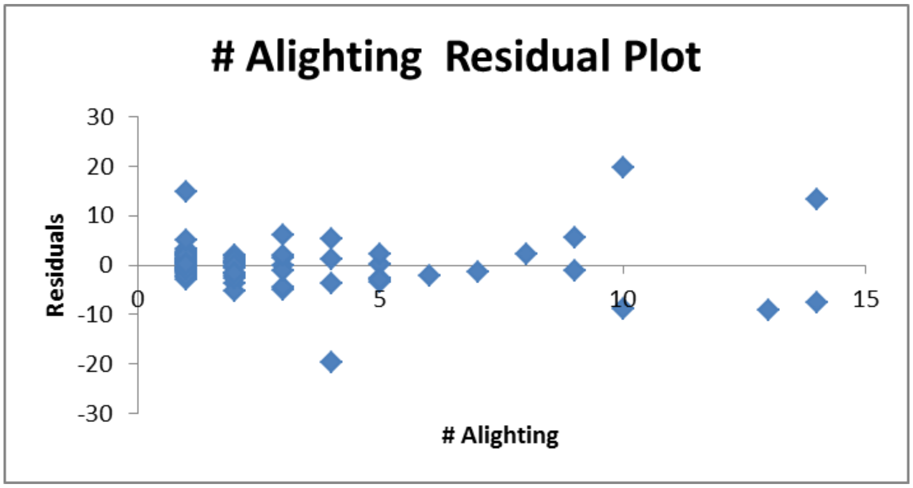
	Coefficients	Standard Error	t Stat	P-value
Intercept	3.73	1.20	3.12	2.52E-03
# Seniors	1.97	0.71	2.77	7.13E-03
# Window	2.19	0.80	2.74	7.57E-03
% Get-Up First	-3.61	1.29	-2.78	6.76E-03
Disabled	59.52	3.87	15.37	5.07E-25
# Alighting	0.46	0.41	1.12	2.66E-01

Table 35: Excel Output: Preferred Alighting Time Model

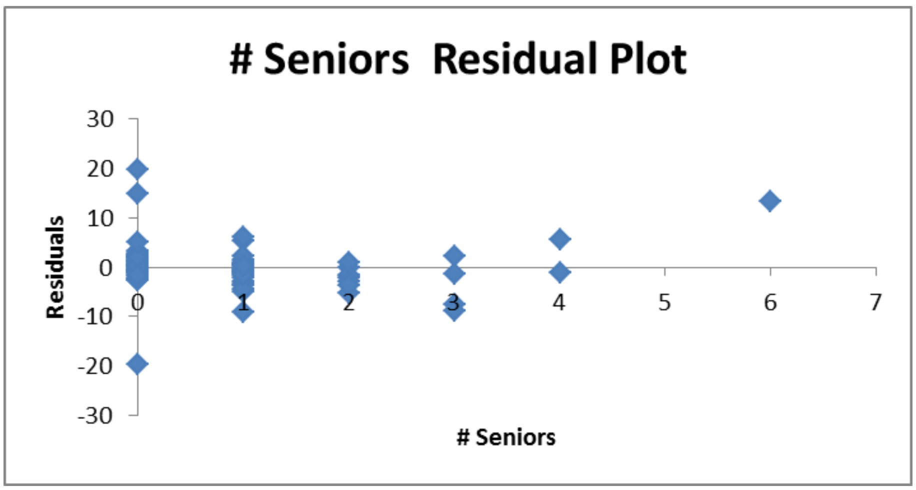
By far, the number of disabled passengers contributed the most to alighting time, with each disabled passenger estimated to add roughly a minute to the overall time. It should be noted that during the data collection process, no more than one disabled passenger was observed to board or alight at any one stop. Older passengers as well as window seated passengers appeared to increase the alighting time by roughly two seconds each, all other factors held constant. The percentage of passengers getting up to approach the exit before the bus stopped was also significant, and the majority of observed alighting movements in the ART system had at least one passenger getting up ahead of time.

An alternate model (included in the Appendices) could be developed which incorporates a significant factor which was excluded from the preferred model, the pre-alighting seating occupancy. This factor had a negative coefficient, indicating a reduction in time (with other factors held constant) as the pre-alighting seating occupancy increased. This factor may reflect the organization of alighting passengers at hub stop locations. While the increased seating occupancy would seem to be a factor that would slow down alighting movements, at higher occupancy levels stopping at hub locations (e.g., Ballston Metro Station, Ballston Common Mall, Courthouse Plaza, Virginia Medical Center), the passengers were observed to anticipate the potential for disorder, and to often intuitively organize themselves in a queuing discipline giving priority to alighting passengers who were seated nearest to an exit. This order appears to have contributed to a decreased per-passenger alighting time.

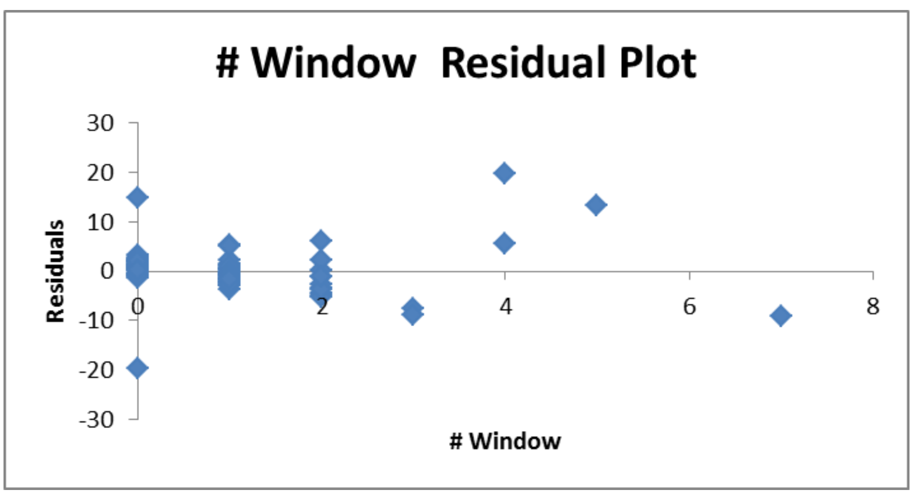
For each preferred model input variable, residual plots (Figure 7) as well as plots comparing observed and predicted alighting time values (Figure 8) are provided. The model appears to fit the data reasonably well. As is the case with boarding observations, the vast majority of alighting observations were of fewer than five passengers at a stop. The number of observations of disabled alighting passengers is also very small, and as a result, there is again a noticeable degree of difference between the observed and predicted results.



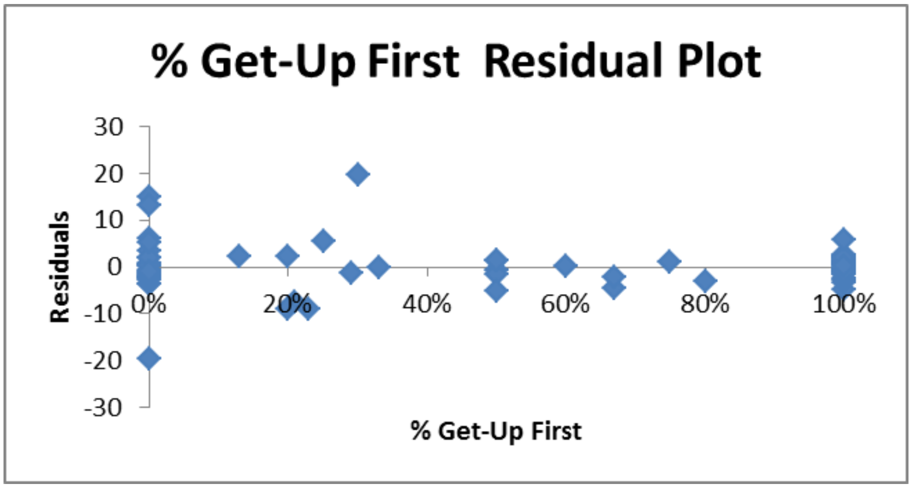
Alighting Residual Plot
30
20
10
0
-10
-20
-30
Residuals
0
5
10
15
Alighting



Seniors Residual Plot
30
20
10
0
-10
-20
-30
Residuals
0
1
2
3
4
5
6
7
Seniors



Window Residual Plot
30
20
10
0
-10
-20
-30
Residuals
0
2
4
6
8
Window



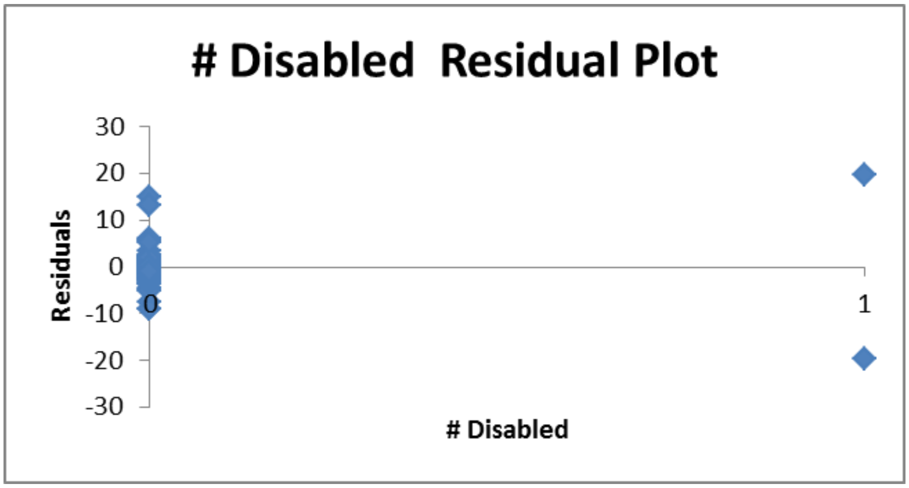
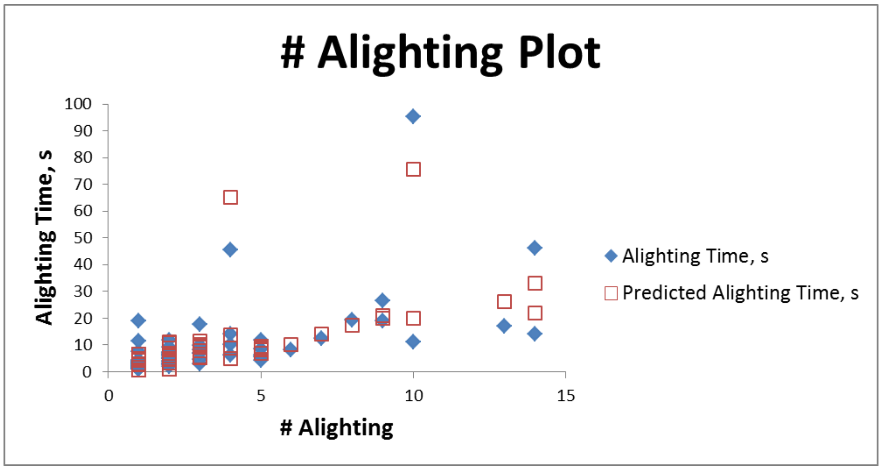
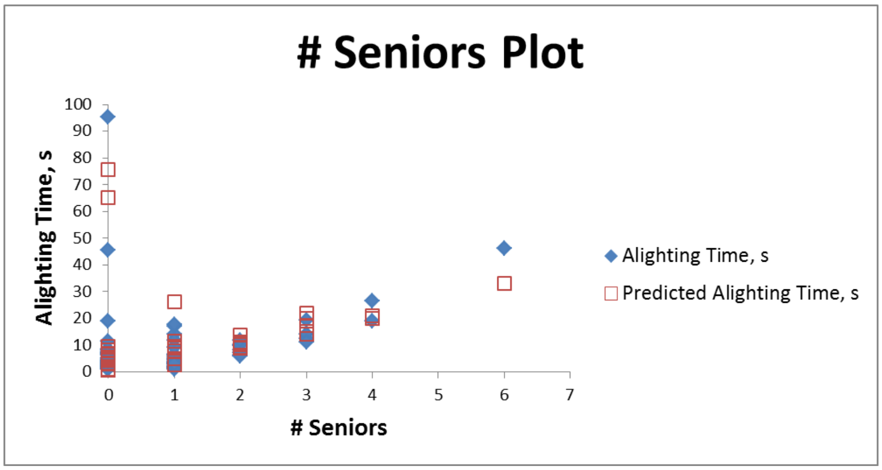


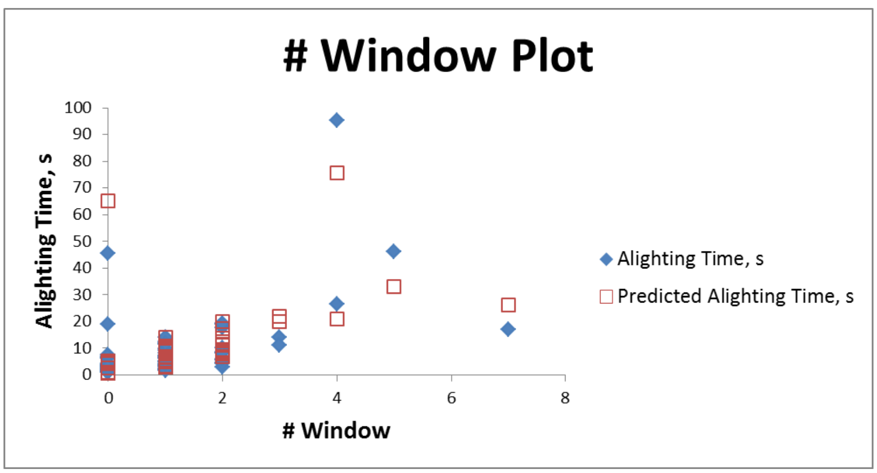
Figure 7: Residual Plots of Preferred Alighting Time Model Predictors



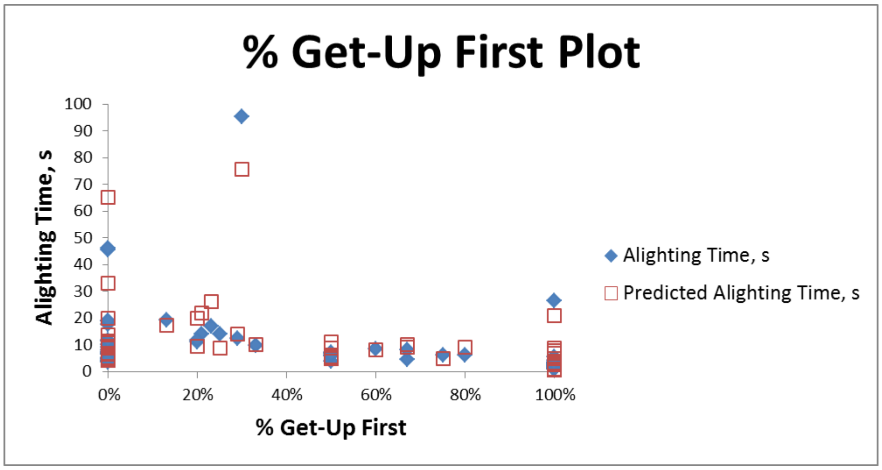
Alighting Plot
Alighting Time, s
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
Alighting
Alighting Time, s
Predicted Alighting Time, s



Seniors Plot
Alighting Time, s
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
Seniors
Alighting Time, s
Predicted Alighting Time, s



Window Plot
Alighting Time, s
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
Window
Alighting Time, s
Predicted Alighting Time, s



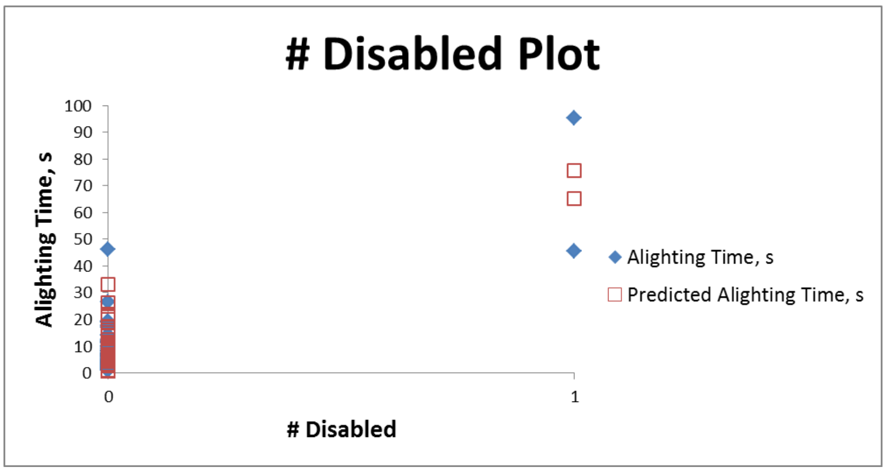


Figure 8: Plots of Preferred Boarding Time Model Predictors

5.3 Evaluation of Hypotheses

General Window Preference The average window preference index score for all passengers was 1.28 and the average aisle preference index score for all passengers was 1.11. As illustrated previously, these indexed scores were based on the number of specific seat types available when a passenger chose to sit in window or aisle seat. The results of a t-test indicate that this observed difference was not statistically significant. A preference for window seats over aisle seats would have an apparently negative effect on boarding and alighting times based on the regression analysis. Some of the sub-groups of passenger agents did have a statistically significant preference for window seating over aisle seating, however. It is not clear whether this preference is due to the desire to avoid having to get up for boarding or alighting passengers (a risk that all aisle seated passengers have when the adjacent window seat is occupied or about to be occupied), or if the window seat provides other more desirable forms of utility (e.g., unobstructed outside view).

Younger Passengers & Upper Level Seating The tabulated results and related t-testing for 95% significance support the hypothesis that Younger passengers prefer upper level seating. This is evidenced by the 0.55 Z-Direction distances for both Younger Males and Younger Females that were observed (Table 14). Indifference between lower level and higher level seating is represented by a value of 0.5 (lower level Z=0, upper level Z=1). The upper level preference of teenage passengers is likely significantly higher than the overall Younger passenger preference because of the number of Younger passengers who were informally observed to accompany Middle and Older females (presumably older female family members or nannies) in the lower level. The majority of Younger passengers observed were in the teenage age range.

Closer Female Spacing The average tabulated results (Table 16) and related t-testing results confirm the hypothesis that female passengers are more likely to sit next to other female passengers than to male passengers. Female passengers also tend to sit closer to all passengers of either sex than are men, which may suggest that female passengers may generally prefer less separation. The female preference for sitting next to other females was also observed in the studies discussed by Gifford [18], and there may be psychological factors (e.g., safety concerns) that account for this preference. Because the majority of female passengers were observed to be Middle or Older, their observed common preference for lower level seating may account for at least some of the closer spacing between females in the observed system.

Older Passengers & Lower Level Seating Older passengers in general were hypothesized to prefer lower level seating based on the lower level location of reserved seating as well as general mobility issues. The obtained Z direction results (Table 14) only partially confirm this hypothesis. With 95% significance, Older Female passengers followed this rule, however, with 95% significance, Older Males were observed to prefer upper level seating as all other male passenger groups did.

Hispanic Spacing The closer spacing hypothesized for Hispanic seat selectors with respect to other previously boarded passengers was not observed. While the separation distance tables between ethnic groups (Table 18) indicates that Asian seat selectors often tended to separate themselves from previously boarded passengers of other ethnicities with the lowest average distances, the overall spacing differences were not statistically significant.

Heavyness/Bulk The greater separations associated with heavy passengers who occupied more than one seat (or spilled over into adjacent seats) was difficult to capture due to the limitations in the available data points. The values (Table 36) indicate marginally greater than average separation from heavy passengers overall, and in two of the three coordinate directions. These results are not statistically significant, however.

X	Heavy	All
All	0.58	0.53

Y	Heavy	All
All	0.55	0.47

Z	Heavy	All
All	0.49	0.53

Total	Heavy	All
All	1.08	1.04

Table 36: Separations from Heavy and All passengers

<u>Asian and White Spacing</u> The hypothesis that Asian and White passengers would sit closest to passengers of the same ethnicity was not observed although Asian passengers sat closer to Asian passengers than any other group of previously boarded passengers with the exception of "Other." Across all analyzed routes, White seat selectors sat closer to Asian, Hispanic and Other passengers than White passengers.

CHAPTER 6: CONCLUSIONS

6.1 Summary of Study

In this study, boarding, alighting and seating movements were monitored on selected Arlington Transit (ART) bus routes over the course of four weeks in 2013. Collected timing data was combined with seating chart data in order to document passenger seating preferences as well as related boarding and alighting efficiency. Passengers were visually profiled according to their ethnicity, sex, general age group and bulkiness. Multiple linear regression analysis was used to develop boarding and alighting models, and t-testing was used to isolate statistically significant differences between profiled groups in terms of their seating preferences and inter-group separation distances aboard the buses.

This study has increased the understanding of the dynamics of passenger seating preferences and behaviors in the ART bus system, and it has isolated key factors which contribute most to ART boarding and alighting times. This study has also developed a rare link between passenger demographics, seating preferences and dwell time efficiency within a specific bus system.

6.2 Observations: Efficiency, Passenger Differences and Hypothesis Testing

There are statistically significant observed differences in the seating preferences of different ART bus passenger types, some of which apparently affect the dwell time efficiency of buses in the system. Aisle seating, a trend exhibited by Older Female passengers with 90% statistical significance, but not preferred by the ridership at large, contributes to shorter boarding times. Lower level seating, preferred by Older Females with 95% statistical significance, is linked with shorter boarding times.

With 95% statistical significance, Female passengers were observed to seat themselves closer to other Females than to Male passengers, while conversely, Male seat selecting passengers were observed to sit closer to Male passengers than to Female passengers. Without considering the seating type preferences of Male and Female seat selectors, the efficiency effects of the spacing behaviors of each gender group are indefinite.

No clear pattern of seating behavior emerged for the various ethnic groups of passengers in the ART system although it was observed that Asian passengers generally distanced themselves from passengers of other ethnicities by the least total distance. White passengers displayed a trend towards sitting further away from other White passengers on routes where White passengers comprised the plurality of passengers. On routes where White seat selecting passengers were in the minority, the spacing of White passengers with respect to each other noticeably decreased. The efficiency effects of these spacing behaviors are indefinite, however.

Hypothesis testing results were varied. The observed preference for window over aisle seating among observed ART passengers was not statistically significant. With 95% statistical significance, it was observed that Younger passengers prefer upper level seating. Conversely, it was observed that with 95% statistical significance, Older Female passengers (but not Older Male passengers) prefer lower level seating. With 95% statistical significance, it was observed that Female seat selecting passengers sit closer to members of the same and opposite sex than do Male seat selecting passengers. The hypothesis that Hispanic seat selecting passengers prefer closer spacing to other passengers than do seat selecting passengers of other ethnic groups was not supported. Differences in spacing related to bulky passengers could not be substantiated with statistically significant hypothesis testing results. Larger separation spacings hypothesized to be associated with Asian and White seat selectors (with respect to previously boarded passengers of other ethnic groups) were not observed with statistical significance.

6.3 Policy Implications

Cash Fare Payments Policies aimed at encouraging the use of swipe fare cards instead of cash payments could significantly improve the dwell times of the system. The use of cash payments (bills and coins) to pay on board bus fare is a statistically significant factor that appears to substantially increase boarding time. Due to its degree of prevalence (24% of observed boardings included at least one cash fare paying passenger), stronger incentives that are designed to encourage the use of swipe cards (including reductions in fares for SmarTrip® card users) may significantly improve the boarding efficiency of the system as a whole. Such measures, however, would not necessarily improve times when occupancy levels and the number of boarding passengers are low because there would likely be enough space at the front of an ART bus to accommodate a limited number of boarding passengers who could make fare payments without interrupting service as the bus is moving between stops. The boarding time inefficiency associated with cash fare payments could also be controlled to some degree by the setting of fares which are easier for passengers to pay with exact change (e.g., fares which can be paid exactly with a limited number of bills and/or coins).

Lower Level, Aisle and Sideways Seating Lower level, aisle and sideways seating selections are all linked with easier accessibility and movement, and whenever possible, could be encouraged by the driver or by other means. Unlike aisle seats, which are always placed next to window seats and present the possibility of window-aisle seating conflicts, sideways seats (as well as back-to-the-wall front facing seats that are present in the back row of ART buses) provide easier access to passengers and limit the possibility of conflicts during boarding and alighting movements. Bus seating configurations which limit the number of window seats and provide seating with more open access to exits and entrances are more conducive to efficient boarding and alighting movements, and can lead to increases in route capacity.

Getting-Up First Expedited alighting movements occur when the exiting passengers at a particular stop get up and approach the exit before the doors have opened. Fortunately for the ART system, a large percentage of passengers naturally get up and queue at the exit before the doors have opened. Any additional encouragement to get up first would further improve alighting efficiency although safety must be considered. It was also observed that at many hub stop locations with higher seating occupancies, alighting passengers often instinctively conformed to a queuing discipline which gave priority to exiting passengers nearest to the exit portals. This process reduced the alighting time per passenger, and any encouragement the driver can give to reinforce this type of exiting discipline would serve to further enhance the alighting efficiency of the system.

6.4 Limitations of This Study

The results of this study reflect the ART routes which were studied directly and perhaps to a reasonable degree of accuracy, may reflect the conditions of the system at large. There were, however, a number of challenges encountered in the data collection process which may have limited the applicability of this study to the entire system as a whole.

The inability to use video for data collection and the reliance on a one person data collection team are factors that may be behind many of the limitations of this study.

Bias While an official survey was used to select analysis routes, not all ART system routes were able to be analyzed. The five routes selected offer contrasting passenger profiles, however, that do enable a good comparative study of the diverse demographics of ART's ridership. While routes and time periods were varied during the data collection process, it cannot be assumed that a completely accurate and unbiased representation of the analyzed routes was achieved. This study considers the analysis routes both separately and in aggregated form.

Profiling Visual identification issues exist because the determination of the age group, ethnic group classification and even the gender of each individual passenger are not always easy to ascertain. The act of profiling passengers is not an ideal method of classification; however, it is one of the most practical, and possibly one of the most appropriate methods available because this study seeks to identify behaviors among passengers who may visually profile each other when making seat selection decisions. Nevertheless, misclassification may have blurred the existing data.

Data Many of the average spacing values listed in the passenger agent seating tables were derived by fewer than five interactions between agent types, particularly for Asian and Other ethnic categories which account for a small share of the ridership, so valid conclusions were not able to have been drawn from many of the tabulated inter-group interactions. In addition, data in general was difficult to capture for boarding and alighting points of high occupancy because of the difficulty in being able to track down passengers as they entered and exited around standing passengers. As a result, the number of high occupancy data points collected for the boarding and alighting time models was severely limited.

Nonlinear Relationships Excluded from Analysis Multiple linear regression analysis was employed in order to derive boarding and alighting time models in this study. The exclusive use of linear models was initially preferred based on the objective of developing tractable models given the limitations in the collected data and the relatively large number of prediction variables considered for analysis, and this preference was later validated based on the residuals plots and scatterplots of individual variables with respect to predicted and observed response variables. Nevertheless, while nonlinear analysis may have added an unwarranted degree of complexity to the analysis conducted in this study given the limitations in the collected data, it is not inconceivable that the relationships between the respective sets of response and prediction variables may have been more accurately represented with nonlinear models.

6.5 Future Research

Five directions are recommended for future studies related to this one.

Video Data Collection Permission to use video equipment for this study was not granted. If permission were granted to use video, however, a more detailed examination of passenger dynamics would have been acquired, and specific boarding and alighting times could have been assigned to individual passengers instead of relying on probabilistic statistical regression analysis. Moreover, a greater number of data points at higher occupancy levels could have been collected if video (which could be scrutinized for exact details) were captured.

Expanded Route Sampling A similar study could be conducted on the ART system, with a greater number of data points collected over a greater number of routes. A greater variety of routes with different passenger compositions would solidify the ability to draw valid conclusions from the data collected.

Effect of Simultaneous Boarding By design, passenger seat selection was captured relative to the boarded passengers already on board before the boarding process began at any particular stop. The effect that other simultaneously boarding passengers have on each other may have been minimal (and difficult to capture in terms of the data collection methods employed - especially without the use of video), nevertheless it is a factor which may warrant consideration in future studies.

Mode Selection Factors A survey based study of potential ART system passengers may be warranted in order to attempt to determine the effect that the perception of ART's ridership has on mode selection decisions of potential ART passengers. Most of the analysis routes connect residential areas to hub locations, and the segregation that exists in residential areas according to socio-demographic profiles spills over into the ridership of the buses serving those areas. It is possible that sharper differences in inter-ethnic seating may have occurred if not for the non-captive riders who may have taken themselves out of the system during the mode choice stage of the trip making process in order to avoid having any potential interaction with bus system riders.

Mode and System Comparisons Finally, a comparative study incorporating seating behavior on ART buses and comparing it to other bus systems as well as a different transit mode (e.g., WMATA heavy rail) would serve to expand the base of knowledge of passenger behavior. Inter-modal studies would serve to illustrate the role that fare collection and multiple entry and exit portals have on seating as the configuration of WMATA rail cars differs significantly from ART buses.

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APPENDICES

Appendix A: Complete Seating Preference Table

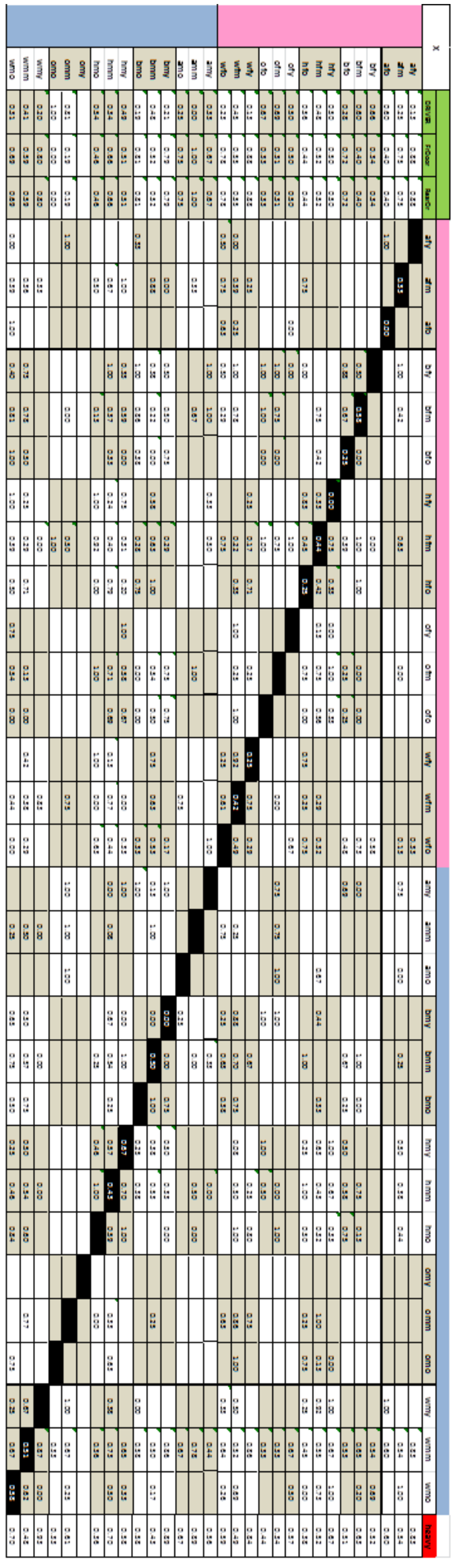
	Seat	Stand	Window	Aisle	Other	Front	Side
afy	1.81	0.00	0.00	2.40	0.96	0.86	1.28
afm	1.93	0.00	1.63	2.08	0.22	1.47	0.29
afo	1.81	0.00	0.69	0.00	1.55	0.34	1.86
bfy	1.86	0.00	2.17	0.69	0.53	1.30	0.64
bfm	1.87	0.00	1.12	0.71	1.13	0.78	1.39
bfo	2.04	0.00	1.21	1.60	0.50	1.22	0.61
hfy	2.34	0.00	0.89	0.00	1.56	0.42	1.83
hfm	2.12	0.00	1.38	1.27	0.60	1.25	0.63
hfo	2.31	0.00	0.00	2.35	0.48	1.02	0.58
ofy	1.88	0.00	0.00	0.00	1.90	0.00	2.39
ofm	1.97	0.00	1.69	0.89	0.52	0.80	1.28
ofo	1.95	0.00	1.17	0.00	1.45	0.00	2.61
wfy	2.14	0.00	0.00	1.13	0.96	0.56	1.28
wfm	2.08	0.08	0.51	1.47	0.81	0.84	1.04
wfo	2.00	0.00	0.78	2.58	0.59	1.21	0.73
amy	1.94	0.00	1.28	0.00	1.36	1.14	0.85
amm	1.95	0.00	3.44	0.00	0.00	1.61	0.00
amo	1.90	0.00	0.00	4.00	0.00	1.60	0.00
bmy	2.07	0.00	1.01	0.00	1.49	0.91	1.08
bmm	1.88	0.15	2.21	1.48	0.36	1.15	0.68
bmo	2.02	0.00	0.79	1.25	0.96	0.82	1.18
hmy	1.99	0.00	2.13	0.54	0.67	1.11	0.81
hmm	2.29	0.00	1.40	1.02	0.72	0.92	0.98
hmo	1.95	0.00	0.67	2.18	0.64	1.01	0.80
omy	NA	NA	NA	NA	NA	NA	NA
omm	1.92	0.00	0.92	1.38	1.06	0.88	1.28
omo	1.89	0.00	3.50	0.00	0.00	1.65	0.00
wmy	1.90	0.00	1.31	0.00	1.21	0.66	1.46
wmm	2.09	0.00	1.15	1.32	0.57	1.20	0.63
wmo	2.04	0.00	1.58	0.75	0.92	1.05	0.89

Appendix B: Generic Separation Distance Table (Interpretation of Separation Distance Tables)

Separation distance values were obtained from the collected data and tabulated by agent group. In each analysis table, seat selector (SS) groups are listed in the left hand column (displayed in a yellow background for the sample chart in Table A0) and previously boarded passenger (PBP) groups are listed in the row directly above the tabulated values (displayed in the blue background for the sample chart in Table A0). The average separation distance between members of a specific seat selector group and a specific previously boarded passenger group is listed in the cell that intersects the horizontal row corresponding to the SS Group and the vertical column corresponding to the PBP group. In the generic separation distance table inserted below, the average separation distance between boarding passengers from SS Group 1 and existing passengers from PBP Group B is Value 1B. The larger the separation distance value, the greater the average distance members of a particular SS Group tend to seat themselves from members of a particular PBP Group.

Tabulated Separation Distance Values		PREVIOUSLY BOARDED PASSENGER GROUP			
		PBP Group A	**PBP Group B**	**…**	**PBP Group N**
SEAT SELECTOR GROUP	**SS Group 1**	Value 1A	Value 1B	…	Value 1N
	SS Group 2	Value 2A	Value 2B	…	Value 2N
	SS Group 3	Value 3A	Value 3B	…	Value 3N
	SS Group 4	Value 4A	Value 4B	…	Value 4N
	SS Group 5	Value 5A	Value 5B	…	Value 5N
	…	…	…	…	…
	SS Group M	Value MA	Value MB	…	Value MN

Appendix C: Complete X Direction Separation Distance Table with Positional Indicators



Appendix D: Complete Y Direction Separation Distance Table with Positional Indicators

Y	Driver	FrDoor	RearDr	sfy	sfm	sfo	bfy	bfm	bfo	hfy	hfm	hfo	ofy	ofm	ofo	wfy	wfm	wfo	smy	smm	smo	bmy	bmm	bmo	hmy	hmm	hmo	omy	omm	omo	wmy	wmm	wmo	heavy
sfy	0.59	0.59	0.10															0.14														0.67		0.67
sfm	0.51	0.51	0.22		0.14		0.50	0.15			0.29			0.20				0.29	0.26		0.40		0.29		0.57	0.46	0.57					0.55	0.00	0.55
sfo	0.29	0.29	0.22	0.14		0.29																									0.14	0.50		0.60
bfy	0.65	0.65	0.42								0.20							0.29														0.44	0.52	0.49
bfm	0.45	0.45	0.46				0.36	0.32	0.14		0.50	0.20		0.20	0.11			0.29	0.25				0.60	0.55		0.55	0.50					0.57	0.17	0.61
bfo	0.44	0.44	0.26				0.55	0.25	0.29		0.55			0.50	0.44			0.21	0.19				0.00	0.17	0.14	0.52	0.44					0.56		0.60
hfy	0.59	0.59	0.54							0.43	0.61	0.50	0.75	0.50	0.67										0.71	0.56	0.50			0.25	0.73	0.40	0.25	0.40
hfm	0.51	0.51	0.40					0.46	0.32	0.48	0.44	0.56	0.75	0.54	0.52		0.27	0.46			0.17	0.54		0.55	0.66	0.52	0.56		0.00	0.25	0.66	0.51	0.34	0.46
hfo	0.46	0.46	0.27		0.45		0.62			0.34	0.55	0.45		0.20	0.17	0.55	0.26	0.50					0.29		0.44	0.54	0.22		0.00	0.17	0.50	0.57	0.17	0.56
ofy	0.21	0.21	0.42			0.14	0.75				0.50							0.29														0.78	0.60	0.72
ofm	0.57	0.57	0.40				0.11	0.24	0.43		0.53						0.20		0.60	0.20	0.50	0.19				0.55	0.50					0.67		0.65
ofo	0.16	0.16	0.52				0.00	0.15	0.29		0.54											0.29			0.10	0.55						0.55		0.62
wfy	0.49	0.49	0.46		0.57					0.40	0.52	0.41		0.00		0.50	0.50	0.46					0.65			0.17	0.23		0.25			0.55		0.52
wfm	0.45	0.45	0.26	0.14	0.57	0.56	0.62	0.55			0.52	0.50	0.62	0.50	0.65	0.14	0.59	0.44		0.51		0.29	0.59	0.73	0.60	0.55	0.26		0.40	0.09	0.60	0.49	0.41	0.55
wfo	0.57	0.57	0.50	0.56	0.50	0.52	0.51	0.54			0.21					0.29	0.25			0.56		0.56	0.20	0.52					0.54		0.54	0.62	0.46	0.65
smy	0.47	0.47	0.62				0.67	0.55		1.00	1.00							0.14					1.00			0.45						0.57		0.65
smm	0.45	0.45	0.11		0.40			0.27						0.20									0.57			0.46	0.40					0.57		0.54
smo	0.50	0.50	0.09														0.20					0.27										0.60		0.60
bmy	0.65	0.65	0.72		1.00		0.74	0.67	0.71		0.66			0.60	0.76			0.60	0.15			0.42	0.60	0.67	0.54	0.50	0.69					0.43		0.46
bmm	0.66	0.66	0.56		0.57		0.46	0.57	1.00	0.49	0.67	0.52		0.75	0.64	0.55	0.67	0.50	0.52	0.67		0.67	0.70	0.67	0.73	0.69			1.00			0.40	0.65	0.44
bmo	0.47	0.47	0.25	0.14			0.55	0.25	0.29		0.51	0.55		0.40	0.55			0.14	0.00						0.20	0.50					0.14	0.59		0.59
hmy	0.55	0.55	0.46		0.14		0.42	0.51	0.29	0.60	0.40	0.60	0.25	0.65	0.76		0.29	0.55	0.50			0.46	0.52		0.47	0.49	1.00					0.62	0.24	0.62
hmm	0.56	0.56	0.41		0.66		0.54	0.50	0.49	0.59	0.59	0.56		0.51	0.24	0.75	0.59	0.66	0.65	0.55		0.36	0.55	0.60	0.41	0.47	0.55		0.65	0.17	0.60	0.49	0.17	0.47
hmo	0.44	0.44	0.52		0.56			0.65		0.40	0.26	0.57		0.00		0.50	0.50	0.59					0.45		0.54	0.55			0.25			0.62		0.56
omy																																		
omm	0.51	0.51	0.44	0.14				0.55			0.74						0.25		0.00	1.00	0.60										0.14	0.61	0.25	0.55
omo	0.64	0.64	0.55								0.55																					0.40		0.40
wmy	0.41	0.41	0.47		1.00						0.67						0.65			0.43			1.00			1.00						0.59	0.65	0.65
wmm	0.49	0.49	0.52		0.42		0.40	0.41	0.00	0.60	0.46	0.61		0.28	0.28	0.51	0.54	0.61		0.50		0.46	0.36	0.40	0.56	0.44	0.42		0.43		0.71	0.55	0.55	0.55
wmo	0.65	0.65	0.54	0.59	0.46	0.00	0.46	0.45	0.50	0.71	0.56	0.25	0.55	0.25	0.55		0.65	0.45		0.45		0.56	0.73	0.73	0.54	0.30	0.27			0.55	0.56	0.45	0.59	0.47

Appendix E: Complete Z Direction Separation Distance Table with Positional Indicators

Z	DRIVER	FrDoor	RearDr	afy	afm	afo	bfy	bfm	bfo	hfy	hfm	hfo	ofy	ofm	ofo	wfy	wfm	wfo	amy	amm	amo	bmy	bmm	bmo	hmy	hmm	hmo	omy	omm	omo	wmy	wmm	wmo	heavy
afy	0.00	0.00	0.00															0.00														1.00		1.00
afm	0.56	0.56	0.56		0.00		1.00	0.00			0.00			0.00				1.00	1.00		1.00		0.00		0.50	1.00	1.00					0.59	0.00	0.59
afo	0.00	0.00	0.00	0.00		0.00																									0.00	1.00		1.00
bfy	0.88	0.88	0.88								0.00							0.75														0.06	0.25	0.15
bfm	0.58	0.58	0.58				0.50	0.00	0.00		0.00	0.00		0.00	0.00			0.60	1.00				1.00	1.00		1.00	0.50					0.60	0.00	0.62
bfo	0.58	0.58	0.58				0.50	0.67	1.00		0.24			1.00	1.00			0.60	0.75				0.00	0.00	1.00	1.00	0.00					0.44		0.50
hfy	0.75	0.75	0.75							1.00	1.00	0.33	1.00	1.00	1.00										1.00	0.50	0.00			0.00	1.00	0.25	0.00	0.25
hfm	0.46	0.46	0.46					0.60	0.50	0.33	0.41	0.00	1.00	0.33	0.50		0.50	0.60			1.00	0.50		0.00	0.72	0.70	0.25		0.00	0.00	0.67	0.54	0.15	0.48
hfo	0.75	0.75	0.75		1.00		1.00			0.33	0.65	0.50		0.00	0.00	1.00	0.50	1.00					0.00		0.67	1.00	0.00		0.00	0.00	1.00	0.58	1.00	0.58
ofy	0.00	0.00	0.00			0.00	1.00				0.00							0.00														1.00	1.00	0.88
ofm	0.50	0.50	0.50				0.00	0.33	0.00		1.00						0.00		1.00	0.00	0.00	0.00				1.00	1.00					0.33		0.50
ofo	0.00	0.00	0.00				0.00	0.00	0.00		0.00											0.00			0.00	0.00						1.00		0.83
wfy	0.50	0.50	0.50		1.00					1.00	0.33	0.50		0.00		1.00	1.00	0.50					1.00			0.00	0.00		0.00			0.50		0.50
wfm	0.40	0.40	0.40	1.00	0.45	1.00	1.00	0.70			0.80	0.00	1.00	1.00	1.00	0.00	0.45	0.67		0.40		0.50	0.45	1.00	1.00	0.50	0.00		1.00	0.00	1.00	0.50	0.41	0.59
wfo	0.20	0.20	0.20	0.50	0.00	0.50	1.00	0.50			0.00					1.00	0.25			1.00		1.00	0.50	0.50					0.33		0.33	0.76	0.65	0.72
amy	0.33	0.33	0.33				0.00	0.00		1.00	0.50							0.00					1.00			0.00						0.67		0.50
amm	0.33	0.33	0.33		1.00			1.00						1.00									1.00			0.50	0.00					0.67		0.83
amo	0.50	0.50	0.50														0.00					0.00										1.00		1.00
bmy	0.57	0.57	0.57		1.00		0.67	0.67	1.00		0.90			1.00	1.00			0.50	0.00			0.00	0.00	0.00	0.00	0.00	1.00					0.45		0.43
bmm	0.83	0.83	0.83		0.50		0.50	0.67	1.00	0.17	0.65	0.50		1.00	1.00	0.00	0.50	0.80	1.00	0.00		0.00	0.50	0.00	0.58	0.89			1.00			0.22	0.50	0.25
bmo	0.50	0.50	0.50	0.00			1.00	0.75	1.00		0.75	0.00		1.00	1.00			0.00	0.00						0.00	0.50					0.00	0.50		0.50
hmy	0.61	0.61	0.61		1.00		0.33	0.50	0.50	0.50	0.40	0.80	1.00	0.75	1.00		1.00	1.00	1.00			0.00	0.50		0.67	0.60	1.00					0.39	0.00	0.59
hmm	0.59	0.59	0.59		0.65		0.33	0.50	0.33	0.59	0.56	0.75		0.57	0.25	1.00	0.58	0.89	1.00	0.00		0.00	0.59	0.60	0.32	0.43	0.57		0.50	0.00	1.00	0.45	1.00	0.43
hmo	0.50	0.50	0.50		1.00			1.00		1.00	0.44	1.00		0.00		1.00	1.00	0.50					1.00		0.00	0.00			0.00			0.50		0.56
omy																																		
omm	0.75	0.75	0.75	1.00				0.00			0.50						1.00		0.00	1.00	0.00										1.00	0.58	1.00	0.25
omo	1.00	1.00	1.00								1.00																					0.00		0.00
wmy	0.40	0.40	0.40		1.00						0.00						1.00			0.00			1.00			1.00						0.50	1.00	0.70
wmm	0.33	0.33	0.33		0.65		0.67	0.60	0.50	1.00	0.69	0.50		0.50	1.00	0.67	0.81	0.50		0.00		0.00	0.72	0.00	0.75	0.75	0.33		0.40		0.67	0.45	0.56	0.47
wmo	0.61	0.61	0.61	1.00	0.50	0.00	0.40	0.00	1.00	0.50	0.67	0.50	0.00	0.00	0.00		1.00	1.00		0.00		0.40	1.00	1.00	0.67	0.50	1.00			1.00	0.50	0.50	0.44	0.52

Appendix F: Complete Total Separation Distance Table with Positional Indicators

Combined	DRIVER	RDoor	RearDr	afy	afm	afo	bfy	bfm	bfo
afy	0.42	0.96	0.88						
afm	0.88	1.19	1.10		0.58		1.50	0.80	
afo	0.76	0.58	0.62	1.01		0.29			
bfy	1.37	1.21	1.15						
bfm	0.97	0.88	0.88				1.09	0.74	0.14
bfo	0.81	1.04	0.99				1.18	1.12	1.07
hfy	1.15	1.28	1.24						
hfm	0.96	1.02	1.00					1.25	0.97
hfo	1.19	1.05	1.02		1.32		1.30		
ofy	0.80	0.64	0.74			0.14	1.25		
ofm	1.01	0.89	0.94				1.01	1.05	0.43
ofo	0.75	0.45	0.75				1.00	1.01	0.29
wfy	0.75	1.24	1.22		1.18				
wfm	0.91	0.95	0.88	1.01	0.87	1.10	1.65	1.20	
wfo	0.56	1.00	0.98	0.89	0.90	1.07	1.32	0.80	
amy	0.85	1.02	1.04				1.20	1.05	
amm	0.65	1.23	1.14		1.15			1.26	
amo	0.85	1.12	1.01						
bmy	0.95	1.54	1.56		1.41		1.26	1.22	1.44
bmm	1.26	1.28	1.26		1.25		0.87	1.25	1.41
bmo	0.80	1.21	1.14	0.56			1.45	1.25	1.17
hmy	1.06	1.14	1.11		1.42		0.82	1.09	0.67
hmm	1.05	1.17	1.15		1.58		1.19	0.96	0.85
hmo	0.96	0.98	0.96		1.27			1.24	
omy									
omm	1.55	0.97	1.04	1.42				0.55	
omo	1.55	1.19	1.05						
wmy	0.70	1.18	1.21		1.48				
wmm	0.99	1.08	1.05		1.07		1.20	1.15	1.00
wmo	1.08	1.22	1.19	1.25	1.00	1.00	1.04	0.99	1.05

Combined	hfy	hfm	hfo	ofy	ofm	ofo	wfy	wfm	wfo
afy									0.56
afm		0.75			0.20				1.06
afo									
bfy		0.20							1.15
bfm		1.12	1.02		0.20	0.11			1.09
bfo		0.95			1.15	1.12			0.87
hfy	1.09	1.46	1.12	1.24	1.50	1.55			
hfm	0.86	0.90	0.74	1.28	1.07	0.94		0.75	1.25
hfo	1.07	1.05	1.12		0.76	0.17	1.29	0.54	1.35
ofy		1.12							0.78
ofm		1.29						0.20	
ofo		1.10							
wfy	1.11	0.60	1.04		0.25		1.15	1.35	0.85
wfm		0.96	0.46	1.54	1.18	1.56	0.95	0.91	0.99
wfo		0.78					1.07	0.84	
amy	1.45	1.41							1.01
amm					1.45				
amo								0.78	
bmy		1.55			1.48	1.47			0.90
bmm	0.96	1.25	0.90		1.59	1.61	0.82	1.08	1.14
bmo		1.01	0.82		1.08	1.05			0.56
hmy	1.26	0.87	1.22	1.44	1.41	1.55		1.04	1.20
hmm	0.77	0.97	1.55		1.14	0.85	1.26	1.06	1.51
hmo	1.47	1.16	1.15		1.00		1.50	1.12	0.92
omy									
omm		1.24						1.27	
omo		1.45							
wmy		0.67						1.51	
wmm	1.19	0.99	1.14		0.69	1.04	1.05	1.06	0.91
wmo	1.41	1.15	1.05	0.82	0.42	0.55		1.57	1.09

Combined	amy	amm	amo	bmy	bmm	bmo	hmy	hmm	hmo
afy									
afm	1.51		1.08		0.58		0.95	1.22	1.22
afo									
bfy									
bfm	1.05				1.54	1.05		1.29	1.15
bfo	0.96				0.67	0.50	1.16	1.25	0.87
hfy							1.58	1.19	0.61
hfm			1.21	0.91		0.47	1.56	1.10	0.67
hfo					1.04		0.95	1.65	0.63
ofy									
ofm	1.59	0.78	1.12	1.02				1.05	1.50
ofo				1.04			1.00	0.66	
wfy					1.35			0.50	0.84
wfm		0.70		1.17	1.08	1.46	1.20	1.06	0.96
wfo		1.58		1.18	0.86	0.78			
amy					1.48			0.43	
amm					1.15			1.12	0.40
amo				0.58					
bmy	1.00			0.45	0.80	1.00	0.78	0.55	1.58
bmm	1.07	1.22		0.67	1.25	1.20	1.17	1.50	
bmo	1.00						0.52	0.95	
hmy	1.45			0.45	1.26		1.26	1.22	1.75
hmm	1.20	0.29		0.70	1.05	0.92	0.95	0.89	1.15
hmo					1.12		0.75	1.05	
omy									
omm	1.00	1.75	1.17						
omo									
wmy		0.43			1.41			1.41	
wmm		0.65		0.72	1.16	0.85	1.05	1.07	0.90
wmo		0.65		1.10	1.49	1.41	1.00	0.87	1.54

Combined	omy	omm	omo	wmy	wmm	wmo	heavy
afy					1.47		1.47
afm					0.96	1.00	0.96
afo				1.01	1.45		1.45
bfy					0.77	0.89	0.75
bfm					1.19	0.50	1.20
bfo					1.11		1.19
hfy			0.25	1.60	0.87	1.05	0.87
hfm		1.00	0.58	1.59	1.07	0.95	1.02
hfo		0.25	0.77	1.15	0.87	1.01	0.66
ofy					1.59	1.55	1.51
ofm					1.00		1.05
ofo					1.42		1.54
wfy		0.79			1.20		1.17
wfm		1.44	1.01	1.55	1.02	1.01	1.07
wfo		0.68		0.70	1.28	0.97	1.22
amy					1.23		1.23
amm					1.25		1.57
amo					1.54		1.54
bmy					1.19		1.19
bmm		1.44			0.85	1.08	0.86
bmo				0.14	1.05		1.05
hmy					1.12	0.52	1.09
hmm		1.06	0.66	1.24	1.15	1.14	1.12
hmo		0.25			0.96		0.91
omy							
omm				1.42	1.04	1.06	0.92
omo					0.52		0.52
wmy					1.26	1.18	1.41
wmm		1.10		1.58	1.06	1.15	0.95
wmo			1.29	0.86	1.15	1.05	1.16

Appendix G: Initial Boarding Time Model (Excel Output)

Regression Statistics	
Multiple R	0.82
R Square	0.67
Adjusted R Square	0.63
Standard Error	16.92
Observations	122.00

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	13	61467.99	4728.31	16.52	3.84E-20
Residual	108	30916.47	286.26		
Total	121	92384.45			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	11.47	3.44	3.34	0.00
Pre-B Seat Occupancy	-19.94	22.54	-0.88	0.38
Pre-B Minority Occupancy (non-Asian)	8.14	49.98	0.16	0.87
# Boarding	7.72	2.30	3.35	0.00
# Cash Fare	15.46	3.50	4.42	0.00
# Seniors	-1.11	2.56	-0.43	0.67
# Female	-2.48	2.36	-1.05	0.30
# Standing	1.62	9.25	0.18	0.86
# Window Boarding	-3.28	3.08	-1.06	0.29
# Whites	-1.40	1.80	-0.78	0.44
# Upper Level	6.75	2.34	2.89	0.00
# Conflicts	-2.51	6.55	-0.38	0.70
# Disabled	65.65	11.45	5.73	0.00
# Aisle Boarding	-9.14	3.33	-2.75	0.01

Appendix H: Initial Alighting Time Model (Excel Output)

Regression Statistics	
Multiple R	0.93
R Square	0.87
Adjusted R Square	0.86
Standard Error	4.79
Observations	82

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	8	11222.68	1402.84	61.21	2.68E-29
Residual	73	1672.98	22.92		
Total	81	12895.67			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	5.48	1.52	3.61	0.00
Pre-Alighting Seat Occupancy	-8.23	4.04	-2.04	0.05
# Alighting	0.53	0.50	1.06	0.29
# Seniors	2.05	0.75	2.75	0.01
# Upper Level	-0.09	0.81	-0.12	0.91
# Conflicts	1.04	1.06	0.98	0.33
# Window	2.13	0.89	2.41	0.02
Disabled	62.15	4.35	14.30	0.00
% Get-Up First	-3.41	1.32	-2.59	0.01

Appendix I: Alternate Boarding Time Model (Excel Output)

Regression Statistics	
Multiple R	0.82
R Square	0.67
Adjusted R Square	0.65
Standard Error	16.24
Observations	122
F	39.22
Significance F	1.22E-25
Regression df, SS	6, 62056
Residual df, SS	115, 30329

	Coefficients	Standard Error	t Stat	P-value
Intercept	3.82	2.65	1.44	1.52E-01
# of Boarding Passengers	8.77	1.93	4.54	1.38E-05
# Paying Cash Fare Passengers	13.78	3.14	4.38	2.62E-05
# Upper Level SS Passengers	4.36	1.99	2.19	3.05E-02
# Disabled Boarding Passengers	60.45	10.66	5.67	1.08E-07
# Aisle SS Passengers	-7.98	2.58	-3.09	2.51E-03
#seniors*#females interaction	-1.74	0.62	-2.78	6.37E-03

Appendix J: Alternate Alighting Time Model (Excel Output)

Regression Statistics	
Multiple R	0.93
R Square	0.87
Adjusted R Square	0.86
Standard Error	4.75
Observations	82
F	82.59
Significance F	5.20E-31
Regression df, SS	6, 11200
Residual df, SS	75, 1695

	Coefficients	Standard Error	t Stat	P-value
Intercept	5.37	1.43	3.76	3.39E-04
# Senior Alighting Passengers	2.24	0.71	3.15	2.34E-03
# Window Alighting Passengers	2.03	0.79	2.58	1.19E-02
% Get-Up First Alighting Passengers	-3.57	1.27	-2.81	6.24E-03
# Disabled Alighting Passengers	61.74	3.96	15.60	3.00E-25
# Alighting Passengers	0.60	0.41	1.48	1.42E-01
% Pre-Alighting Seating Occupancy	-7.80	3.90	-2.00	4.92E-02

Appendix K: Miscellaneous Separation Tables by Route

TOTAL DISTANCE	Route 41 Blacks	Route 41 Hispanics	Route 41 Whites
Route 41 Blacks	1.17	1.03	0.97
Route 41 Hispanics	0.98	1.02	1.12
Route 41 Whites	1.17	0.94	1.05

# Obs	Route 41 Blacks	Route 41 Hispanics	Route 41 Whites
Route 41 Blacks	10	32	20
Route 41 Hispanics	53	155	103
Route 41 Whites	15	39	29

#SS, Route 41	
Blacks	15
Hispanics	65
Whites	15
Rest	16

(a): Average Ethnic Group Separation on Route 41 (top)
Number of Observations/Interactions (middle)
Number of Observed Seat Selectors along Route 41 (bottom)

TOTAL DISTANCE	Route 51 Blacks	Route 51 Hispanics	Route 51 Whites
Route 51 Blacks	1.08	1.15	0.89
Route 51 Hispanics	0.89	0.90	1.06
Route 51 Whites	1.11	1.20	0.96

# Obs	Route 51 Blacks	Route 51 Hispanics	Route 51 Whites
Route 51 Blacks	23	2	30
Route 51 Hispanics	3	2	15
Route 51 Whites	11	6	17

#SS, Route 51	
Blacks	17
Hispanics	10
Whites	11
Rest	4

(b): Average Ethnic Group Separation on Route 51 (top)
Number of Observations/Interactions (middle)
Number of Observed Seat Selectors along Route 51 (bottom)

TOTAL DISTANCE	Routes 52 & 53 Blacks	Routes 52 & 53 Hispanics	Routes 52 & 53 Whites
Routes 52 & 53 Blacks	NA	1.07	1.02
Routes 52 & 53 Hispanics	1.12	NA	0.93
Routes 52 & 53 Whites	1.14	1.01	1.10

# Obs	Route 52 & 53 Blacks	Route 52 & 53 Hispanics	Route 52 & 53 Whites
Route 52 & 53 Blacks	0	9	23
Route 52 & 53 Hispanics	1	0	5
Route 52 & 53 Whites	9	7	81

#SS, Route 52 & 53	
Blacks	12
Hispanics	4
Whites	32
Rest	16

(c): Average Ethnic Group Separation on Route 52&53 (top)
Number of Observations/Interactions (middle)
Number of Observed Seat Selectors along Route 52&53 (bottom)

TOTAL DISTANCE	Route 75 Blacks	Route 75 Hispanics	Route 75 Whites
Route 75 Blacks	0.97	1.73	1.29
Route 75 Hispanics	1.13	1.42	0.99
Route 75 Whites	1.10	1.10	1.11

# Obs	Route 75 Blacks	Route 75 Hispanics	Route 75 Whites
Route 75 Blacks	10	1	11
Route 75 Hispanics	4	3	10
Route 75 Whites	35	13	37

#SS, Route 75	
Blacks	8
Hispanics	6
Whites	15
Rest	4

(d): Average Ethnic Group Separation on Route 75 (top)
Number of Observations/Interactions (middle)
Number of Observed Seat Selectors along Route 75 (bottom)