MICHIGAN OHIO UNIVERSITY TRANSPORTATION CENTER

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Report No: MIOH UTC TS33 2011-Final

Bowling Green State University

DEVELOPING a MODEL-BASED DECISION SUPPORT SYSTEM for CALL-A-RIDE PARATRANSIT SERVICE PROBLEMS

FINAL REPORT

PROJECT TEAM

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DISCLAIMERS

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List of Acronyms

ADA	Americans with Disabilities Act
AVL	Auto Vehicle Locators
ETA	Estimated time of arrival
IRV	Interactive Voice Response
MBTA	Massachusetts Bay Transport Authority
MDC	Mobile Data Computer
OTA	Office of Transportation Access
PCA	Personal Care Assistant
US DOT	U.S. Department of Transportation
VTS	Veterans Transportation Services

Introduction

Paratransit is the transportation service that supplements larger public transportation systems by providing individualized rides without fixed routes or timetables. In 1990, the Americans with Disabilities Act (ADA) was passed which allows passengers who cannot use regular public transportation services due to their physical, cognitive, or mental disability to use alternative paratransit services complimentary to the fixed route services already in place. Such paratransit was not mandated until 1990 by law, but has been provided to individuals in a similar form in the greater Boston metropolitan area since 1977.

The U.S. Department of Transportation (USDOT) regulations, which implement the transportation provisions of the ADA, require that public transit agencies that provide fixed route service also provide "complementary paratransit service" to persons with disabilities who are unable to use the fixed route system. The level of service provided by the paratransit program must be "comparable" to that provided by the fixed route service. There are six service criteria that define the comparability of this complementary service: 1) service area; 2) response time; 3) fares; 4) days and hours of operations; 5) trip purposes served and; 6) capacity constraints.

Section 12143 of the ADA rules and regulations states that if an entity operates a fixed route system (other than a system which provides solely commuter bus service) it is considered to be discriminatory to those individuals with disabilities. This includes individuals who use wheelchairs and cannot access a level of service (1) which is comparable to the level of designated public transportation services provided to individuals without disabilities using such system; or (2) in the case of response time, which is comparable, to the extent practicable, to the level of designated public transportation services provided to individuals without disabilities using such system. The requirement is that any entity running a fixed route system must provide comparable service for an area of ½ mile surrounding each of the fixed rail or bus route. Fares, days and hours, trip purposes (i.e. going to work, going to medical appointment, going shopping, etc.), and capacity constraints are required to be comparable to that of a fixed route service.

The paratransit service required by the Americans with Disabilities act states that prices to its customers must compare to that of the public transit already in existence. Since the public transit fare is usually quite low, the state government that typically finances the public transit system needs to deal with the dilemma of absorbing the mounting cost of paratransit. The rising cost of paratransit is due to many factors. These include vehicle purchases, maintenance and repairs, insurance, fuel, driver wages, administration, overhead and incentive programs for contractors. As demand rises with the increase of elderly persons from the Baby Boomer era and disabled veterans returning from the Iraq and Afghanistan wars, there is a need for more affordable paratransit service. Since the revenue from the riders' fares only covers a small portion of the cost of running paratransit services, there is a growing concern that quality of service will be compromised. The rising costs are directly associated with the increased demand, because more vehicles and drivers are needed to cover the increased demand. Rising fuel costs are also a cause for concern as the recent crude oil price hit nearly $100 a barrel. In addition, paratransit regulation often mandates the establishment of specific operating policies with respect to: 1) the level of assistance provided; 2) employee training; 3) secure systems; 4) accommodation of service animals and life support equipment and; 5) no-show policies. Lastly, rules and regulations require that public entities providing complementary paratransit have a process for determining eligibility for ADA Paratrasit and who qualifies to use the paratransit service.

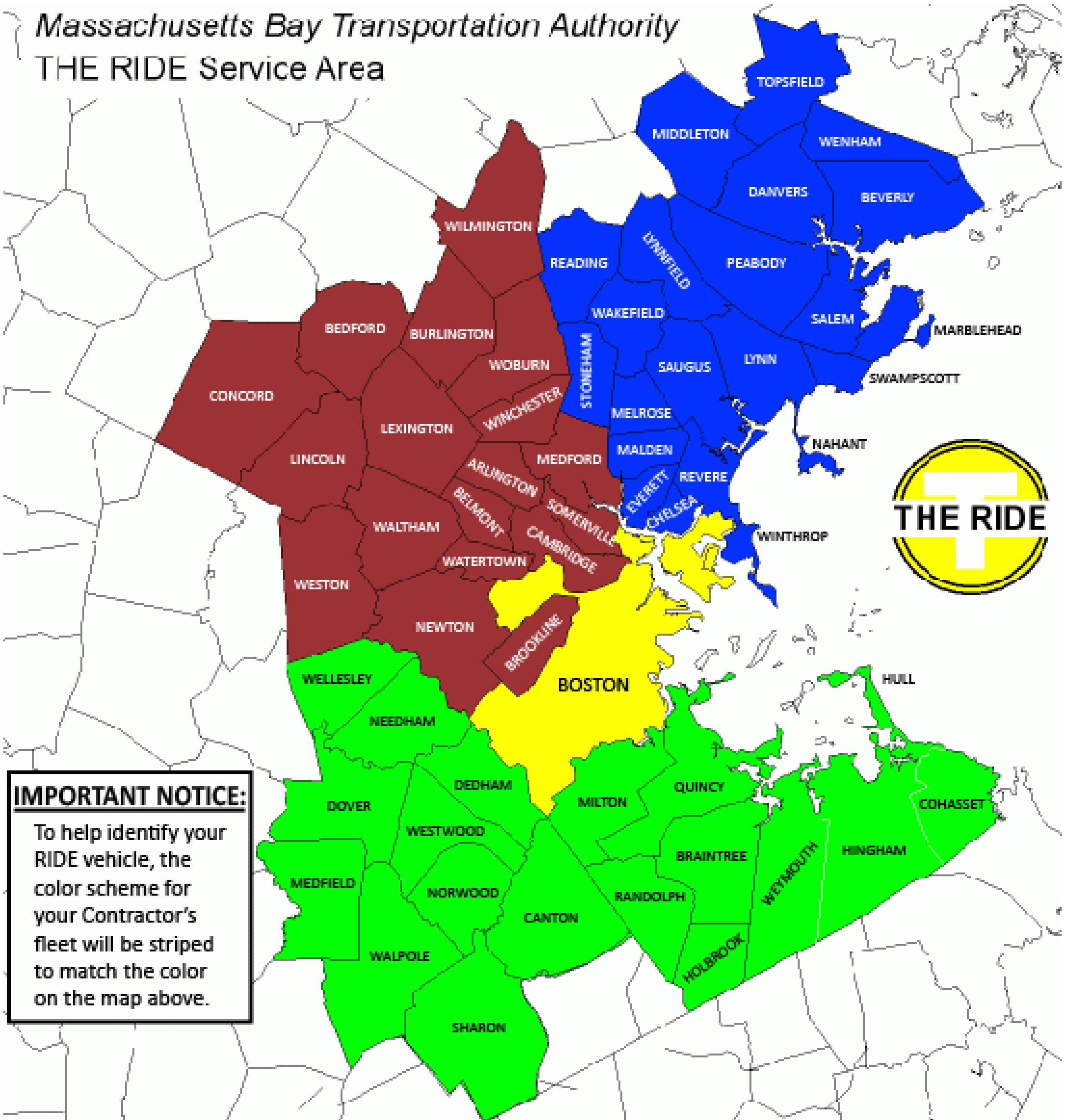
There are two types of paratransit services required by ADA: 1) door-to-door service and; 2) curb-to-curb service. Door-to-door service is the service in which the driver will assist the rider from their door to the vehicle at their pickup location and will assist the rider from the vehicle to the door of their destination while curb-to-curb service is similar to a taxi service where the driver will wait in the vehicle for the rider to embark the vehicle and drop them off at the rider's destination without any assistance. Since door-to-door service takes more time and additional driver's efforts, such services may be curtailed in times of budget crisis. There are many studies that have been performed to evaluate the efficiency of paratransit systems worldwide. These include peer to peer analyses as well as historical data analyses. Some studies identify the increased need for paratransit service as well as improvements that will need to be made in order to meet the demand of paratransit passengers, (Lave and Rosemary, 2000). Other research evaluates the efficiency levels of individual paratransit systems with the specific objective of identifying the most efficient agencies and the sources of their efficiency. Thus, upon identifying the most efficient systems along with the influencing factors, new service policies, management and operational strategies may need to be developed for improved resource utilization and quality of service (Fu et al., 2007). In a similar manner, there have been studies on the development of methodologies to estimate confidence intervals of certain analyses of efficiency of individual urban paratransit agencies and the statistical significance of trends in individual agency efficiency (Barnum et al., 2007). The studies discussed above were taken into consideration in what analysis would be appropriate for the historical data provided by the Massachusetts Bay Transport Authority's (MBTA) THE RIDE Paratransit system in the Greater Boston area. The background information about the MBTA's THE RIDE program, the data provided, and analysis performed will be discussed in the following paper.

1. MBTA's THE RIDE

The Massachusetts Bay Transport Authority's (MBTA) THE RIDE is the paratransit system in place in the Greater Boston metropolitan area in Massachusetts. THE RIDE program is an advanced notice, shared-ride, door-to-door paratransit program for persons with disabilities adhering the ADA's rules and regulations. This paratransit service has been running since 1970, twenty years before the requirement of such service. This gives THE RIDE a bit of an advantage because of the experience it has in running such a service.

THE RIDE program currently operates under Federal ADA regulations, providing service to over 60 cities and towns covering 688 square miles, 7 days a week, generally from 6 a.m. to 1 a.m., including holidays. THE RIDE costs each passenger $2.00 per one way trip.

THE RIDE program is managed by the MBTA's Office of Transportation Access, (OTA) comprised of seventeen (17) staff members. OTA is located at Ten Park Plaza and oversees THE RIDE program. The staff in OTA administers and manages all aspects of THE RIDE program. Their responsibilities include setting service policies and standards, contracting and overseeing contracted service providers, rider eligibility certification, and customer service (handling and investigating rider complaints), and posting fare deposits to customer's RIDE accounts. The office also purchases and leases many of the 635 lift-equipped vans/sedans used by the three (3) contracted service providers. THE RIDE uses three contractors to perform its obligation of Paratransit service. They are Greater Lynn Senior Services, Veterans Transportation Services, and the Joint Venture. All contractors were required to bid on the service contract to best exemplify the type of customer service, pricing, and other systems in place to meet and exceed the requirements of the ADA. As per the map in Figure 1, denoted by color, are the service areas for each contractor. Greater Lynn Senior Services is responsible for the area in blue to the North of Boston, Veterans Transportation Services (VTS) is responsible for the area in red to the Northwest of Boston, and Joint Venture is responsible for the area in green to the south of Boston. All contractors are responsible for Boston, in yellow on the map.



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- Shared = All contractors serve this area
- North - Greater Lynn Senior Service - 1-888-319-7433(V) 1-800-621-0420(TTY)
- Northwest -Veterans Transportation Services - 1-877-765-7433(V) 1-888-553-8294(TTY)
- South - The Joint Venture TTI/YCN - 1-888-920-7433(V) 1-888-607-7757(TTY)

Figure 1. The Areas Serviced by THE RIDE

The cities and towns covered by the MBTA's THE RIDE in the four service areas marked with different colors of Figure 1 are, in Blue: Beverly, Chelsea, Danvers, Everett, Lynn, Lynnfield, Malden, Marblehead, Melrose, Middleton, Nahant, Peabody, Reading, Revere, Salem, Saugus, Stoneham, Swampscott, Topsfield, Wakefield, Wenham, and Winthrop; in Red: Arlington, Bedford, Belmont, Brookline, Burlington, Cambridge, Concord, Lexington, Lincoln, Medford, Newton, Somerville, Waltham, Watertown, Weston, Wilmington, Winchester and Woburn; in green: Braintree, Canton, Cohasset, Dedham, Dover, Hingham, Holbrook, Hull, Medfield, Milton, Needham, Norwood, Quincy, Randolph, Sharon, Walpole, Westwood, and Weymouth and; in yellow: Boston, which includes Allston, Back Bay, Brighton, Charlestown, Chinatown, Dorchester, Downtown Boston, East Boston, Fenway, Hyde Park, Jamaica Plain, Mattapan, North End, Roslindale, Roxbury, South Boston, South End and Roxbury.

In addition to providing Paratransit service to the aforementioned 60 plus towns and communities, THE RIDE also has cooperative agreements with Brockton Area Transit and with the MetroWest Regional Transit Authority to provide THE RIDE service to and from the main transit terminal in Brockton and the Wellesley Farms Commuter Rail Station. This also allows Brockton Area Transit and MetroWest Regional Transit Authority area residents to use their respective Paratransit services and then transfer to MBTA THE RIDE vehicles to travel to and from points in THE RIDE service area.

In some instances of travel, transfers may be required. That is, a rider may be going from one area serviced by one contractor to another area serviced by another contractor. This is also the case with the above cooperative agreements. There are two transfer sites within THE RIDE's service area, they are: 1) Ruggles and; 2) Malden/Medford. In both cases, transfers are necessary to provide more efficient service. For example, if a rider requests a trip from Salem to Concord, it is more efficient to have a vehicle transfer in Malden/Medford so that the vehicle coming from Salem (contractor Greater Lynn Senior Service) is able to pick up another rider in the area that it services right after the drop off rather than driving all the way to Concord and then coming back into its service area to pick up another rider. If there were no transfers, there would be a lot of wasted time and miles in between each trip in such cases.

The US Department of Transportation's ADA regulations require that all transit entities that provide complimentary paratransit service also have a process for determining who is "ADA paratransit eligible." In summary of the specific criteria stated in this regulation indicate that persons with disabilities are eligible for ADA required paratransit if because of their disability, they:

- Are prevented from traveling to or from fixed route stops or stations;
- Are unable to use a bus route or rail station for a particular the route or station is not yet accessible; or
- Are unable to "navigate" the systems (e.g. not able to be oriented to place or time, have problem solving skills, community safety skills, or have other skills needed to use the system).

Not only is it a requirement to have an eligibility determination process, but this process must also meet several regulatory requirements. These include the following:

- Interim service must be provided if determinations are not made within 21 calendar days of receipt of a completed application.
- Written notice must be given of the determination and if eligibility is denied or limited, the specific reasons for this decision must be disclosed. These letters must also describe how the applicants can appeal the decision.
- An appeals process is required. Appellants must be given the opportunity to be heard in person and have others provide information on their behalf. There must be a "separation of authority" between those involved in the appeal process and those involved in the initial determination. Appeals must be accepted for at least 60 days after the notice of the initial decision is given and appeal must be decided within 30 days of the appeal hearing.

All drivers receive sensitivity and safety training so they may respond in a responsible and proper manner. Drivers provide assistance into and out of vehicles and from and to the main entrance or lobby area of the rider's point of origin and destination, respectively. Drivers also assist individuals who use wheelchairs, at the rider's point of origin and destination, up a ramp of over a maximum of one curb and/or one step (several steps if a rider is ambulatory). In addition to this assistance, the driver will help a manageable number of shopping bags to the door of a rider's destination. This door-to-door service is very customer satisfaction oriented as it provides very personal assistance. With this assistance comes less efficiency as a service. The average time it takes for a vehicle to leave a pick up or drop off location is between 6 and 8 minutes. This is valuable time that could be used driving to the next pick up or drop-off location.

Each vehicle is equipped with a Mobile Data Computer (MDC) which provides GPS; it also disables touch screen while driving and has a radio for emergency situations and Auto Vehicle Locators (AVL's) to provide more accurate routes and data as well as lessen the radio time being used by each driver. This provides the rider with a much more pleasant and safe trip. The AVLs also provide the operators with real time vehicle location so it makes it easier for the operators to alter a driver's route without the driver's knowledge of a change. This control can be helpful because of the real time knowledge of where each of the contractor's vehicles is at any given time during operations can be utilized in rerouting a vehicle to accommodate last minute trips as well as transferring a trip to a different vehicle which otherwise would have been missed or caused the contractor to have a late trip and therefore would be penalized for that trip.

When scheduling a trip, a rider has up to fourteen (14) days before and until to 4pm on the day prior to their trip to schedule with THE RIDE. There are two possible requests for each trip as far as time is concerned. One is that a rider may request a trip based on what time they request to leave their pickup location and the other is that a rider may request a trip based on what time they request to arrive at their drop off location. The routing system is able to provide scheduling based on either type of request.

Once the 4pm on the day before deadline passes, a specialized routing program developed by Strategen Inc. then schedules the trips for each contractor based on the specifications of each contractor. There are a few common constraints by which each contractor must comply. These constraints include riding time and departure time and arrival time constraints. The departure time requested by the rider must be met within 30 minutes of the requested time. The arrival time must be within certain parameters set by each individual contractor, but remains within the parameters of the rider's preferences. For example, a rider may want to arrive at his or her doctor's appointment at 9:00am. The parameter is to arrive at the location by 9:00am, but a contractor may set up a parameter in the software that requires the drop off at the location to be fifteen (15) minutes before the required time so that the rider is not late for their appointment. The riding time constraint is at the very least that if a trip requires less than thirty (30) minutes to complete, that the rider will not be in the vehicle for more than sixty (60) minutes and; if the trip requires more than thirty (30) minutes to complete the rider will not be in the vehicle for more than twice the required time for that trip.

Other required information, which is generally linked to a rider's profile upon receiving eligibility from THE RIDE, includes the need of equipment such as wheelchairs, scooters, walkers and service animals. Also, a rider must specify if he or she has a Personal Care Assistant (PCA) or guest riding with them. The PCA can ride free of charge. PCA's and guests must travel at the same time as the certified rider to and from the same destination. This information required to schedule a trip is important when routing vehicles with different types of accessibilities, i.e. wheelchair accessible and to ensure the appropriate vehicle is dispatched to each pick up location.

On the day of the trip, the rider must be ready five (5) minutes before his or her scheduled pickup and must be prepared to wait up to fifteen (15) minutes after that time. The driver must wait for the rider for five (5) minutes from the time of the scheduled pickup. If the rider is not at the pickup location within five (5) minutes, the driver can obtain clearance from his or her dispatcher to leave. A rider is considered a *NO SHOW* if he or she fails to cancel his or her trip within one hour of the scheduled pickup or fails to show up within five minutes after the scheduled pickup time. If the driver does not arrive within fifteen (15) minutes after the scheduled pickup time, the rider should call the Contractor for an estimated time of arrival (ETA) or can reschedule his or her pickup at that time. If a driver is late 15 to 30 minutes there is a 10% penalty of the total value paid to the Contractor for that trip. If a driver is late more than 30 minutes, the trip is not paid to the Contractor. These types of penalties give incentive to the Contractors to honor promised times, use the routing program and make appropriate adjustments throughout the day to ensure timely pickups.

The phone system uses an Interactive Voice Response (IVR) system to callback riders once their trip has been scheduled with promise times for each pick up for the next day in the scheduling program discussed above. These call backs occur the evening before the scheduled trips after the routing schedule has been produced by the software and prior to 9:00pm. The IVR is a system that takes all of the promised times from the schedule produced and automatically calls the riders to confirm these times.

When the rider is on the phone he or she can confirm or cancel his or her trip using the automated system. This provides for a more streamlined system and in essence lowers costs further discussed below.

There are many costs associated with providing paratransit service to an area such as the metro-Boston area. These costs include mobilization costs, fixed costs – admin overhead, and fixed operational costs for each contractor. Mobilization costs include administrative personnel wages/fringes, rent, utilities, telephone, supplies, furniture/equipment, computer hardware, computer software, MDC/AVL, IVR, general insurance, vehicle expenses, communications system and profit. Mobilization costs exclude any and all capital expense. Annual fixed costs for administration and overhead costs include all mobilization costs, amortized, and any and all capital expenses. These would include all expense categories within the mobilization costs except vehicle expenses replaced with vehicle purchases. Fixed operational costs include driver salaries/fringes, vehicle maintenance, vehicle insurance, fees/licenses, other, and profit. Other costs include fuel which is reimbursed to the Contractor for the actual price paid per gallon up to the average price per day in the Boston Metro Area, as listed via the AAA website. The Contractor is responsible for providing actual receipts for all gasoline purchases for services rendered, specifying whether receipts were for fuel purchases for Authority owned or Contractor owned vehicles, adjusting the amount of reimbursement sought each month to ensure nothing exceeds the AAA recorded average per day and providing a summary report each month by day and by vehicle.

With all of these costs taken into consideration, the average net cost per passenger one way trip is $41.61 for fiscal year 2010 (July through December 2009). As one can see, the fare of $2.00 per each one way trip hardly covers the actual net cost of the trip. The fares that are not charged to PCAs even though a seat taken in a vehicle can also be considered a cost that is being paid with no revenue to offset it.

The costs discussed above are also associated with the service that is provided to each rider. These services include riding times, meeting required pickup and drop off times, and personalized assistance provided by the drivers. The metrics of these services are discussed above and will now be summarized. The riding time may not exceed an hour if the direct drive time required for the trip is less than thirty (30) minutes; otherwise, the riding time may not exceed twice the direct drive time required if that time is greater than or equal to thirty (30) minutes. Pickup times must be within 15 minutes of the promised time for the Contractor to avoid penalties. These penalties are a savings to THE RIDE, but also incentive to have excellent performance which is a greater value in providing the best customer service. Lastly, assistance provided by the driver such as carrying groceries to the door, assisting the rider to and from the door of their drop off and pickup locations, respectively. All of the aforementioned services and service parameters come at a cost to the Contractor, THE RIDE, and ultimately, taxpayers.

2. Data, Analysis, and Results

The data was provided by Veterans Transportation Services in two reports, both in Excel 2007 (.xlsx) format; 1) "Veterans – The Ride Manifest By Stop" Printed 05/05/2010 at 18:30 and; 2)"MBTA Daily Posted Routes for 05/06/2010." The printed Manifest By Stop printed on May 5, 2010 contained all the planned trips for May 6, 2010 and the Daily Posted Routes contained all actual executed routes for May 6, 2010.

The first report provided, "Veterans – The Ride, Manifest By Stop," included specific information on the Registered Passenger ID, Passenger Name, Requested Pickup and Drop off Locations, Ambulatory information (i.e. whether a rider is able to walk or not), Wheelchair information, Equipment needs, Service needs, Additional Descriptions, Directions and Notes. The ambulatory information is provided by a binary code. On the report it reads Amb: and then either a 0 or 1. If Amb: 0, then the rider is unable to walk; if Amb: 1, then the rider is able to walk. For noting whether or not a rider needs a wheelchair, it is similarly noted: WC: 0, if a wheelchair is not needed and WC: 1, if a wheelchair is needed. The next section is Equipment Needs which is denoted by the following and defined in parenthesis: A (Braces), C (Cane), R (Crutches), X (Extra Space), O (Oxygen), P (Power Chair), T (Prosthetics), S (Scooter), K (Walker), W (Wheelchair), TP (TTY Phone), TW (TTY Work), I (Infant Car Seat), and B (Child Booster Seat). The Service Needs section was not utilized in this report. Additional Descriptions provided a section where the name of the actual location was typically put, i.e. the name of the hospital or rehabilitation center. Directions and Notes gave the driver additional information on how the rider may have wanted to go, if the rider needed assistance to and from the door, what floor the doctor's office is on, etc. In general, the additional information provided to the driver is to better service the rider to and from their requested locations.

The second report provided, "MBTA Daily Posted Routes for 05/06/2010," included information such as the Registered Passenger ID, a unique identifier for each rider; the Trip ID, unique identifier for each trip; the Same Day Scheduling information denoted by "Yes" or "No;" the Passenger Name, Trip Disposition denoted by OK, Late16, Late30, No-Show, and Canceled. OK means that the driver arrived on time and the rider was picked up. Late16 means that the driver arrived more than 15 minutes later than the Promised Time, but not more than 30 minutes late to pick up the rider. Late30 means the driver arrived more than 30 minutes after the Promised Time, but still picked up the rider. No-Show means that the rider was not there within five minutes upon the driver's arrival or failed to cancel the scheduled trip with at least one hour's notice. If the driver arrives at the No-Show pickup location, the driver waited for the rider for 5 or more minutes and then can acquired the clearance to leave. Canceled means that the trip was properly canceled and usually the driver is not even dispatched to that rider's pickup location.

Other information included in the report is Required Time, the time the rider requested to be picked up or the time at which it is necessary to be picked up to arrive at requested destination at a certain time; the Promised Time, the time the contractor has confirmed to pick up the rider; the Pickup Arrive Time and Pickup Leave Time are the times the driver arrived to pick up the rider and the time the driver left with the rider on board; the Drop off Arrive Time and Drop off Leave Time are the times when the driver arrived at the location to drop off the rider and the time the driver left that location without the rider on board; the Pickup address and city, the Drop off address and city, Personal Care Assistant (PCA) information, Vehicle ID and Driver ID.

With the aforementioned information included in the reports provided, they can be compared to one another to get a sense of how many changes to trips and routes are made after the 6:30pm cutoff time on the previous day. From the amount of changes being made, one can see how complicated it can become to rearrange routes and how necessary it is to have a reliable program to route the trips as well as an experienced staff to manually reroute vehicles according to the changes throughout the day. The changes a rider can make to his or her reservation include, but are not limited to time changes, pickup and drop off locations changes, cancellations, no-showing for one's ride. Changes made to the routes throughout the day manually are caused by weather, traffic, construction, and delays at pickup and drop off locations.

The Daily Posted Routes for 05/06/2010 contained data for all rides executed by Veterans Transportation Services for May 6, 2010. Each trip is a one way trip from an origin to a destination. There were a total of 2,376 completed rides for this day, comprised of 2204 on time completed trips, 164 Late 16 to 30 minute trips and 8 Late > 30 minute trips. The total completed trips were originally out of a total of 4,105 requested trips for this particular day, comprised of 836 cancelled trips, 303 No-Show trips, 2,754 On time trips, 202 Late 16 to 30 minute trips, and 10 Late > 30 minute trips. As it can be seen in the second set of data mentioned above, even if a trip is considered on time, it does not mean it was a completed on time trip and the same is true for late trips. Please see Appendix A for a pie chart showing the proportion of rides and their outcomes discussed above with the additions of scheduled and prescheduled trips, i.e. cancelled trips, No-Show trips, same day scheduled trips and prescheduled trips.

The Manifest was used to determine the ambulatory status, wheelchair needs and to confirm the pickup and drop off locations of each rider printed in the Daily Posted Routes for May 6, 2010. If a rider was included in the Daily Posted Routes, but not in the Manifest, their ambulatory status was then undetermined and that trip would be eliminated from the data used for analysis. The rationale for eliminating these trips with missing ambulatory information is that for each trip to be analyzed, the information must be complete for each ride and rider and therefore all data with complete information can be examined using the same tests and analysis.

For each trip, the minimum and maximum public transit times and direct drive times and mileage were determined using Google Maps (http://maps.google.com/maps?hl=en&tab=wl). The public transit times were manually produced while the direct drive times and mileage were found by using a software program developed for this research utilizing Google Maps and inserting the data into the Excel (xlsx) worksheet with all other data. The direct drive times and mileage were then checked individually to ensure the accuracy of the data. Both the public transit times and direct drive times and mileage URL's were produced using software developed for the research as to ease the manual process. The pickup and drop off locations were verified using the Manifest to ensure accuracy of the times. Also for each trip, it was determined whether or not it was a shared ride, if a wheelchair was needed for each passenger and the passenger's ambulatory status.

Once the minimum and maximum public transit times and the direct drive times were obtained, the data was then filtered to determine what data was viable for research. The exclusions were trip data for which public transit was not an option, data for which ambulatory information was not available for a particular rider, no shows, and canceled trips. There were also some trip data that was excluded due to a zero travel time, an unreasonable drop off arrive and/or leave or a blank drop off arrive and/or leave time. This type of data either indicated that the trip was canceled, a rider was a no-show or it was determined that the driver may have forgotten to indicate the drop off arrive and/or leave time. After the data was filtered for all criteria mentioned above, the result was 2168 trips with viable and complete data to analyze.

The data for each trip included minimum public transit time, maximum public transit time, actual Paratransit time, direct drive time, and the maximum allowable riding time. The maximum allowable riding time is defined using the formula: if direct drive time is less than 30 minutes, the actual Paratransit time should not exceed an hour and if the direct drive time is greater than 30 minutes, the actual Paratransit time should not exceed twice the direct drive time. Also, other data that was included for each ride was whether or not it was a shared ride, if the rider was ambulatory, and if the rider needed a wheelchair.

Each data set of Minimum Public Transit Time, Maximum Public Transit Time, Actual Paratransit Time and Maximum Allowable Ride Time for each ride was determined not to fit a Normal Distribution. Please see graphs in Appendix B for Normality Tests and Histograms for each Minimum Public Transit, and Actual Paratransit. These tests excluded values greater than 100 minutes for Minimum Public Transit, values greater than 150 for Maximum Public Transit, and greater than 80 minutes for Actual Paratransit as these values were not necessary in determining the distribution of the data sets. Even though the datasets did not fit the Normal Distribution, it was determined that hypothesis testing could still be used to properly analyze and conclude with what options THE RIDE may have to change their system and perhaps lower costs by using more share rides.

This determination was concluded from the clause that although the population is assumed to be normally distributed, in practice, it has been found that as long as the sample size is not very small and the population is not very skewed, the *t* distribution gives a good approximation to the sampling distribution of the average difference D, (Levine et al., 2001). By increasing the number of shared rides, it could, however, increase ride times and may in turn lower customer satisfaction.

Hypothesis testing usually begins with some theory, claim, or assertion about a particular parameter of a population. The hypothesis that the population parameter is equal to the claimed value is referred to as the *null hypothesis*. In this case, the null hypothesis is that the difference of means of each population is equal to a certain value. The *alternative hypothesis* is must be true if the null hypothesis is not. In each case described below, the difference of means is equal to X – Y = D. It was then determined what D might equal and that would be the null hypothesis. Next it was decided if D would be greater than each value it was set equal to in the null hypothesis, concluding with the alternative hypothesis. Hypothesis testing is designed so that the rejection of the null hypothesis is based on evidence from the sample that the alternative hypothesis is far more likely to be true (Levine, et al., 2001).

There were several hypothesis tests run to determine how well THE RIDE is performing relative to the public transit system run by the MBTA and to the maximum allowable riding time. The tests were performed for all data, for all single rides and for all shared rides at a 99% confidence interval. All hypothesized values are in minutes.

For all data, both single rides and shared rides, hypothesis testing was run using Excel 2007's t-test: Paired Two Samples for Means and Minitab 15.1.0.0's Paired t-Test. Running these tests took only seconds and each software program provided the same results with different formats and statistical values that were useful when determining whether the test was run correctly and interpreting the results. This is shown in Appendix C, D, and E for All Data, Single Rides, and Shared Rides, respectively.

The confidence level for all of the hypotheses tests performed is 99% or $\alpha = 0.005$. The results from Minitab include N, the mean, the standard deviation and the standard error of the mean for each data set and the lower bound of the mean difference for the 99% confidence level. The Excel results give the mean, variance, and number of observations for each data set and the Pearson Correlation, Hypothesized Mean Difference, the degrees of freedom (df), the t Stat, the P(T<=t) one-tail, the t Critical one-tail, the P(T<=t) two-tail and the t Critical two tail values for the test. The output from Excel and MINITAB was used to verify the results of both as well as supplement the output with one another.

2.1. All Data Analysis and Results

I. The following three hypotheses tests were performed for all data.

Let X – Y = D, X and Y defined for each test and let N = 2168 for each test.

i. Let X = Minimum Public Transit Time. Let Y = Actual Paratransit Time.
$H_O : \mu_D = 11$
$H_A : \mu_D > 11$

ii. Let X = Maximum Public Transit Time. Let Y = Actual Paratransit Time.
$H_O : \mu_D = 24$
$H_A : \mu_D > 24$

iii. Let X = Maximum Allowable Ride Time. Let Y = Actual Paratransit Time.
$H_O : \mu_D = 28$
$H_A : \mu_D > 28$.

All data included 2168 viable rides per the data management discussed previously. For all data hypothesis tests, the results are shown in Appendix C. In the hypothesis test I.i., for Minimum Public Transit Time vs. Actual Paratransit Time it can be seen that the T-Value is 3.84 and the P-Value us 0.00. That is, on a Normal Distribution, the T-Value 2.3263 has about 99% of values under the Normal Distribution to the left of it and only about 1% of values to the right of it. With a T-Value of 3.84, it is determined that the percentage of values to the right is equal to the P-Value and ultimately equal to zero. With these results, it can be concluded that we reject the null hypothesis that $\mu_D = 11$ and accept the alternative hypothesis, $H_A : \mu_D > 11$. To express these statistical results in terms of the test shown here, it can be seen that it is accepted that the mean difference is greater than 11 minutes between Minimum Public Transit Time and Actual Paratransit Time. This means that on the average Actual Paratransit is 11 minutes faster than the fastest Public Transit route.

Following the same values in the rest of the testing for all data, in hypothesis test I.ii., it is concluded that Actual Paratransit Time is 24 minutes faster than Maximum Public Transit Time; I.iii., it is concluded that; I.iii., it is concluded that Actual Paratransit Time exceeded the expectation of the Maximum Allowable Ride Time rule by 28 minutes.

2.2. Single Ride Data Analysis and Results

II. The following three hypotheses tests were performed for all single rides completed.

Let $X - Y = D$, X and Y defined for each test and let $N = 1290$.

i. Let X = Minimum Public Transit Time. Let Y = Actual Paratransit Time.

$H_O : \mu_D = 16$

$H_A : \mu_D > 16$

ii. Let X = Maximum Public Transit Time. Let Y = Actual Paratransit Time.

$H_O : \mu_D = 28$

$H_A : \mu_D > 28$

iii. Let X = Maximum Allowable Ride Time. Let Y = Actual Paratransit Time.

$H_O : \mu_D = 34$

$H_A : \mu_D > 34$.

Out of the 2168 total rides, there were 1290 single rides. For the single ride data, the following can be concluded based on the output found in Appendix D: II.i.: Actual Paratransit is 16 minutes faster than the Minimum Public Transit; III.ii.: Actual Paratransit Time is 28 faster than Maximum Public Transit Time; III.iii.: Direct Drive Time is 23 minutes faster than Actual Paratransit Time and; III.iv.: Actual Paratransit Time exceeded the expectations of the Maximum Allowable Ride Time rule by 19 minutes.

2.3. Shared Ride Data Analysis and Results

III. The following three hypotheses tests were performed for all shared rides completed.

Let $X - Y = D$, X and Y defined for each test and let $N = 878$.

i. Let X = Minimum Public Transit Time. Let Y = Actual Paratransit Time.

$H_O : \mu_D = 3$

$H_A : \mu_D > 3$

ii. Let X = Maximum Public Transit Time. Let Y = Actual Paratransit Time.

$H_O : \mu_D = 16$

$H_A : \mu_D > 16$

iii. Let X = Maximum Allowable Ride Time. Let Y = Actual Paratransit Time.

$H_O : \mu_D = 19$

$H_A : \mu_D > 19$.

Out of the 2,168 total rides, there were 878 shared rides. For the shared ride data, the following can be concluded based on the output found in Appendix E: III.i.: Actual Paratransit is 3 minutes faster than the Minimum Public Transit; II.ii.: Actual Paratransit Time is 16 faster than Maximum Public Transit Time and; II.iii.: Actual Paratransit Time exceeded expectations of the Maximum Allowable Ride Time rule by 34 minutes.

2.4. Actual Paratransit Time vs. Direct Drive Time

Upon graphing Actual Paratransit Time vs. Direct Drive Time, it can be seen visually in Appendix F, that Actual Paratransit Time is generally greater than the Direct Drive Time Required. The circles in black represent all rides' Actual Paratransit Time vs. Direct Drive Time and the squares in red represent the Maximum Allowable Riding Times. This was discussed previously where the Actual Paratransit Time should not exceed 60 minutes if the Direct Drive Time required is less than 30 minutes and should not exceed two times the Direct Drive Time required if the Direct Drive Time is greater than 30 minutes. It can be seen that there are not a significant amount of Actual Paratransit Time that exceeds the Maximum Allowable Time and is calculated to be about 6.27% of all rides. Of Single Rides, Actual Paratransit Time exceeds the Maximum Allowable Time 1.78% of the time and of Shared Rides, Actual Paratransit Time exceeds the Maximum Allowable Time 12.87% of the time.

This difference can be explained because when there are shared rides, it requires longer riding times for some passengers. For an example, Rider A may be picked up at his or her origin location and before reaching his or her destination, the driver may pick up Rider B. If Rider B is dropped off before Rider A, Rider A has spent more riding time in the vehicle than he or she would have had it been a single ride where Rider A would have gone directly from his or her origin location to his or her destination.
Overall, the 6.27% of rides being over the Maximum Allowable Time is not very many rides considering the amount of rides completed per day. In total for this particular day, it represents 136 rides out of 2168 of the rides in our data set.

3. Concluding Remarks

In comparing the Actual Paratransit Time to the Minimum and Maximum Public Transit Time and to the Maximum Allowable Ride Time, it can be concluded that THE RIDE is exceeding expectations by both being better or comparable to the public transit provided, having very low late rates, and having a low rate of exceeding the maximum allowable riding time. In all cases, the average riding times were faster than taking the average public transit being it the Minimum Public Transit Time or the Maximum Public Transit Time and the average riding times were significantly less than the Maximum Allowable Ride Times.

There are some adjustments THE RIDE could make in order to decrease costs. Since the rides that are provided are exceeding expectations and in some cases very considerably exceeding them it can be determined that customer satisfaction is high and costs are high. In order to lower cost, there may be some impact on customer satisfaction.
That is, one way to lower costs would be to have more shared rides. More shared rides would mean employing less drivers, utilizing less vehicles, perhaps less fuel, but would also mean longer riding times in the vehicles for riders and therefore less customer satisfaction.

If one was to look at All Data and the hypothesis tests previously discussed in the Data, Analysis, and Results: All Data Analysis and Results sections, it can be seen that overall the riding times are 11 minutes faster than Minimum Public Transit Times, 24 minutes faster than Maximum Public Transit Time, and exceeds the expectation of the Maximum Allowable Ride Time rule by 28 minutes. This can be interpreted as if there is 11 minutes or even 24 minutes that THE RIDE could be using and still be within the comparative rules of the public transit in the Greater Boston area imposed by the ADA laws. In the same respect, THE RIDE is running 28 minutes better than expected with regards to the Maximum Allowable Ride Times. This means that THE RIDE and/or its Contractors could loosen up some of their constraints in their software to allow for more shared rides and perhaps lengthen riding times slightly, and could potentially save on the costs to run the program.

When looking at the Shared Ride Data, it can be seen that it is worse than both the All Data and Single Ride analysis where riding times are only better by 3 minutes against the Minimum Public Transit times and 16 minutes against the Maximum Public Transit times. Also, it is not as fast versus the Maximum Allowable Riding Time at about 19 minutes faster than the other categories. This can be explained very easily as it has been discussed previously as well. Because they are shared rides, riders endure longer riding times due to the scheduling of pickups and drop-offs that are not consecutive to each rider. It may cause concern to allow more share rides for customers, but may make sense for cutting costs as even the shared rides are exceeding expectations and is quite comparable to public transit whether be it the minimum or maximum public transit times.

In the same notion, with regards to the Single Ride Data, it can be seen that these times are significantly better than All Data and Shared Ride Data. For Single Ride Data, the overall riding times are better than Minimum and Maximum Public Transit Times by 16 minutes and 28 minutes, respectively. The Single Ride Data is running about 34 minutes better than the Maximum Allowable Riding Times. It is very clear in this case that allowing for more shared rides could lower costs while still keeping customer service intact. If this recommendation should be taken into consideration to loosen some constraints to allow for more shared rides, it would be recommended that very conservative changes are made. That way the change could come slowly and perhaps could be manipulated to have very slight changes in customer service, but could have significant cost effects.

In general, as it can be seen by the results above, THE RIDE and its contractor, Veterans, are performing very well relative to all Paratransit services compared. It is very important that THE RIDE is comparable to the public transit service provided locally as well as abiding by constraints such as the Maximum Allowable Riding Time Rules and it is clear that THE RIDE passes with flying colors.
In light of this, it is possible to lower costs while maintaining these services and perhaps another look at what might be able to be changed would be worthwhile.

<u>4. References</u>

Barnum, Darold T., Gleason, John M. and Hemily, Brendon (2007), "Using Panel Data Analysis to Estimate Confidence Intervals for the DEA Efficiency of Individual Urban Paratransit Agencies," *UIC Great Cities Institute*, Publication Number GCP-07-10. Chicago, IL, UIC Great Cities Institute.

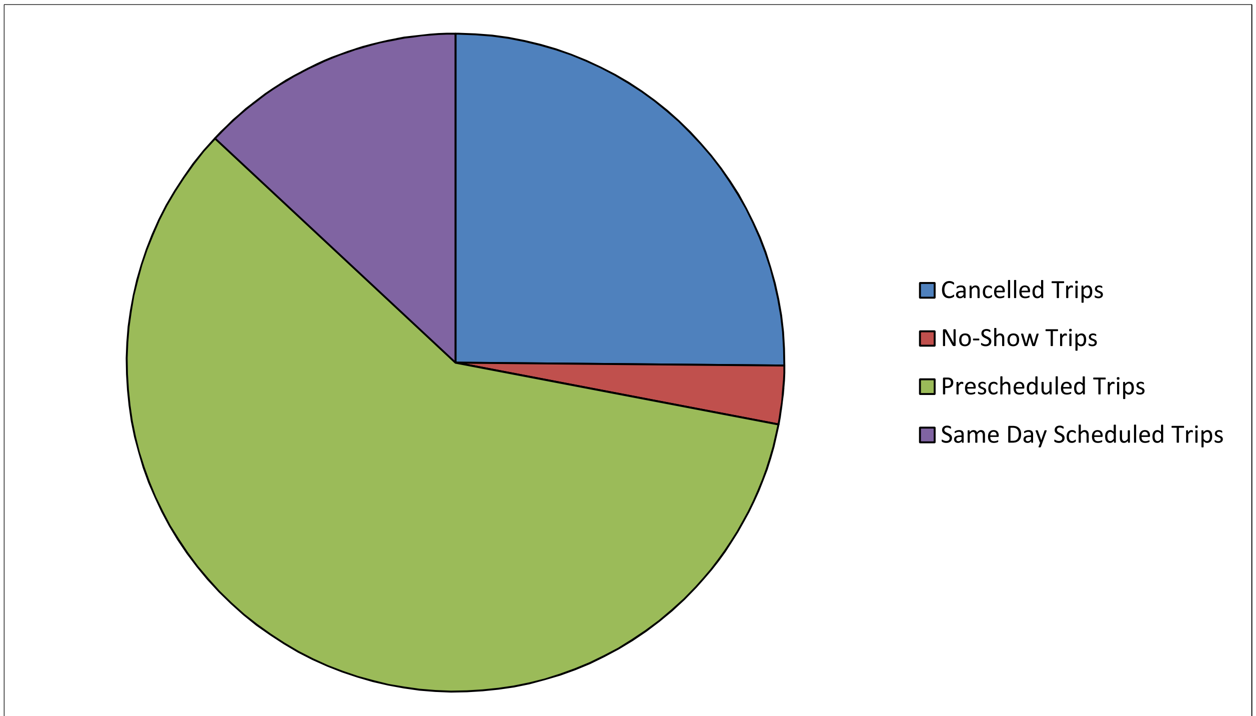
Fu, Liping, Yang, Jingtao and Casello, Jeff (2007), "Quantifying Technical Efficiency of Paratransit Systems by Data Envelopment Analysis Method," *Journal of the Transportation Research Board*, Vol. 2034, pp. 115-122.

Lave, Roy and Rosemary, Mathias (2000), "State of the Art of Paratransit," *Transportation in the New Millennium*, Washington, DC: Transportation Research Board.

Levine, David M., Patricia P. Ramsey, and Robert K. Smith (2001), *Applied Statistics For Engineers and Scientists Using Microsoft Excel and MINITAB*, Upper Saddle River, New Jersey: Prentice-Hall, Inc.

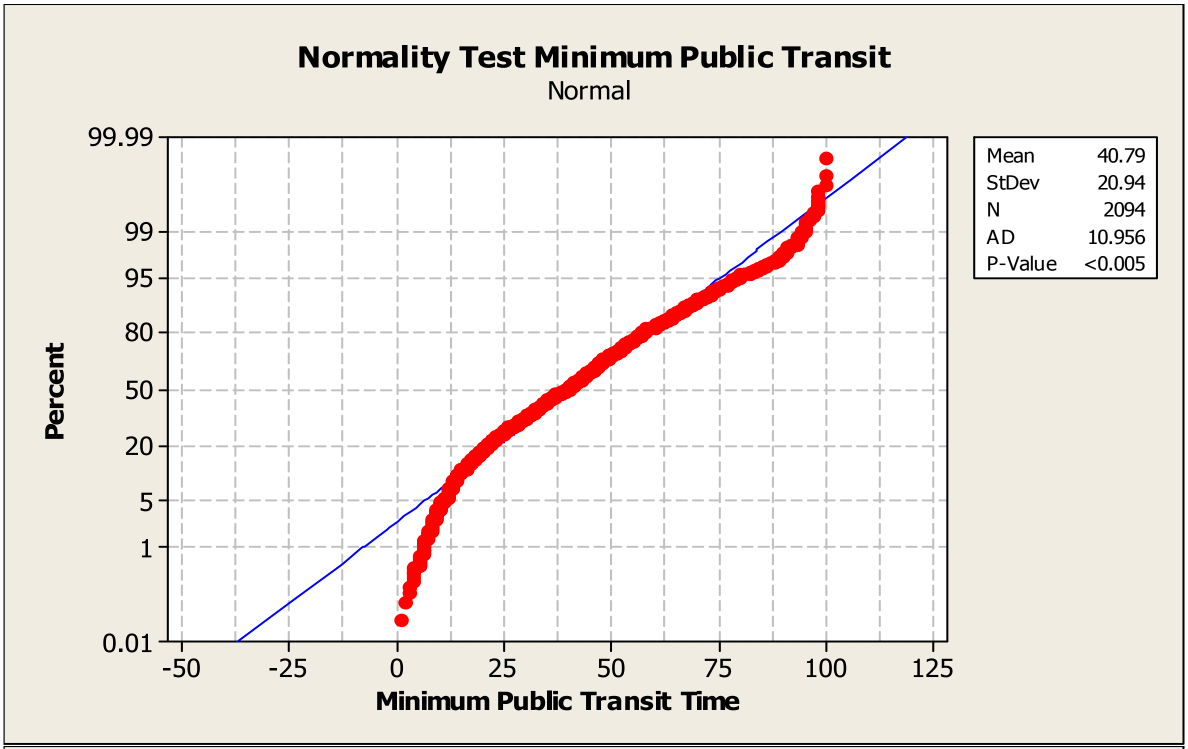
Massachusetts Bay Transportation Authority (2009), *THE RIDE GUIDE R2.0.*, Boston: MBTA-OTA Office for Transportation Access.

Appendix A

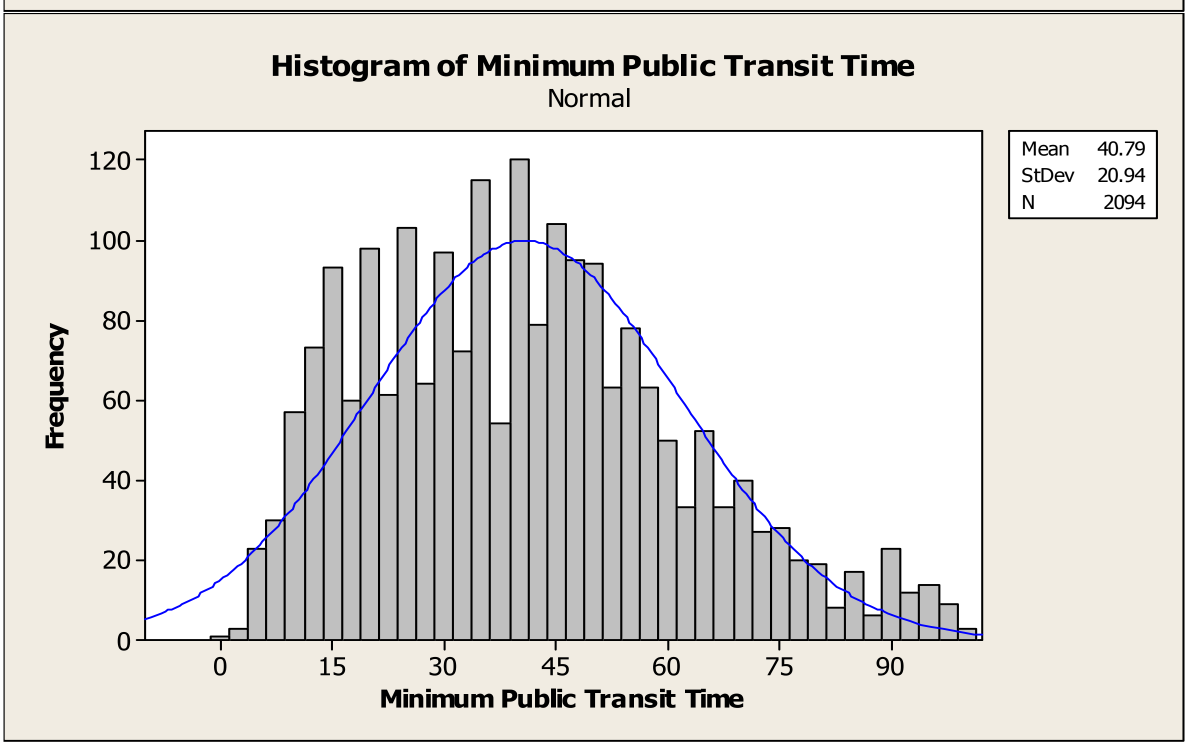


Cancelled Trips	**836**
No-Show Trips	**95**
Prescheduled Trips	**1960**
Same Day Scheduled Trips	**434**

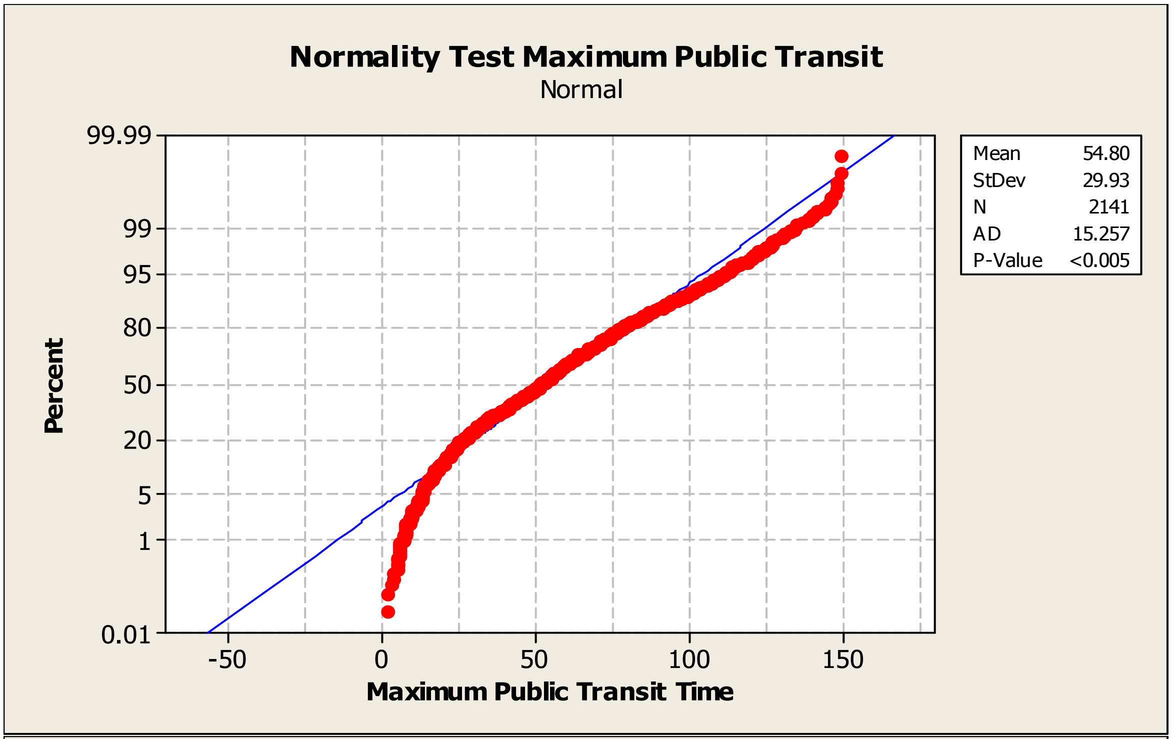
Appendix B

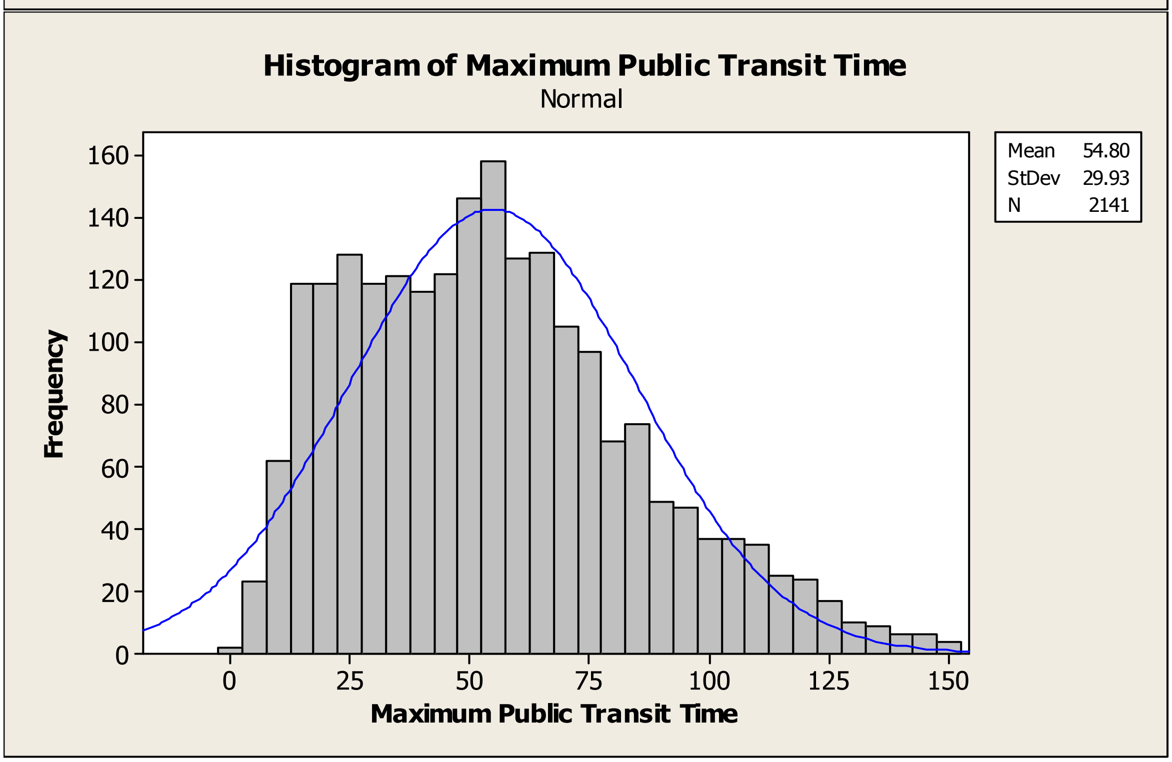


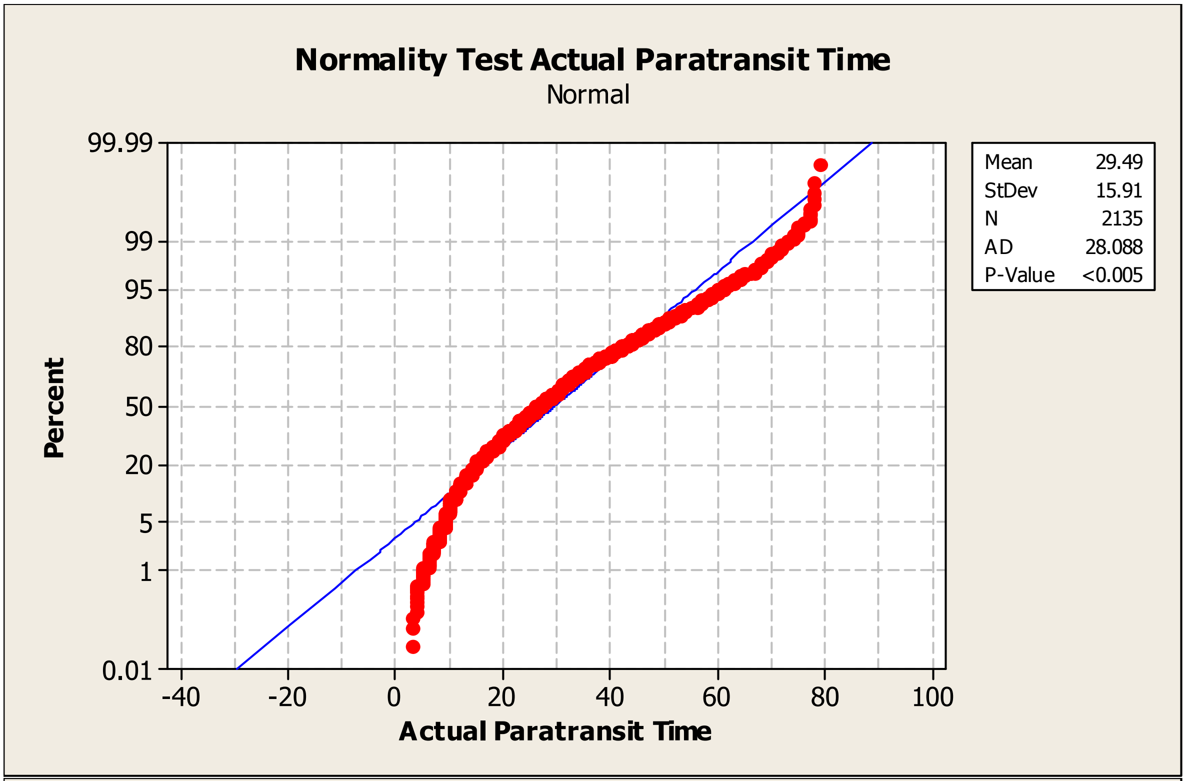
Normality Test Minimum Public Transit
Normal
Percent
99.99
99
95
80
50
20
5
1
0.01
-50
-25
0
25
50
75
100
125
Minimum Public Transit Time
Mean 40.79
StDev 20.94
N 2094
AD 10.956
P-Value <0.005

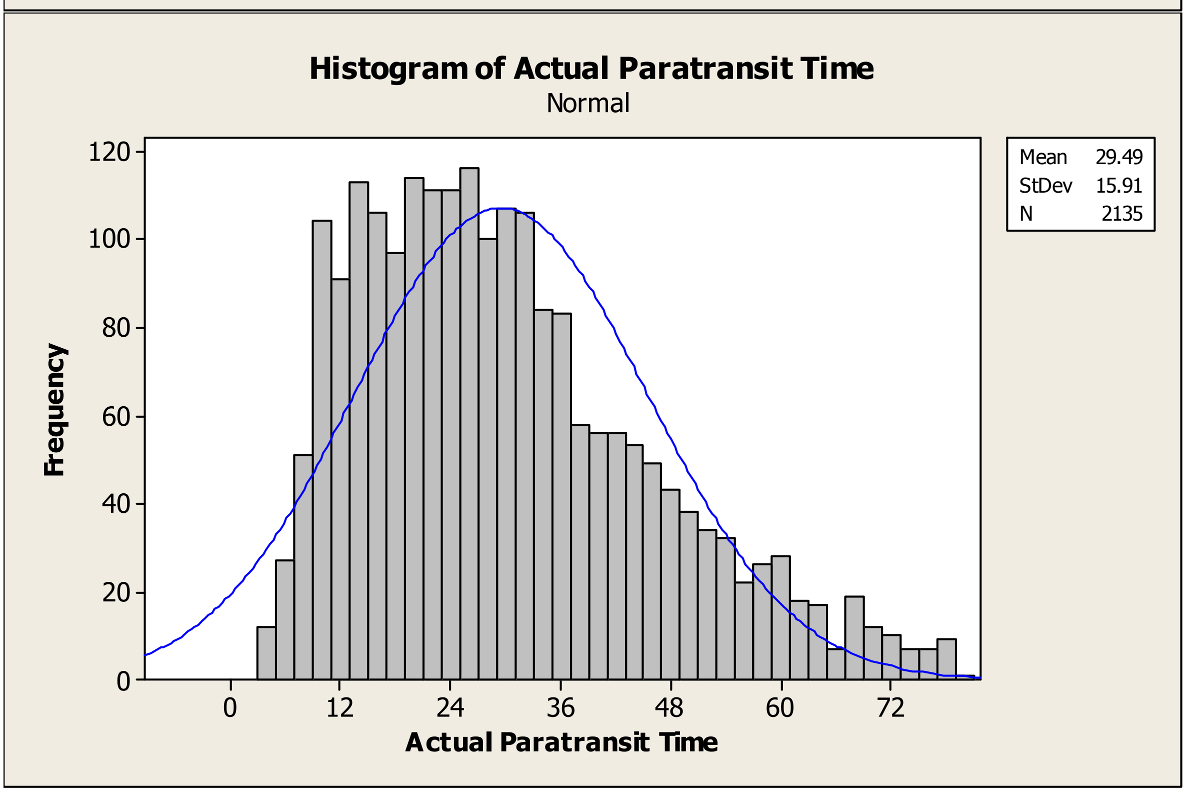


Histogram of Minimum Public Transit Time
Normal
Frequency
120
100
80
60
40
20
0
0
15
30
45
60
75
90
Minimum Public Transit Time
Mean 40.79
StDev 20.94
N 2094


Normality Test Maximum Public Transit
Normal
Mean 54.80
StDev 29.93
N 2141
AD 15.257
P-Value <0.005
Percent
99.99
99
95
80
50
20
5
1
0.01
-50
0
50
100
150
Maximum Public Transit Time


Histogram of Maximum Public Transit Time
Normal
Mean 54.80
StDev 29.93
N 2141
Frequency
160
140
120
100
80
60
40
20
0
0
25
50
75
100
125
150
Maximum Public Transit Time


Normality Test Actual Paratransit Time
Normal
Percent
99.99
99
95
80
50
20
5
1
0.01
-40
-20
0
20
40
60
80
100
Actual Paratransit Time
Mean 29.49
StDev 15.91
N 2135
AD 28.088
P-Value <0.005


Histogram of Actual Paratransit Time
Normal
Frequency
120
100
80
60
40
20
0
0
12
24
36
48
60
72
Actual Paratransit Time
Mean 29.49
StDev 15.91
N 2135

Appendix C

Paired T for Min Public Transit - Actual Paratransit Time

	N	Mean	StDev	SE Mean
Min Public Transit	2168	43.426	25.163	0.54
Actual Paratransit	2168	30.503	17.902	0.384
Difference	2168	12.932	23.294	0.5

99% lower bound for mean difference: 11.758
T-Test of mean difference = 11 (vs > 11): T-Value = 3.84 P-Value = 0.000

t-Test: Paired Two Sample for Means

	Variable 1 - Min Pub Trans	*Variable 2 -Actual Paratransit*
Mean	43.42573801	30.50322878
Variance	633.1573806	320.4734552
Observations	2168	2168
Pearson Correlation	0.456205958	
Hypothesized Mean Difference	11	
df	2167	
t Stat	3.842786119	
P(T<=t) one-tail	6.25727E-05	
t Critical one-tail	2.578099976	
P(T<=t) two-tail	0.000125145	
t Critical two-tail	2.809912003	

Paired T for Max Public Transit - Actual Paratransit Time

	N	Mean	StDev	SE Mean
Max Public Transit	2168	56.496	34.27	0.736
Actual Paratransit	2168	30.503	17.902	0.384
Difference	2168	25.993	30.969	0.665

99% lower bound for mean difference: 24.444
T-Test of mean difference = 24 (vs > 24): T-Value = 3.00 P-Value = 0.001

t-Test: Paired Two Sample for Means

	Variable 1 - Max Pub Trans	*Variable 2 - Actual Paratransit*
Mean	56.49584871	30.50322878
Variance	1174.446683	320.4734552
Observations	2168	2168
Pearson Correlation	0.436696063	
Hypothesized Mean Difference	24	
df	2167	
t Stat	2.995870105	
P(T<=t) one-tail	0.001383831	
t Critical one-tail	2.578099976	
P(T<=t) two-tail	0.002767662	
t Critical two-tail	2.809912003	

Paired T for Rules for Max Paratransit Time - Actual Paratransit Time

	N	Mean	StDev	SE Mean
Rules for Max Paratransit Time	2168	60.07	0.7	0.015
Actual Paratransit	2168	30.503	17.902	0.384
Difference	2168	29.567	17.828	0.383

99% lower bound for mean difference: 28.675
T-Test of mean difference = 28 (vs > 28): T-Value = 4.09 P-Value = 0.000

t-Test: Paired Two Sample for Means

	Variable 1 - Rules for Max Paratransit	*Variable 2 - Actual Paratransit*
Mean	60.0701107	30.50322878
Variance	0.489775345	320.4734552
Observations	2168	2168
Pearson Correlation	0.124995861	
Hypothesized Mean Difference	28	
df	2167	
t Stat	4.092301428	
P(T<=t) one-tail	2.21376E-05	
t Critical one-tail	2.578099976	
P(T<=t) two-tail	4.42752E-05	
t Critical two-tail	2.809912003	

Appendix D

Paired T for Min Public Transit - Actual Paratransit Time

	N	Mean	StDev	SE Mean
Min Public Transit	1290	42.656	25.111	0.699
Actual Paratransit	1290	24.649	13.159	0.366
Difference	1290	18.007	20.729	0.577

99% lower bound for mean difference: 16.663
T-Test of mean difference = 16 (vs > 16): T-Value = 3.48 P-Value = 0.000

t-Test: Paired Two Sample for Means

	Variable 1 - Min Pub Transit	*Variable 2 - Actual Paratransit*
Mean	42.65581395	24.64883721
Variance	630.5796597	173.1558753
Observations	1290	1290
Pearson Correlation	0.565964506	
Hypothesized Mean Difference	16	
df	1289	
t Stat	3.477381253	
P(T<=t) one-tail	0.000261594	
t Critical one-tail	2.579648826	
P(T<=t) two-tail	0.000523188	
t Critical two-tail	2.811875655	

Paired T for Max Public Transit - Actual Paratransit Time

	N	Mean	StDev	SE Mean
Max Public Transit	1290	55.011	32.835	0.914
Actual Paratransit	1290	24.649	13.159	0.366
Difference	1290	30.362	27.86	0.776

99% lower bound for mean difference: 28.555
T-Test of mean difference = 28 (vs > 28): T-Value = 3.05 P-Value = 0.001

t-Test: Paired Two Sample for Means

	Variable 1 - Max Pub Transit	*Variable 2 - Actual Paratransit*
Mean	55.01085271	24.64883721
Variance	1078.106942	173.1558753
Observations	1290	1290
Pearson Correlation	0.549763198	
Hypothesized Mean Difference	28	
df	1289	
t Stat	3.045033339	
P(T<=t) one-tail	0.001186866	
t Critical one-tail	2.579648826	
P(T<=t) two-tail	0.002373731	
t Critical two-tail	2.811875655	

Paired T for Rules for Max Paratransit Time - Actual Paratransit Time

	N	Mean	StDev	SE Mean
Rules for Max Paratransit	1290	60.076	0.689	0.019
Actual Paratransit	1290	24.649	13.159	0.366
Difference	1290	35.427	13.052	0.363

99% lower bound for mean difference: 34.581
T-Test of mean difference = 34 (vs > 34): T-Value = 3.93 P-Value = 0.000

t-Test: Paired Two Sample for Means

	Variable 1 - Rules for Max Paratransit	*Variable 2 - Actual Paratransit*
Mean	60.07596899	24.64883721
Variance	0.475217253	173.1558753
Observations	1290	1290
Pearson Correlation	0.180146608	
Hypothesized Mean Difference	34	
df	1289	
t Stat	3.927096267	
P(T<=t) one-tail	4.52645E-05	
t Critical one-tail	2.579648826	
P(T<=t) two-tail	9.05291E-05	
t Critical two-tail	2.811875655	

Paired T for Min Public Transit - Actual Paratransit Time

	N	Mean	StDev	SE Mean
Min Public Transit	878	44.557	25.209	0.851
Actual Paratransit	878	39.105	20.319	0.686
Difference	878	5.452	24.806	0.837

99% lower bound for mean difference: 3.501
T-Test of mean difference = 3 (vs > 3): T-Value = 2.93 P-Value = 0.002

t-Test: Paired Two Sample for Means

	Variable 1 - Min Pub Transit	*Variable 2 - Actual Paratransit*
Mean	44.55694761	39.1047836
Variance	635.5149973	412.8784035
Observations	878	878
Pearson Correlation	0.422715869	
Hypothesized Mean Differer	3	
df	877	
t Stat	2.929160015	
P(T<=t) one-tail	0.001743422	
t Critical one-tail	2.581446873	
P(T<=t) two-tail	0.003486844	
t Critical two-tail	2.814155654	

Paired T for Max Public Transit - Actual Paratransit Time

	N	Mean	StDev	SE Mean
Max Public Transit	878	58.68	36.19	1.22
Actual Paratransit	878	39.105	20.319	0.686
Difference	878	19.57	34.05	1.15

99% lower bound for mean difference: 16.89
T-Test of mean difference = 16 (vs > 16): T-Value = 3.11 P-Value = 0.001

t-Test: Paired Two Sample for Means

	Variable 1 - Max Pub Transit	*Variable 2 - Actaul Paratransit*
Mean	58.67767654	39.1047836
Variance	1309.374894	412.8784035
Observations	878	878
Pearson Correlation	0.382570761	
Hypothesized Mean Differer	16	
df	877	
t Stat	3.108848584	
P(T<=t) one-tail	0.000969397	
t Critical one-tail	2.581446873	
P(T<=t) two-tail	0.001938795	
t Critical two-tail	2.814155654	

Appendix E

Paired T for Rules for Max Paratransit Time - Actual Paratransit Time

	N	Mean	StDev	SE Mean
Rules for Max Paratransit	878	60.062	0.715	0.024
Actual Paratransit	878	39.105	20.319	0.686
Difference	878	20.957	20.254	0.684

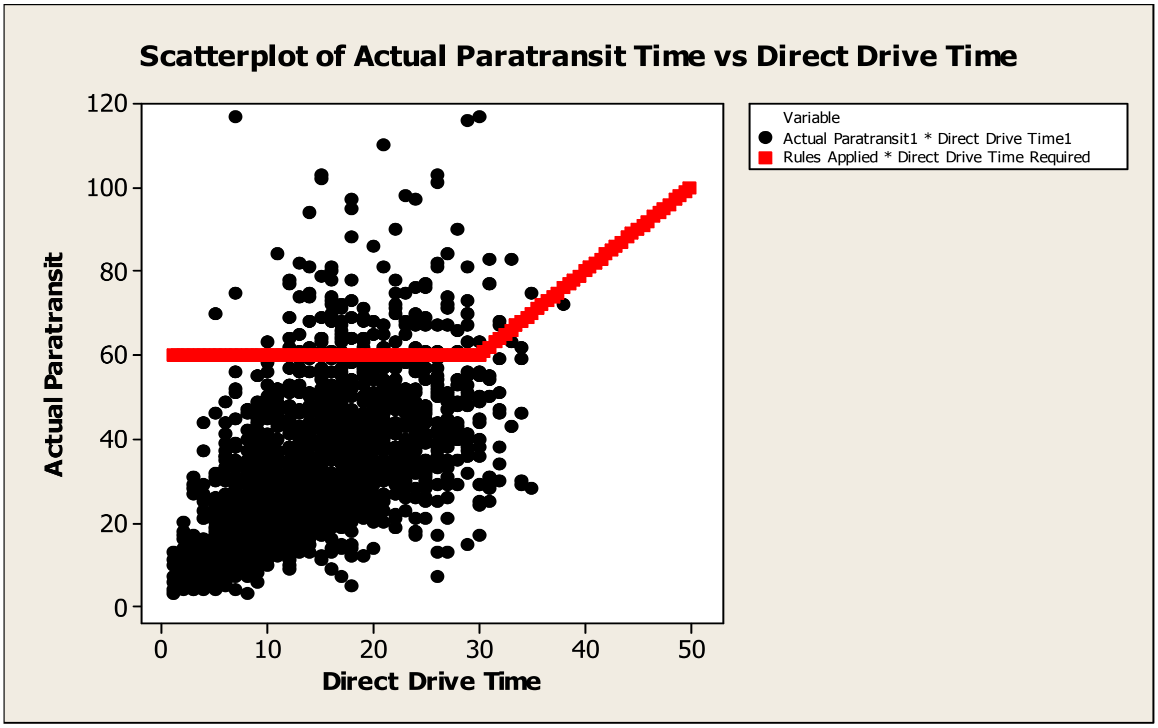
99% lower bound for mean difference: 19.364

T-Test of mean difference = 19 (vs > 19): T-Value = 2.86 P-Value = 0.002

t-Test: Paired Two Sample for Means

	Variable 1 - Rules for Max Paratransit	*Variable 2 - Actual Paratransit*
Mean	60.06150342	39.1047836
Variance	0.511606403	412.8784035
Observations	878	878
Pearson Correlation	0.109550166	
Hypothesized Mean Differer	19	
df	877	
t Stat	2.86269502	
P(T<=t) one-tail	0.002150299	
t Critical one-tail	2.581446873	
P(T<=t) two-tail	0.004300598	
t Critical two-tail	2.814155654	

Appendix F



Scatterplot of Actual Paratransit Time vs Direct Drive Time
Actual Paratransit
Direct Drive Time
0
20
40
60
80
100
120
0
10
20
30
40
50
Variable
Actual Paratransit1 * Direct Drive Time1
Rules Applied * Direct Drive Time Required