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Journal of Transportation Management

Volume 24 | Issue 1 Article 5

4-1-2013

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Recommended Citation

Melachrinoudis, Emanuel, Min, Hokey, & Selneck, Candace. (2013). A decision support system for developing the managerial policy of urban paratransit services: A case study of the Massachusetts Bay Transit Authority. Journal of Transportation Management, 24(1), 37-62. doi: 10.22237/jotm/1364774640

A DECISION SUPPORT SYSTEM FOR DEVELOPING THE MANAGERIAL POLICY OF URBAN PARATRANSIT SERVICES: A CASE STUDY OF THE MASSACHUSETTS BAY TRANSIT AUTHORITY

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ABSTRACT

In the wake of the Americans with Disability Act (ADA) of 1990, paratransit services were offered to improve mobility, employment opportunities, and access to community services for individuals who are mentally or physically handicapped. Due to the complexity involved in ADA rules and transportation regulations as well as the customized, on-demand service requirements, paratransit services are far more costly to render than fixed-route based mass transit services. In times of ongoing budget crisis among public entities, many public transit authorities cope with a dilemma of meeting the growing demand and complex service requirements, while controlling rising paratransit costs. Considering this dilemma, this paper proposes a decision support system (DSS) that can aid the mass transit authority in evaluating paratransit service performance, while continually improving performance over time. To validate the usefulness of the proposed DSS, it has been applied to the actual case of the Massachusetts Bay Transit Authority (MBTA).

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 allowed passengers who cannot use regular public transportation services due to their physical, cognitive, or mental disability to use alternative paratransit services complementary to the fixed route services already in place. Such paratransit was not mandated by law until 1990, 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 which 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. Such comparability is determined by six service criteria: (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 state that if an entity operates a fixed route system (other than a system which provides solely commuter bus service) but fails to provide paratransit and other special transportation services to these individuals, it is considered to be discriminatory against individuals with disabilities. This includes individuals who use wheelchairs. These individuals should be allowed to use 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 such as the Massachusetts Bay Transit Authority (MBTA) running a fixed route system must provide a comparable service area of ½ mile surrounding each of the fixed rail or bus routes. 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 ADA states that prices to its customers must be comparable to that of the public transit already in existence. Since the public transit fare is usually quite low, the state and municipal governments that typically finance the public transit system need 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, 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. For example, fares covered less than 4% of the MTA New York City Transit's operating expenses (Lowenstein, 2006). 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 given crude oil prices in the range of $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 time 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 (Lave and Rosemary, 2000; Min, 2011) recognized 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. Other studies such as Fu, Yang and Cosello (2007) and Min and Lambert (2010) evaluated the comparative performance of individual paratransit systems to identify "best practice" (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 better quality of service (Fu, Yang and Cosello, 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, Gleason and Brendon, 2007). The studies discussed above were taken into consideration in deciding what analysis would be appropriate for the historical data provided by the MBTA's THE RIDE Paratransit system in the Greater Boston area.

MBTA's THE RIDE

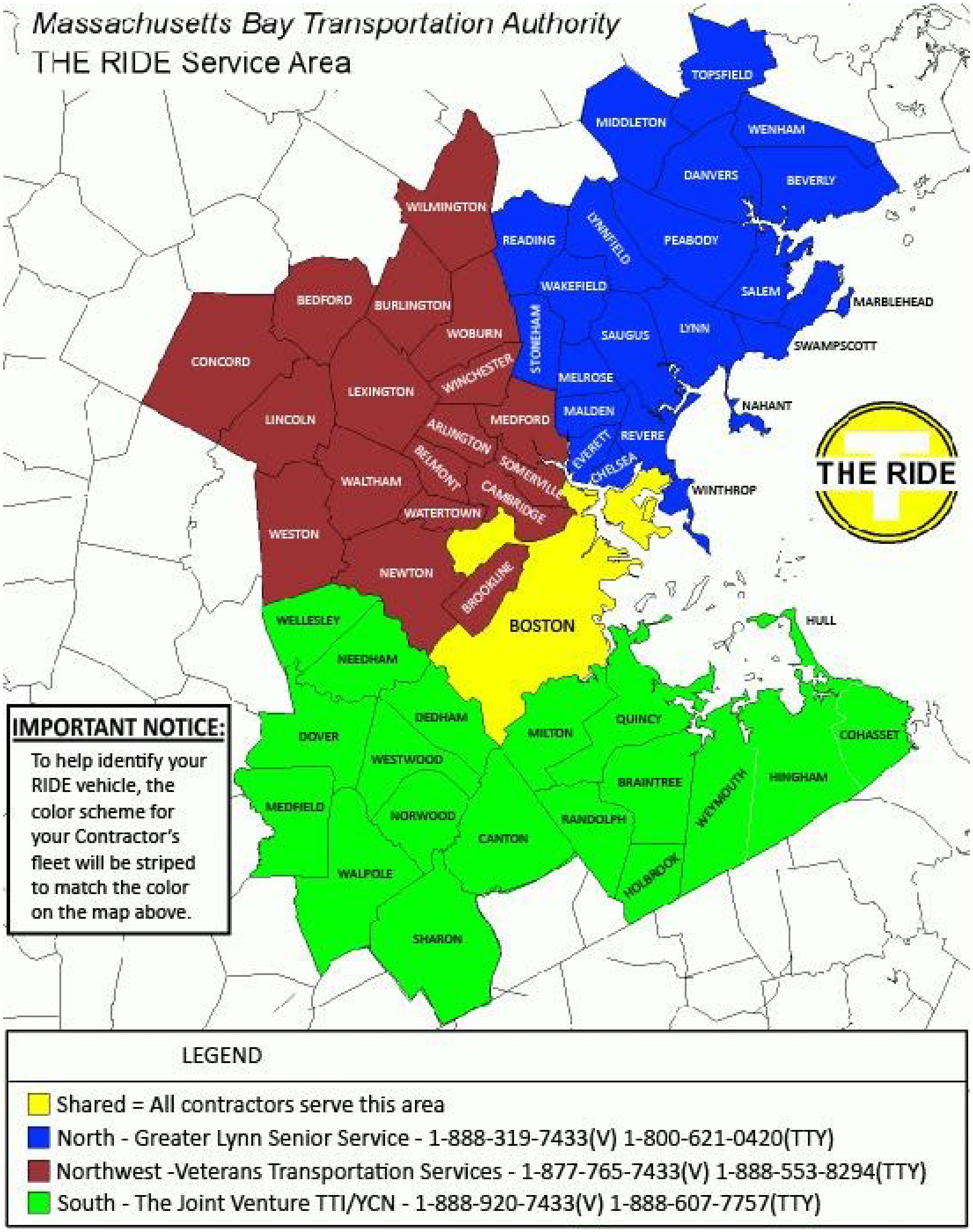
The Massachusetts Bay Transit Authority's (MBTA) THE RIDE is the paratransit system in place in the Greater Boston Metropolitan area in Massachusetts. THE RIDE program is an advanced notice, shared-ride, door-to-door paratransit program for persons with disabilities adhering to the ADA's rules and regulations. 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. 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 contracted service providers: (1) Greater Lynn Senior Services; (2) Veterans Transportation Services; and (3) the Joint Venture. THE RIDE uses these three contractors to meet its obligations to provide paratransit service. 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 ADA requirements. The map below depicts the service area for each contractor with different shades~~colors~~. 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.

The cities and towns covered by the MBTA's THE RIDE in the four service areas are as follows (see Figure 1). (1) North of Boston: Beverly, Chelsea, Danvers, Everett, Lynn, Lynnfield, Malden, Marblehead, Melrose, Middleton, Nahant, Peabody, Reading, Revere, Salem, Saugus, Stoneham, Swampscott, Topsfield, Wakefield, Wenham, and Winthrop. (2) Northwest of Boston: Arlington, Bedford, Belmont, Brookline, Burlington, Cambridge, Concord, Lexington, Lincoln, Medford, Newton, Somerville, Waltham, Watertown, Weston, Wilmington, Winchester and Woburn. (3) South of Boston: Braintree, Canton, Cohasset, Dedham, Dover, Hingham, Holbrook, Hull, Medfield, Milton, Needham, Norwood, Quincy, Randolph, Sharon, Walpole, Westwood, and Weymouth. (4) 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 more than 60 towns and communities, THE RIDE also has cooperative agreements with the Brockton Area Transit and with the MetroWest Regional Transit Authority

FIGURE 1
THE RIDE SERVICE AREA



IMPORTANT NOTICE:

To help identify your RIDE vehicle, the color scheme for your Contractor's fleet will be striped to match the color on the map above.

LEGEND

🟨 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)

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 service 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 operated by the Greater Lynn Senior Services can 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 a case.

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

- Prevents them from traveling to or from fixed route stops or stations;
- Does not allow them to use a bus route or rail station for a particular route or station;
- Does not allow them to "navigate" the systems without others' assistance.

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.
- A written notice must be given, once the decision on eligibility has been made. This notice includes the disclosure of specific reasons for denial or limit. This notice should also describe how the applicants can appeal the decision.
- An appeal process is required. Appellants must be given the opportunity to be heard in person and can 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. An appeal must be accepted within at least 60 days after the notice of the initial decision. That appeal must be decided within 30 days of the appeal hearing.

All drivers receive sensitivity and safety training so that they can 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 the rider carry a manageable number of shopping bags to the door step of a rider's residence. This door-to-door service is customer-centric as it provides customized personal assistance. This assistance, however, creates less efficiency than a standard service. For example, 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 Mobile Data Computers (MDC's) which contain a global positioning system (GPS); it disables touch screen while driving and has a radio for emergency situations. It also has Auto Vehicle Locators (AVL's) that provide more accurate routes and data as well as lessen the radio time being used by each driver. This equipment provides the rider with a much more pleasant and safer trip. In addition, the AVL's provide the operators with real time vehicle location which makes it easier for the operators to alter a driver's route without his/her knowledge of a change. This control can be helpful due to the real time knowledge of whereabouts of the contractor's vehicles at any given time. The AVL can be further 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.

The routing system is able to provide trip schedules based on a rider's requests. Once at 4 p.m. on the day before a deadline passes, a specialized routing program developed by Strategen Inc. schedules the trips for each contractor. There are a few common constraints by which each contractor must comply. These constraints include riding time, 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 9:00 a.m. The parameter is to arrive at the location by 9:00 am, but a contractor may set up a parameter in the software that requires the drop off at the location to be fifteen minutes before the required time so that the rider is not late for his/her appointment. The riding time constraints ensure that for a trip that takes less than 30 minutes to complete (direct time), the rider will not be in the vehicle for more than 60 minutes. If the trip takes more than 30 minutes to complete, the rider should 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 needs of equipment (e.g., wheelchairs, scooters, and walkers) and service animals. Also, a rider must specify if he or she has a Personal Care Assistant (PCA) or a guest riding with him/her. The PCA can ride free of charge. PCA's and the guest must travel at the same time as the certified rider to and from the same destination. This information is important for the RIDE to ensure that a vehicle with appropriate equipment is dispatched to each pick up location, when routing vehicles with different types of wheelchair accessibilities.

On the day of the trip, the rider must be ready five minutes before his or her scheduled pickup and must be prepared to wait up to fifteen minutes after that time. The driver must wait for the rider for five minutes from the time of the scheduled pickup. If the rider is not at the pickup location within five minutes, the driver can obtain clearance from his/her dispatcher to leave. A rider is considered a *NO SHOW* if he or she fails to cancel his/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 minutes after the scheduled pickup time, the rider should call the Contractor for an Estimated Time of Arrival (ETA) or can reschedule his/her pickup at that time. If a driver is late 15 to 30 minutes, there is a 10% penalty of that 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 penalties force 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 promised 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 9:00 p.m. 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/she can confirm or cancel his/her trip automatically. This provides a more streamlined system and in essence lowers costs further as discussed below.

There are many cost elements associated with the RIDE. These are mobilization costs, administrative overhead expenditures, and 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 operating expenses, communications system and profit. Mobilization costs exclude any and all capital expense. Administration and overhead expenditures include all amortized and capital expenses. Operational costs include driver salaries/fringes, vehicle maintenance, vehicle insurance, fees/licenses, and so forth. These costs also include fuel cost 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 or 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.

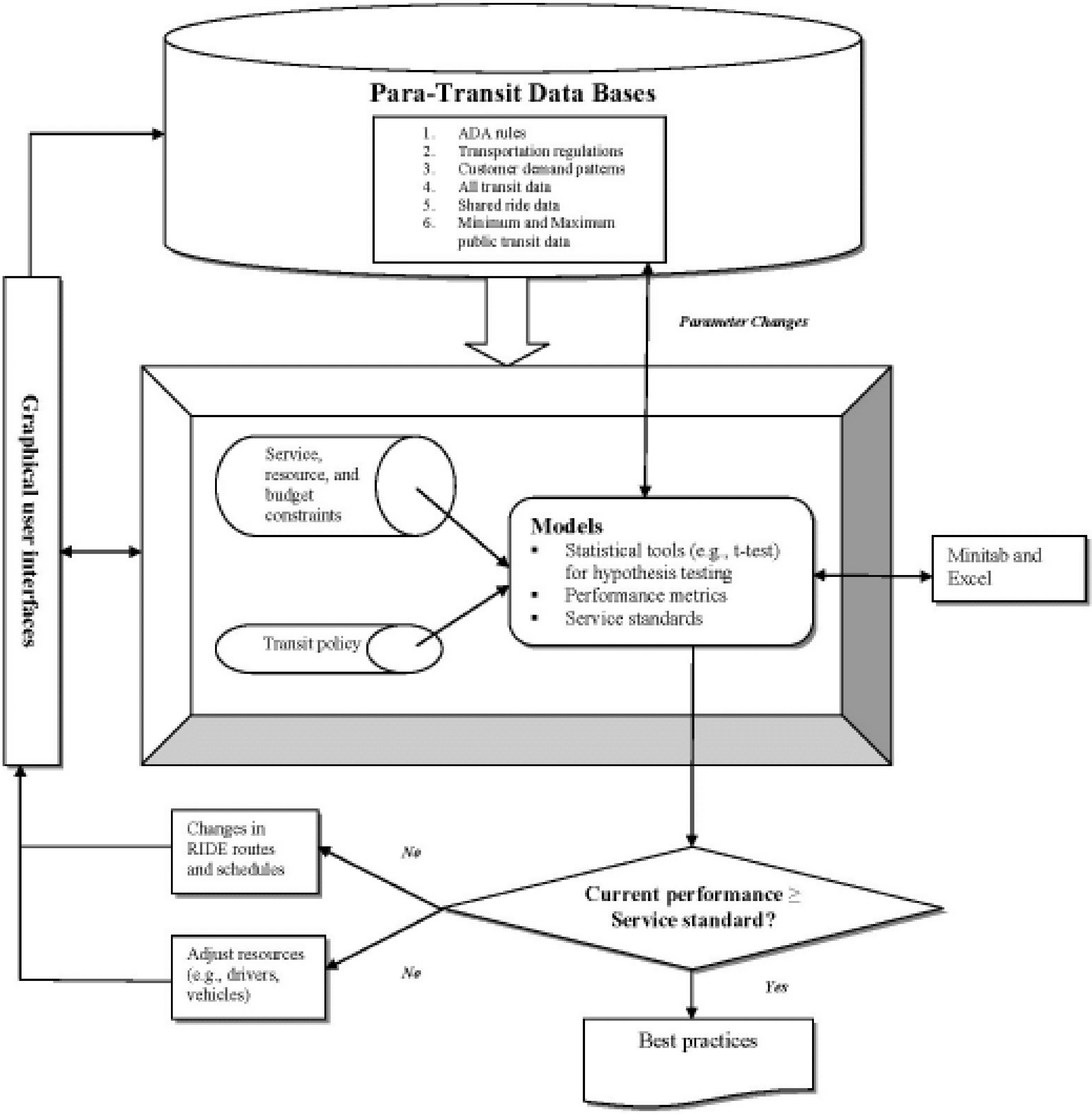
With all of these costs taken into consideration, the average net cost per passenger one way trip is $41.61 for fiscal year 2010 (July through December 2009). As one can see, the fare of $2.00 per each one way trip hardly covers the actual net cost of the trip (mere 4.8% of the operating cost). The fares that are not charged to PCA's even though a seat is taken are considered a cost that is being paid with no revenue to offset it. The aforementioned costs are also associated with the service that is provided to each rider. These services include 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 *maximum allowable riding time* is a standard used by Veterans Transportation Services to maintain the quality of paratransit services and is defined using the formula: The riding time may not exceed an hour if the direct drive time required for the trip is less than 30 minutes; else, the riding time may not exceed twice the direct drive time required if that time is greater than or equal to 30 minutes.
- Pickup times must be within 15 minutes of the promised time for the Contractor to avoid penalties. These penalties are considered savings to THE RIDE, but also incentives for providing the best customer service.
- Assistance provided by the driver includes carrying groceries to the door and 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.

DECISION SUPPORT FRAMEWORK

To deal with a constant dilemma of making a trade-off between costs and rider service requirements, a decision support system (DSS) was developed. Its basic architecture is graphically depicted in Figure 2. As Figure 2 shows, the implementation of DSS begins with the development of data bases. Once necessary data are fed into the model which will be used to gauge the efficiency (both service and cost) of current paratransit services, the model outcome will be assessed to see if the current services are of acceptable quality. If dissatisfied with the

FIGURE 2
BASIC ARCHITECTURE OF THE DECISION SUPPORT SYSEM
FOR THE RIDE



paratransit service performance, the current paratransit route structures and schedules have to be changed while considering adjusting required resources (adding drivers, working overtime, and leasing/purchasing more vehicles under budget constraints). The impact of such changes on service quality and overall costs will be evaluated based on the summary of the outcomes in visual forms such as graphs and tables.

To demonstrate the usefulness of the aforementioned DSS framework, we first collected the actual data and then analyzed such data using statistical tools. The goal was to compare the quality of paratransit services to the public transit services. Paratransit ride data were provided by the Veterans Transportation Services contractor in two separate 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 Manifest By Stop 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, and 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 given, 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 travel ~~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 help better serve the riders 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 five or more minutes and then 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 this 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.

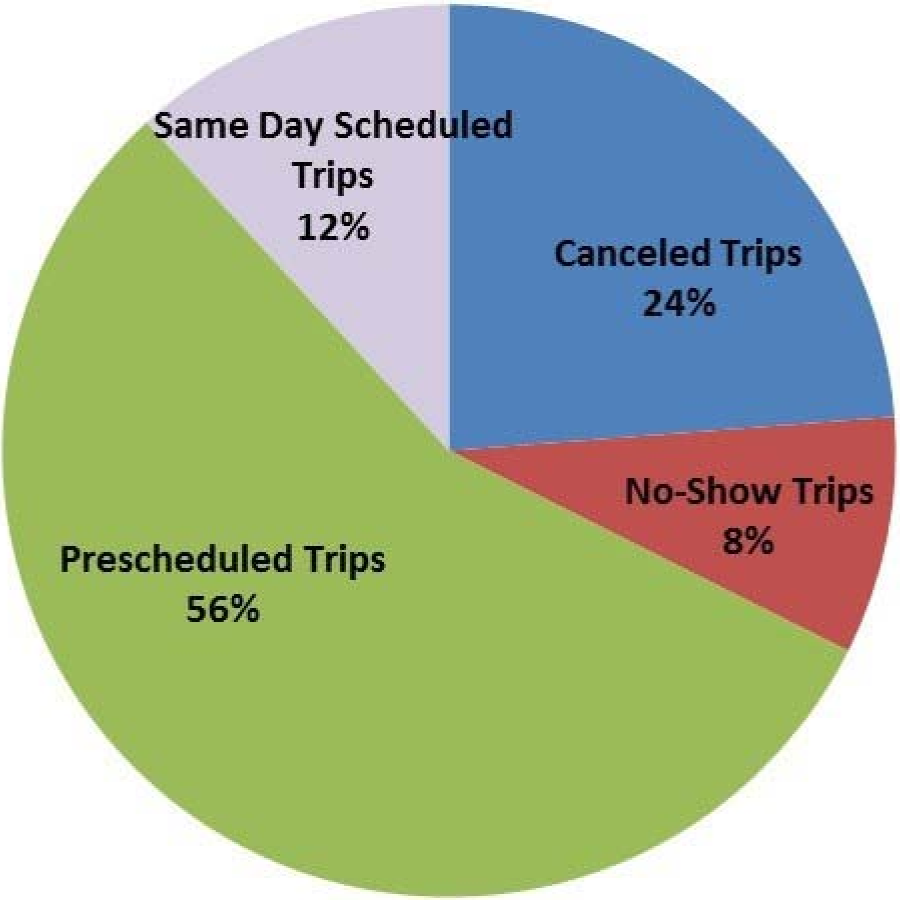
With the aforementioned information, the reports can be compared to one another to get a sense of how many changes in trips and routes are made after 6:30 p.m., i.e., cutoff time on the previous day. From the extent of changes being made, one can see how complicated it may become to rearrange routes 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, and no-showing for one's ride. Changes made to the routes throughout the day manually are caused by weather, traffic, road 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 on 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. Figure 3~~2~~ below shows in a pie chart the proportion of rides and their outcomes discussed above with the addition of scheduled and prescheduled trips, i.e. cancelled trips, No-Show trips, and executed trips that were either prescheduled or scheduled the same day.

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 therefore all data with complete information can be examined using the same tests and analyses.

For each trip, the minimum and maximum public transit times, direct drive times and mileage were determined. The public transit times were produced using MBTA's Trip Planner (http://mbta.com/rider_tools/trip_planner). By entering an origin and a destination, MBTA's Trip Planner generates several alternative itineraries (routes). The total trip time of a route typically consists of walking time, transit time on one or more transportation lines (subway or bus), and waiting time in case of transfers. A rider may select the route with the longest total public transit time (which usually has fewer transfers), the route with the shortest time (which usually has more transfers), or a route with total time in-between. To compare with the paratransit times, we selected the two extreme times, the minimum and the maximum public transit times. The direct drive times and mileage were found using Google Maps (http://maps.google.com/maps?hl=en&tab=wl). The data collection process of the public transit times and direct drive times along with mileage URL's was automated using a software program developed for this research to ease the manual process. The software program reads a set of origins-destinations from an Excel (.xlsx) spreadsheet to the web site and retrieves and stores the output data into the same spreadsheet. The collected data were subsequently checked

FIGURE 3
A ClASSIFICATION OF PARATRANSIT TRIPS



Cancelled Trips	836
No-Show Trips	303
Executed Prescheduled Trips	1960
Executed Same Day Scheduled Trips	416

individually to ensure their accuracy. The pickup and drop off locations of prescheduled trips were verified using the Manifest to ensure accuracy of the times. 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.

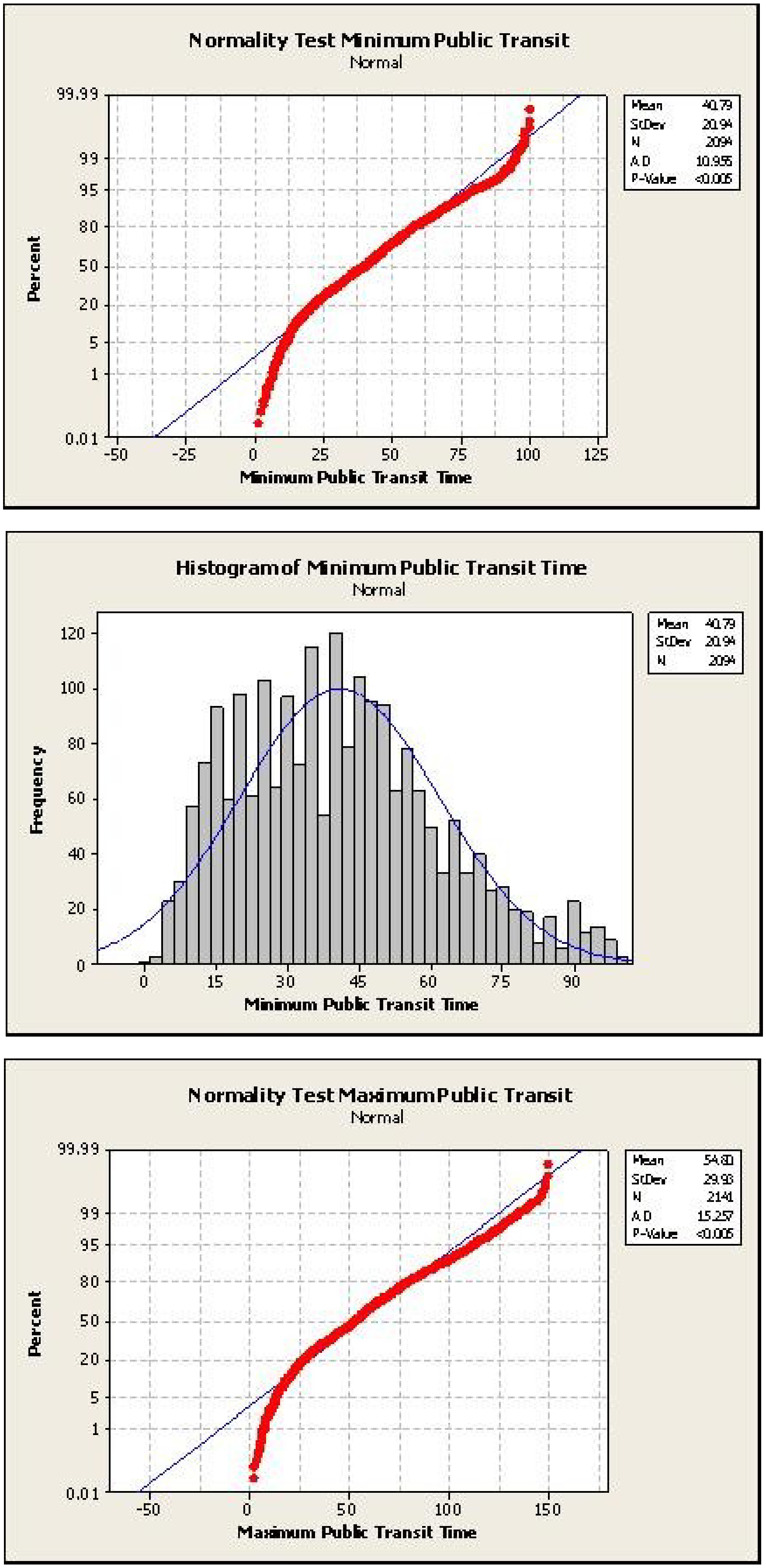
Once the minimum and maximum public transit times and the direct drive times were obtained, the data was then filtered to determine what data was viable for analysis. The exclusions were trip data for which public transit was not an option, data for which ambulatory information was not available for a particular rider, no shows, and canceled trips. There were also some trip data that were excluded due to a zero travel time, an unreasonable drop off arrival and/ or departure or a blank drop off arrival and/or departure 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 arrival and/or departure time. After the data was filtered for all criteria mentioned above, the result was 2,168 trips with viable and complete data to analyze.

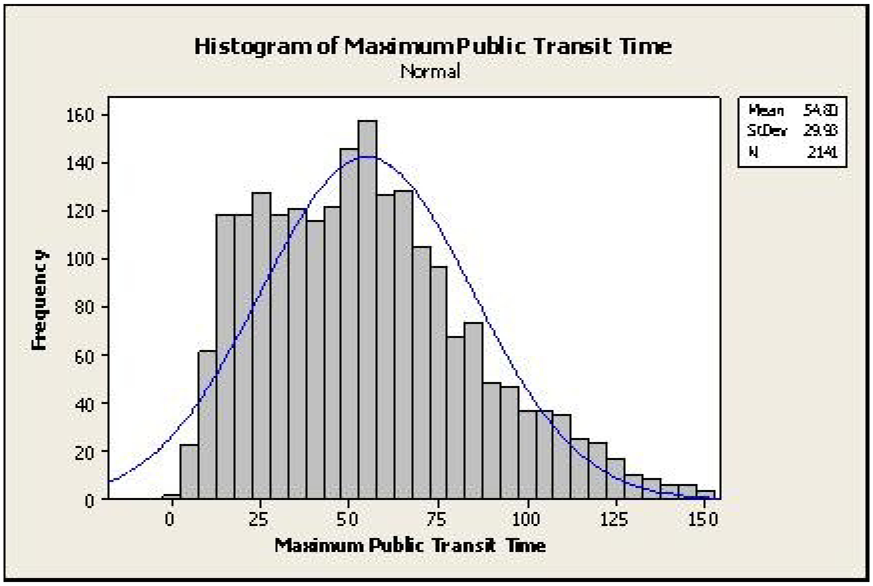
To compare the quality of paratransit services to the scheduled transit services, one can statistically compare the means of the transit times of rides of the two populations taken separately, i.e., paratransit rides and public transit rides. However, since we want to detect any significant difference due to the experimental process (paratransit versus public transit) and not due to experimental units (paratransit rides versus public transit rides), we should analyze the data in pairs. For each trip *i*, specified by the origin address and destination address, the difference of the realized paratransit time (x_i) from the minimum or maximum corresponding public transit time (y_i) was computed, i.e. $d_i = y_i - x_i$. The (x_i, y_i) is thus considered a pair of observations of two random variables (X, Y) and d_i an observation of their difference, $D = Y – X$. Taking expectations of both sides yields $\mu_D = \mu_Y - \mu_X$. In other words, we can make inferences regarding the difference of the means of the two populations ($\mu_Y - \mu_X$) by making inferences regarding the mean of the differences, μ_D. If the observations from each population are normal, the Student's t-statistic can be used to test a hypothesis about the difference in the means (Walpole et al., 2002).

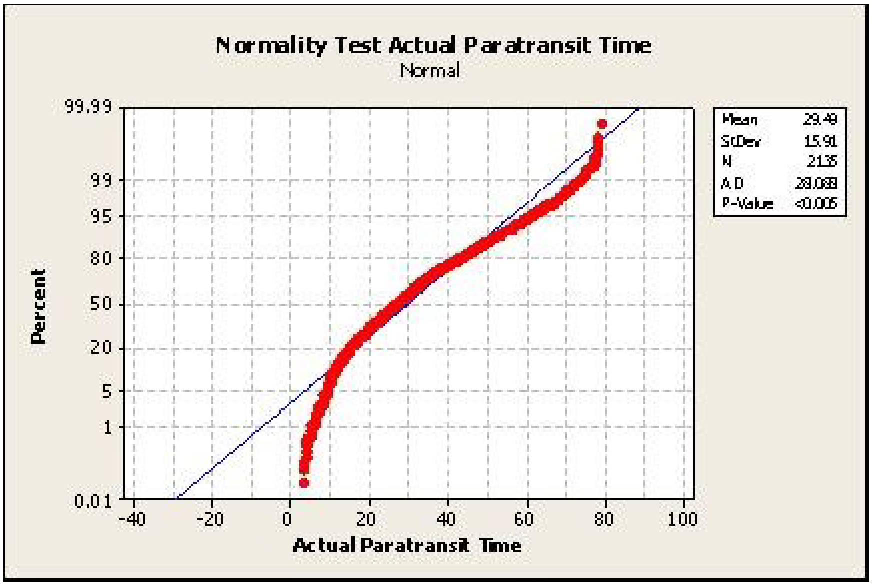
Each data set of Minimum Public Transit Time, Maximum Public Transit Time, Actual Paratransit Time and Maximum Allowable Ride Time was tested for normality. Figure 4 contains the normal probability plots and the histograms for all data sets, obtained with Minitab statistical 15.1.0.0 software. As it can be seen, all data sets fail the normality test. However, even though the data sets do not fit the normal distribution, hypothesis testing could still be performed since the sample size is very large and the population is not very skewed. Under these assumptions the Student's *t* distribution gives a good approximation to the sampling distribution of the average difference *D*, (Levine et al., 2001). Hence the Student's t-statistic was used in hypothesis testing.

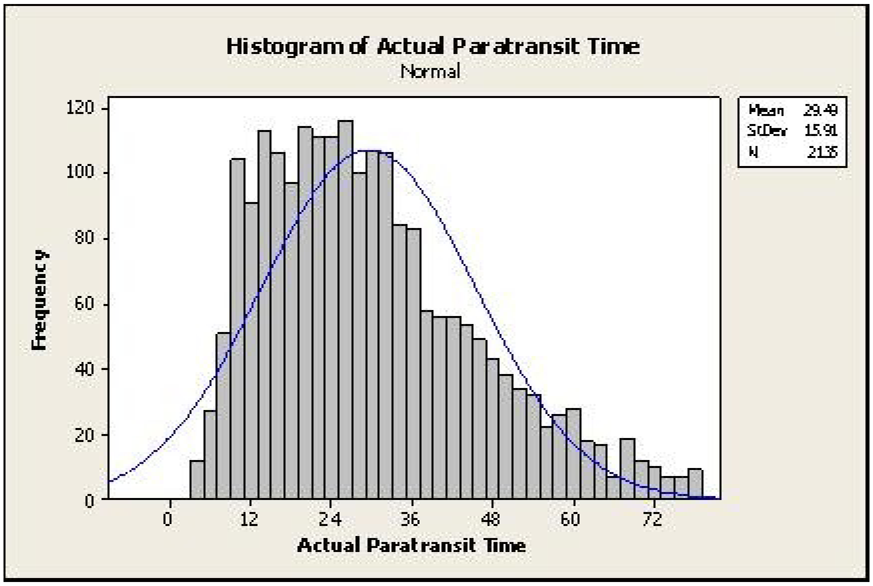
In this case, the *null hypothesis* (H_O) is that the difference of the means of the two populations (μ_D) is equal to a certain value *v*, i.e. $\mu_D = v$. The *alternative hypothesis* (H_A) is that $\mu_D > v$. The alternative hypothesis must be true if the null hypothesis is rejected. Hypothesis 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). By observing the descriptive statistics of the sample, *v* was selected to be 3 to 4 times the *standard error of the mean* lower than the *sample mean difference*. Several *Paired t-Tests* were conducted to determine how well THE RIDE is performing relative to the public transit system and to the maximum allowable riding time. Since shared rides are expected to have higher paratransit times than single rides, separate tests were performed for single rides, shared rides and all rides combined. All hypothesis tests were run using Excel 2007's t-test *Paired Two Samples*

FIGURE 4
A COMPARISON OF PUBLIC V. RIDE TRANSIT TIME PATTERNS




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


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

for Means and Minitab's 15.1.0.0's *Paired t-Test*. Running these tests took only seconds. The above two software provide the same results but different formats and statistical values that are useful when determining whether the test was run correctly and interpreting the results. This is shown in Tables 1, 2, and 3 for All Data, Single Rides, and Shared Rides, respectively, where all times are expressed in minutes.

The results from Minitab include the sample size N, the mean, the standard deviation, the standard error of the mean for each data set and the 99% lower bound for the mean difference. The Excel results give the mean, variance, sample size for each data set and the Pearson Correlation, Hypothesized Mean Difference, the degrees of freedom (df), the t-statistic, and several P(T<=t) and t-Critical values for level of significance á = 0.005. The output from Excel and Minitab was used to verify the results of both as well as supplement the output with one another.

ALL DATA ANALYSIS AND RESULTS

All data included N = 2,168 viable rides, as discussed previously. The following three hypotheses were tested:

$D = X - Y$, where X and Y are defined below for each test.

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

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

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

The results are shown in Table 1. In the hypothesis test (i), for Minimum Public Transit Time vs. Actual Paratransit Time, the *t*-statistic is -3.84, the P-Value is 6.25×10^{-5} and the *t* Critical one-tail is -2.578. H_O is rejected because *t*-statistic < *t* Critical one-tail and the very small P-Value (very close to zero) strengthens the conclusion that the alternative hypothesis H_A is true ($\mu_D > 11$). In terms of paired differences, 99% of them are higher than 11.758 minutes (99% lower bound for mean difference) and 99.99% of them (1 - P-Value) are higher than 11 minutes. Therefore, the testing supports the statement that the average Actual Paratransit time of a trip is more than 11 minutes faster than the fastest (Minimum Public Transit Time) route for that trip.

Following the remaining test results of Table 1, one can conclude that on the average, Actual Paratransit (ii) is 24 minutes faster than the Maximum Public Transit Time; and (iii) exceeds the expectation of the Maximum Allowable Ride Time rule by 28 minutes.

Single Ride Data Analysis and Results

Out of the 2,168 total rides, there were N = 1,290 single rides. The following three hypotheses were tested:

$D = X - Y$, where X and Y are defined below for each test.

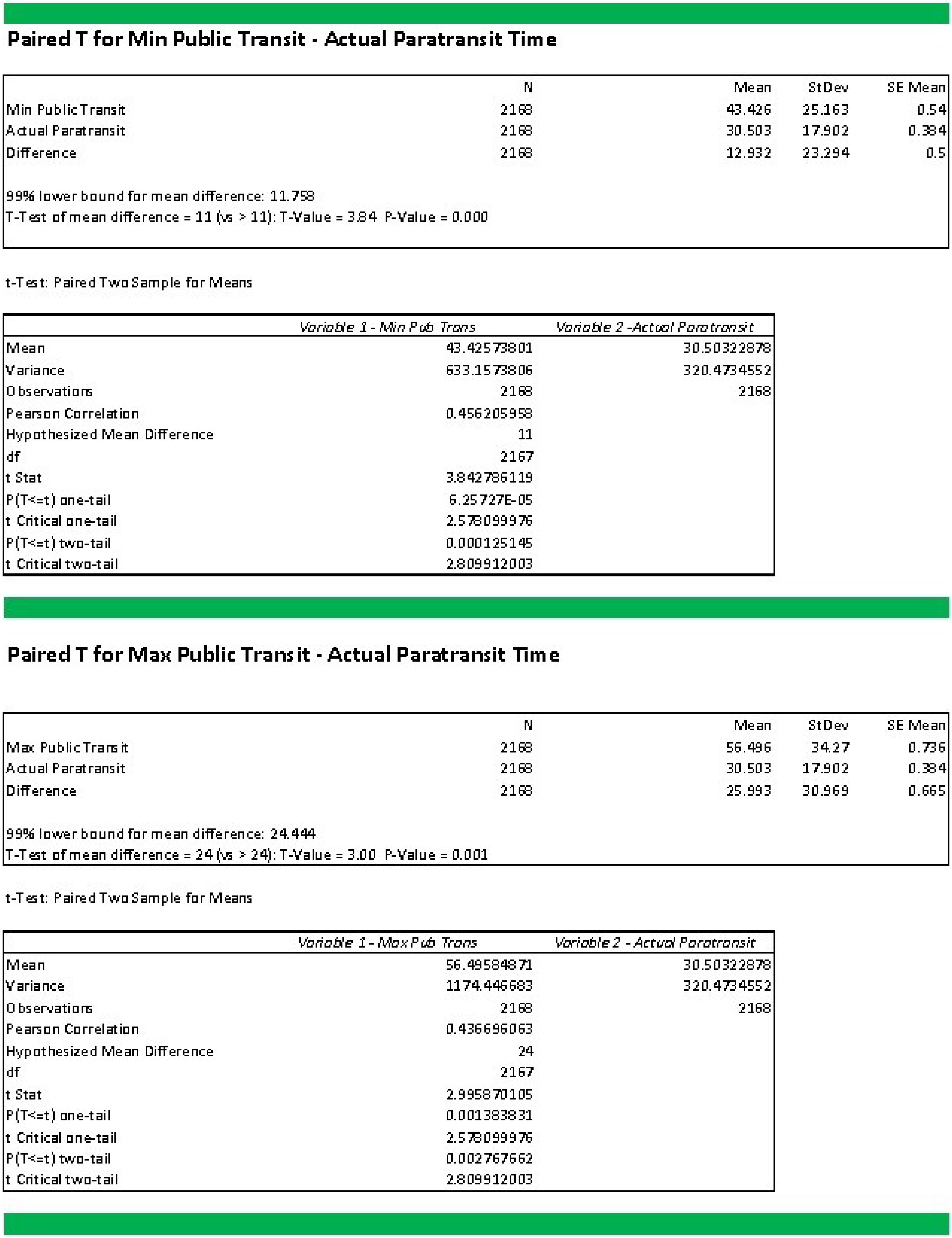
iv. X = Minimum Public Transit Time; Y = Actual Paratransit Time.
$H_O : \mu_D = 16$
$H_A : \mu_D > 16$

v. X = Maximum Public Transit Time; Y = Actual Paratransit Time.
$H_O : \mu_D = 28$
$H_A : \mu_D > 28$

vi. X = Maximum Allowable Ride Time; Y = Actual Paratransit Time.
$H_O : \mu_D = 34$
$H_A : \mu_D > 34$.

For the single ride data, the following conclusions can be drawn based on the output of Table 2: on the average, Actual Paratransit (iv) is 16 minutes faster than using the fastest Public Transit route; (v) is 28 faster than the longest Public Transit route; and (vi) exceeds the expectations of the Maximum Allowable Ride Time rule by 34 minutes.

TABLE 1
TEST RESULTS FOR ALL



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	

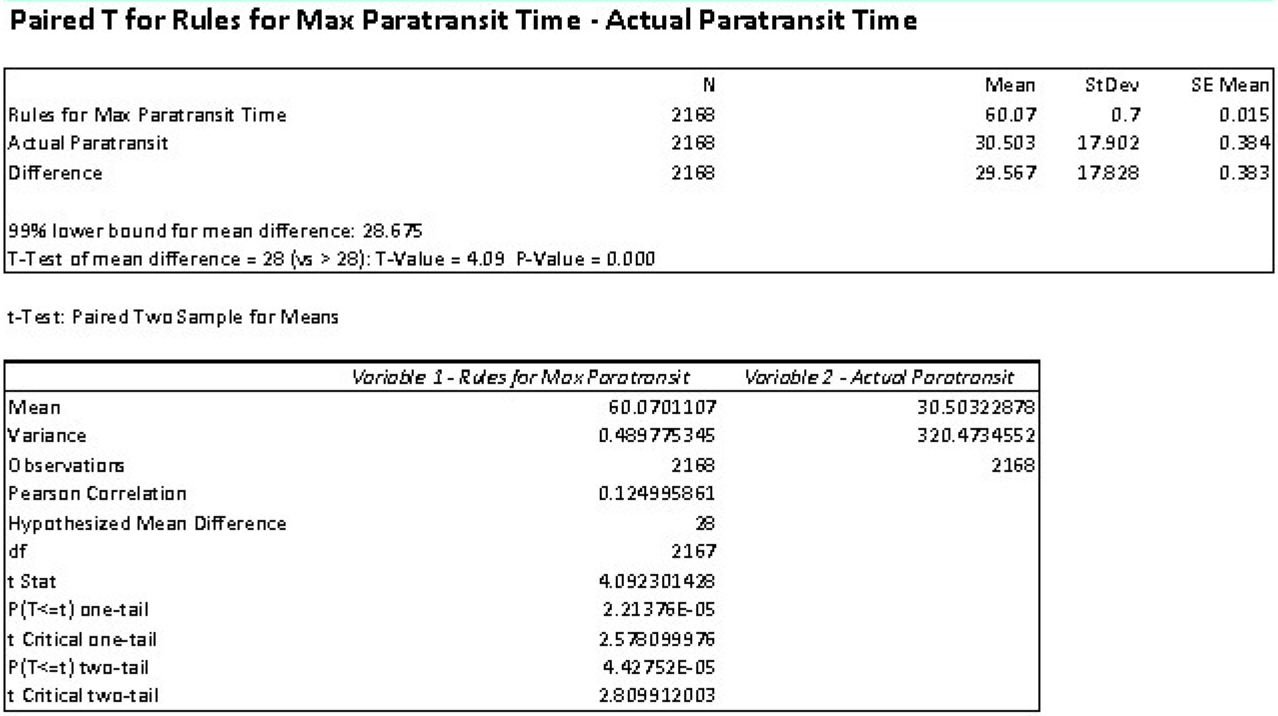
Paired T for Max Public Transit - Actual Paratransit Time

	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

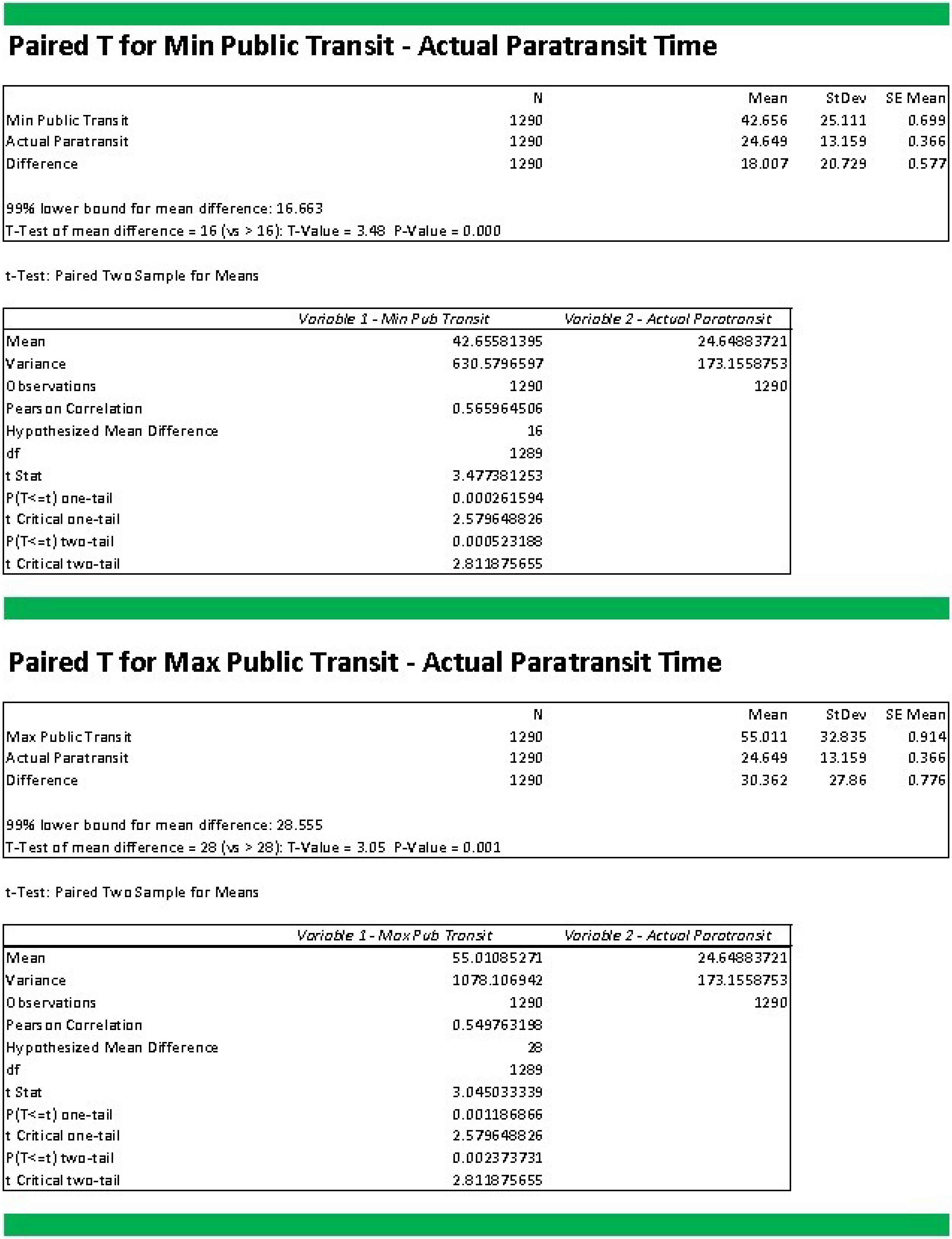
	N	Mean	StDev	SE Mean
Rules for Max Paratransit Time	2168	60.07	0.7	0.015
Actual Paratransit	2168	30.503	17.902	0.384
Difference	2168	29.567	17.828	0.383

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	

TABLE 2
TEST RESULTS FOR THE SINGLE RIDE DATA



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

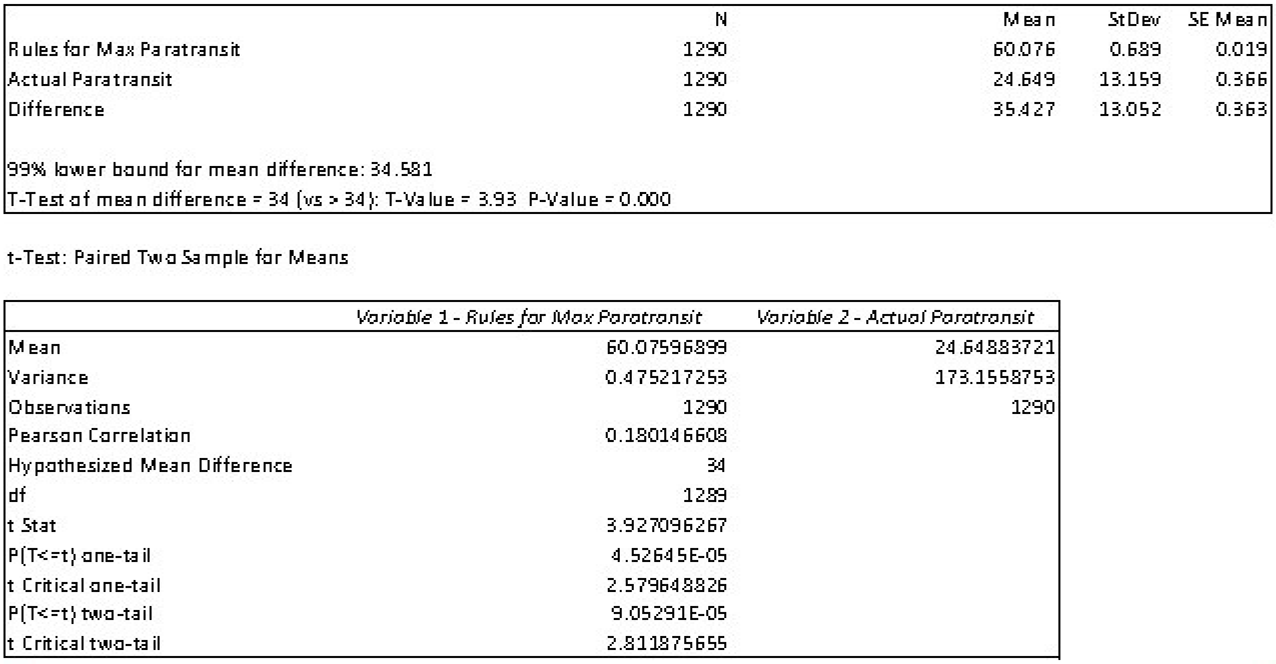
99% lower bound for mean difference: 28.555

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

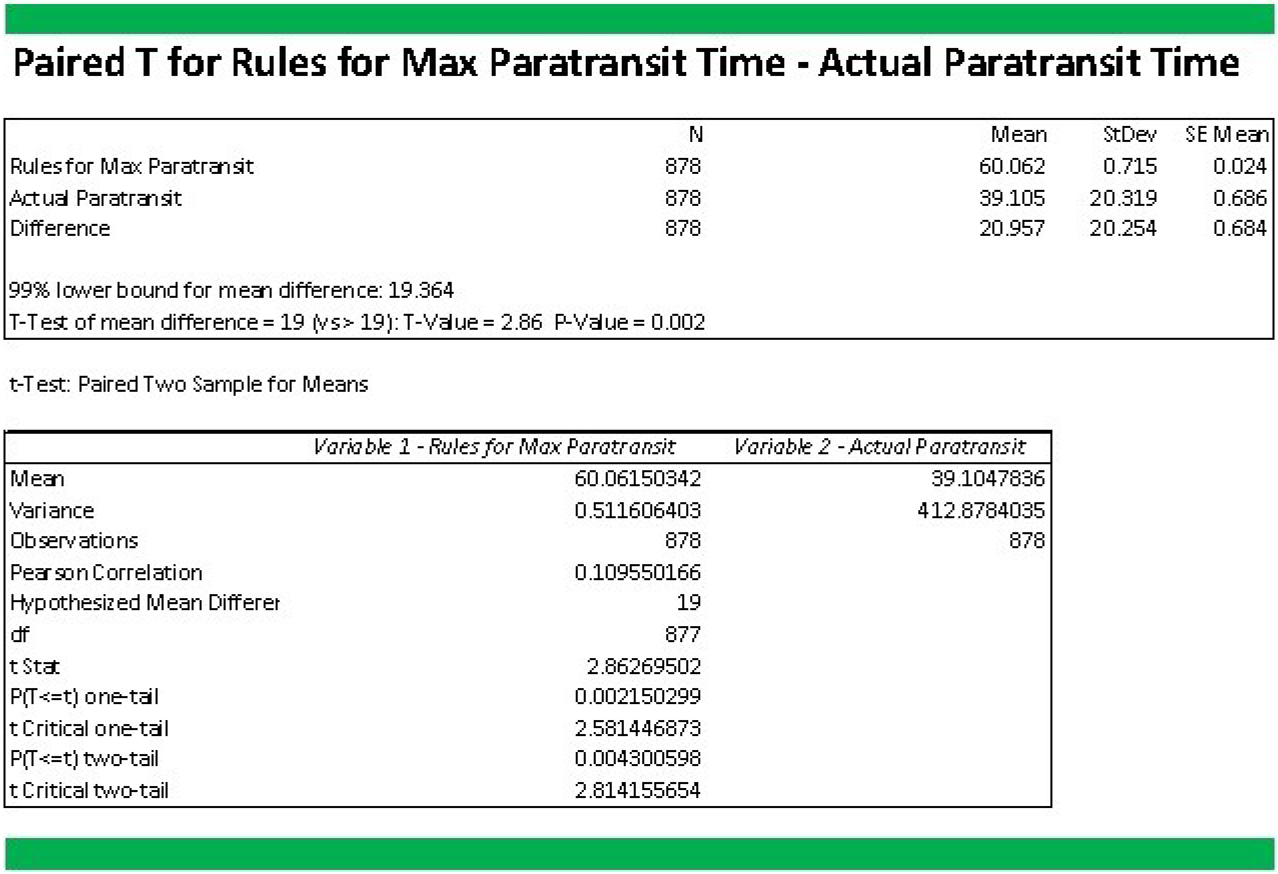
99% lower bound for mean difference: 34.581

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	

TABLE 3
TEST RESULTS FOR THE SHARED RIDE DATA



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	

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	

Shared Ride Data Analysis and Results

Out of the 2,168 total rides, there were N = 878 shared rides. The following three hypotheses were tested:

$D = X - Y$, where X and Y are defined below for each test.

vii. X = Minimum Public Transit Time; Y = Actual Paratransit Time.

$H_O : \mu_D = 3$

$H_A : \mu_D > 3$

viii. X = Minimum Public Transit Time; Y = Actual Paratransit Time.

$H_O : \mu_D = 16$

$H_A : \mu_D > 16$

ix. X = Maximum Allowable Ride Time; Y = Actual Paratransit Time.

$H_O : \mu_D = 19$

$H_A : \mu_D > 19$.

For the shared ride data, the following conclusions can be drawn based on the output of Table 3: on the average, Actual Paratransit (iv) is 3 minutes faster than the using the fastest Public Transit route; (v) is 16 faster than the longest Public Transit route; and (vi) exceeds the expectations of the Maximum Allowable Ride Time rule by 19 minutes. A summary of all hypothesis testing results is provided in Table 4.

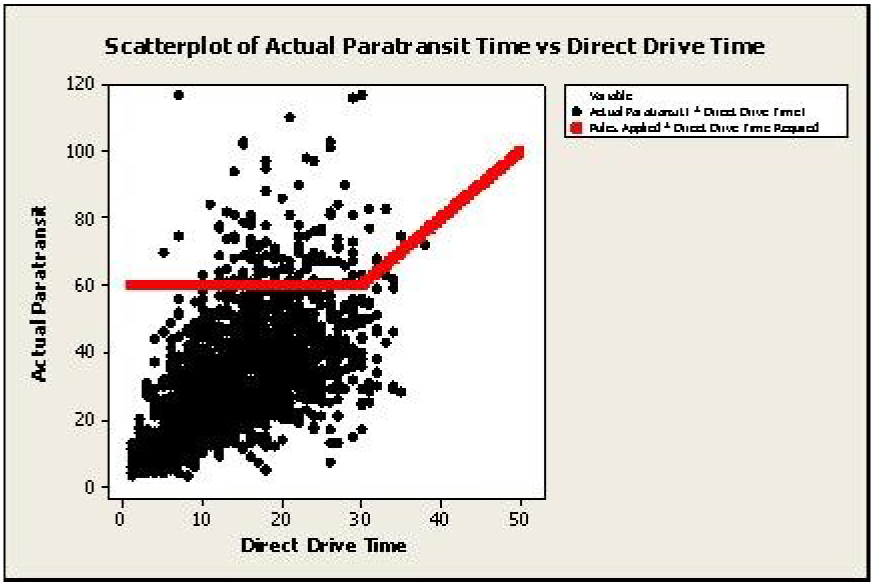
Actual Paratransit Time vs. Direct Drive Time

All trips that were executed by the Veterans Transportation Services contractor on 05/06/2010 are displayed as black bullets in Figure 5. The coordinates of each bullet's center are the Actual Paratransit Time and the Direct Drive Time. The bent gray line, consisting of a horizontal segment (for *Direct Drive Time* ≤ 30 minutes) and an unbounded line segment with the slope of 1, divides the first orthant into two subspaces. Points that are above the line, inside the upper subspace, correspond to rides that violate the Maximum Allowable Riding Time rule. As it can be seen in Figure 5, there is not a significant amount of rides that violate the rule, 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 happens because when there are shared rides, it requires longer riding times for some passengers. For 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 that particular day, it is 136 rides out of 2,168 of the rides in our data set.

TABLE 4
AVERAGE TIMES (MINUTES) PARATRANSIT RIDES ARE SHORTER

	All Data	Single Rides Only	Shared Rides Only
Min Public Transit	11	16	3
Max Public Transit	24	28	16
Maximum Promised	28	34	19

FIGURE 5
PARATRANSIT TIMES COMPLYING WITH THE MAXIMUM ALLOWABLE RIDE TIME RULE



Concluding Remarks and Managerial Implications

By comparing the Actual Paratransit Time to the Minimum and Maximum Public Transit Time and to the Maximum Allowable Ride Time, we concluded that THE RIDE is exceeding expectations by both being better or comparable to the public transit provided, having a slim chance of being late, and having a small chance of exceeding the maximum allowable riding time. In all cases, the average riding time was faster than taking the public transit, being it the Minimum Public Transit Time or the Maximum Public Transit Time, and the average riding time was significantly less than the Maximum Allowable Ride Time.

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 exceeding them considerably, we concluded that customer satisfaction is high while costs are high. In order to lower cost, customer satisfaction has to be sacrificed. For example, shared rides can be utilized more to lower costs. More shared rides would mean employing fewer drivers, deploying fewer vehicles with lower fuel consumption, but would also mean longer riding times for riders and subsequently lower customer satisfaction.

If one was to look at All Data and the hypothesis testing summary results of Table 4, it can be seen that overall 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 requirements of public transit in the Greater Boston area imposed by the ADA rules. In the same respect, THE RIDE created 28 minutes of extra cushions for the Maximum Allowable Ride Times. This means that THE RIDE and/or its Contractors could loosen up some of their constraints in their DSS to allow for more shared rides and perhaps lengthen riding times slightly, but could potentially save some costs to run the program.

When looking at the Shared Ride Data, it turned out to be worse than both the All Data and Single Ride Data analysis where riding times are only shorter 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. 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 paratransit service 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 Observations 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 faster than the Maximum Allowable Riding Times. It is very clear in this case that allowing for more shared rides could lower costs while maintaining an acceptable level of customer service. In general, THE RIDE and its Contractor, Veterans Transportation Services, are performing very well when all the Paratransit services are compared. It is apparent that THE RIDE is comparable to quality of the public transit service provided locally. In other words, THE RIDE passes the performance test with flying colors and gives room for further cost savings, while abiding by the Maximum Allowable Riding Times rule.

Learned from the successful implementation of THE RIDE, other transit agencies may exploit the proposed DSS framework. There are three key elements for a successful implementation of the DSS for transit agencies:

1) Development and periodic update of accurate para-transit databases;
2) Incorportation of pertinent transit knowledge (e.g., transit policy) and appropriate problem solving tools (e.g., operations research and statistical techniques) into model bases;
3) Creation of user interfaces with both data and model bases to provide actionable alerts, problem diagnosis, and decision alterternatives on a real-time basis.

As evidenced by THE RIDE, the proposed DSS can help the transit agency significantly enhance its para-transit services and reduce operating costs by automating routing/scheduling procedures and making timely and structured information available to transit authorities.

Acknowledgements

The authors thank Paul Strobis and Carol Joyce-Harrington of MBTA's Office for Transportation Access for providing access to the RIDE data. This research was partially supported by the U.S. Department of Transportation, Research and Innovative Technology Administration - grant MIOH UTCTS13, and the University Transportation Center (UTC) at the University of Detroit-Mercy.

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