DRT ACCESSIBILITY TOOL
User Guide

DRT ACCESSIBILITY TOOL

User Guide

December 2008

Jeffrey LaMondia • Nazneen Ferdous • Chandra R. Bhat

CONTENTS

EXECUTIVE SUMMARY

Demand Response Transit (DRT) is a critical form of transportation for mobility-impaired, low income, and small/ medium-sized communities. This type of service transports riders on demand. Unfortunately, DRT systems face many challenges that restrict how well they can serve their community, including limited funding, understaffing, aging fleets, a lack of technical support, a lack of quantification of level of service standards, and limited modeling/planning practices. This guide discusses a unique DRT Accessibility Tool developed for the Texas Department of Transportation that addresses these challenges by determining how well a DRT system serves its riders and the most efficient ways to improve this service. The DRT Accessibility Tool, which is developed in Microsoft Access based on DRT travel logs, service characteristics and surveys from Brownsville, Texas, uses a system of models to simulate actual daily DRT travel patterns. The DRT Accessibility Tool is transferable, practical, and valuable for all small and medium sized communities. The tool utilizes service fleet and region information that all system operators already have, and it is designed to be applicable to demand response systems of any size and location. Ultimately, DRT system operators can use the Accessibility Tool in two ways. First, they can evaluate their current accessibility levels for various combinations of population groups, times of day, and travel purposes. Second, the Accessibility Tool allows system operators to undertake "what if?" scenarios to evaluate changes in fleet characteristics (supply), population demographics (demand), and service areas (scope). Similarly, system operators can predict (and anticipate) future needs of their riders by using the tool to analyze the impact of changes in population demographics. These results have the potential to inform important public transportation planning, budgetary, and policy decisions.

1. HOW TO USE THIS GUIDE

This comprehensive guide provides all of the information necessary to effectively use the Demand Response Transit (DRT) Accessibility Tool, including background literature, underlying methodology, and step-by-step instructions.

The DRT Accessibility Tool was developed to provide the Texas Department of Transportation (TxDOT) Public Transportation Division staff and other transportation professionals within the state of Texas a tool to measure and benchmark the level of accessibility for DRT systems. The tool, which is formulated in Microsoft Access, uses a system of models to simulate actual daily DRT travel patterns for service regions and fleets of any size. In the end, transit system operators and planners have the option of measuring accessibility for various combinations of population groups, times of day, and travel purposes. The goal is to provide decision-makers with detailed information that will enable them to pinpoint areas where DRT service needs improvement or specific populations that need to be targeted.

The DRT Accessibility Tool is unique in that it evaluates the level of accessibility from the customer, or DRT patron, perspective rather than from an operational performance standpoint. While fleet size and efficiency are integral parts of DRT accessibility, ultimately the service must provide convenient connectivity between origins and destinations of interest to the patrons in order to be "accessible". As a result, accessibility is measured based on travel factors that are important to patrons, including travel time, drop off delay, pick up time uncertainty, and unmet demand.

The DRT Accessibility Tool is, as the name states, a *tool* that DRT system operators can work with to improve their transit planning and DRT patron accessibility, rather than an independent program that 'spits out' generic results. Because of this, system operators

will be able to apply their knowledge of the service region, their patrons, and operations with the Tool to arrive at solutions that are meaningful and specific to their area. However, system operators should keep in mind the particulars of a tool such as this that calculates accessibility for each zone relative to the other zones within the service region. While this method allows system operators to identify those zones that stand out with relatively high and low accessibility, system operators will not be able to compare accessibility indices of two different service regions unless they evaluate both at the same time. This also means that there will always be zones with a relative high and low accessibility measures, although the difference may be only minor, regardless of any changes made to the system.

The guide begins with an introduction to demand response transit operations and the current state of the practice in measuring quality of service in Section 2. This section then continues with a detailed account of how the DRT Accessibility Tool was developed as well as the models used to simulate travel and measure DRT accessibility. Section 3 provides an overview of the tool interface, discusses the processing requirements, and outlines the specific data required to run the tool. Users are then presented with step-by-step instructions for using the tool in Section 4. Section 5 describes how the tool can effectively be used for benchmarking and 'What If?' scenario applications. Finally, additional information regarding sample data and technical support are provided in Section 6.

2. BACKGROUND AND FORMULATION

This section presents the background and formulation of the DRT Accessibility Tool. It begins with an introduction to demand response transit operation, the current methods for benchmarking DRT performance, and how this tool builds upon them. The DRT Accessibility Tool incorporates unique spatial datasets in its analysis, and these components are summarized next. Finally, the models and methods used in the tool to simulate DRT travel patterns and measure DRT patron accessibility are discussed.

2.1 INTRODUCTION

Demand response transit (DRT), also known as paratransit or dial-a-ride, is a critical form of transportation for mobility-impaired[1], low-income, elderly, and rural populations. This type of service, which transports riders through an on-demand basis, is commonly used in four main markets: 1) for the general public in rural areas that are not dense enough to support a fixed route transit system, 2) for the general public in urban areas acting independently of a fixed route transit system, 3) for the general public in urban areas as a feeder for a fixed route transit system, and 4) as ADA complementary services required by the 1991 Americans with Disabilities Act (ADA). (Spielberg and Pratt, 2004)

The way DRT operates is as follows: Patrons of the DRT service must call their transit operator, usually at least 24 hours ahead of time, to schedule their trip. As trips are scheduled, transit system operators use optimization software to update the DRT vehicle's route for the given day. DRT vehicle drivers receive this manifest at the beginning of each day, which tells them where they need to go. Schedules can sometimes even become repetitive "subscription type services" in areas where DRT has

---

[1] In this study, the term 'mobility-impaired' considers a range of special populations using transit, including wheelchair bound, blind, walking with an aid, and others.

been long established due to numerous repeat patrons (Kittelson & Associates, Inc., KFH Group, Inc., et al., 2003).

There are many variations of DRT service, depending on the needs of the area. Some system operators provide point-to-point service, transporting patrons to and from specific points like a taxi. Others provide route-deviation service, picking up and dropping off patrons at specific locations but always returning to a loosely defined route much like a bus. Service can be further customized by choosing to pick up and drop off patrons at the requested origins/destination, at convenient locations (including a fixed-route bus stop), or any combination of these. (Spielberg and Pratt, 2004)

All told, there were over 86.6 million unlinked DRT trips in 2005. (US Census Bureau, 2007) Yim and Khattak reported that over 370,000 vehicles and 22,884 private DRT system operators were serving these patrons in 1998 (2000). Regardless of their differences, all of these DRT system operators face similar challenges: they contend with limited funding, understaffing, aging fleets, a lack of technical support, no level of service standards, and few practical modeling/planning practices. These challenges are especially present in small and medium sized communities, where the largest percentages of residents rely on DRT service. In fact, over 21% of the United States' population currently resides in small and medium sized communities (Northeast Midwest Institute, 2002), and these numbers are projected to increase as such areas continue to develop as nationally critical economic centers (Cambridge Systematics, Inc. et al., 2008). As populations within such regions grow, these challenges will be amplified, potentially resulting in reduced mobility and stunted economic growth. Therefore, it is critically important that small and region communities take a proactive approach to transit planning.

Much of the previous work within demand response transit research focuses on DRT operations, including fleet distribution, scheduling, and other supply-side factors.

Studies of how to reduce costs and optimize routing began in the 1970s, when computer-aided scheduling software was first introduced, and have continued ever since (Kessler, 2004). Many studies of DRT best practices exclusively consider operational improvements (KFH Group, Inc. and A-M-M-A, 2001, KFH, 2002, Conklin et al., 2003). Models of customer serviceability (Sandlin and Anderson, 2004), vehicle serviceability (Davenport, et al., 2005), and optimal fleet size (Schofer et al., 2003) have been developed around these operational characteristics as well. This emphasis on operational improvements is partly due to the limited budgets and staffing of transit system operators in small and medium sized communities (Simon, 1998). But, it is also due to the fact that national funding and performance reviews are heavily based on these operational measures. However, DRT operations provide only half of the picture.

DRT system operators and community planners must also consider patron travel needs in order to completely assess the effectiveness of their transit program. Just because a DRT system is cost-effective does not automatically mean that all patrons are getting their preferred service. Fortunately, many researchers and system operators are taking cues from similar fixed-route transit research and beginning to recognize the importance of considering patron-level performance measures when assessing DRT systems (Kittelson & Associates, Inc., Urbitran, Inc., et al., 2003, Bhat et al., 2006, Potts and Marshall, 2007). Measuring accessibility, defined as "the distance that people must travel to obtain goods, services, and participate in activities" (Victoria Transport Policy Institute, 2008) is one such patron-level performance measure. Other researchers have identified on-time pickups, excessive travel times, arrival delays, and unmet demand as additional measures of DRT patron-level performance (Easter Seals Project ACTION, 2002, KFH, 2008). The most common method for evaluating these performance levels is simple benchmarking (i.e. recording and comparing values over time). As a result, many of the reports that include patron-level measures are primarily concerned with identifying the most inexpensive, efficient, and effective methods for recording this information (Easter Seals Project ACTION, 2002, Potts and Marshall, 2007, KFH, 2008,

Victoria Transport Policy Institute, 2008). Small and medium sized communities are most likely to collect these measures by conducting phone interviews with patrons, collecting comment cards, or performing occasional surveys (Simon, 1998). While funding opportunities based on improving DRT accessibility exist, such as the Rural Transportation Accessibility Incentive Program sponsored by the Federal Transit Administration (FTA) (US Department of Transportation, 2008), DRT system operators could benefit from better methods for determining the most effective application of these funds and improving patron travel satisfaction.

Recently, a number of studies have emerged that go beyond simply benchmarking DRT patron travel and performance-related measures. The most common topic of analysis is forecasting rural transit demand based on population characteristics, either through linear regression models, factoring methods, or other means. Most studies predict the total number of DRT patrons within a region (McIntyre et al. 1986, Schofer et al., 2003, Spielberg and Pratt, 2004, Koffman et al., 2007), while some predict the number of different types of DRT patrons within a region, such as elderly, subsidized, low income, youth, and mobility-impaired (McIntyre et al., 1986, Painter et al., 2007). These forecasting studies provide insight into whether demand is being met and the latent need of the service region. Other studies develop methods for calculating typical travel characteristics for patrons based on distances between trip origins and destinations (Schofer et al., 2003), which can later be compared. Southworth et al. (2005) even distinguished differences in travel characteristics (i.e. costs, distance, time, safety, mobility) based on trip purpose and available modes in his cost-benefit analysis tool. Fu (2002) developed a complete simulation system for DRT travel based on dynamic scheduling. While his tool is designed to evaluate the impact that different types of technologies have on scheduling practices, it still models basic patron travel characteristics. However, it has been noted that DRT accessibility measures are especially important in small and medium sized communities because the land uses in these regions are different than anywhere else (Stommes et al., 2005, Blumenberg et

al., forthcoming). For this reason it would be especially important to not only consider DRT patron travel characteristics, but also how these characteristics are related to where DRT patrons specifically want to travel.

The current study builds upon previous work and presents a database tool that simulates DRT travel patterns to measure DRT patron accessibility. The DRT Accessibility Tool is unique because it adds both detailed spatial and individual patron elements to calculate accessibility for various types of individuals, times of day, trip purposes, and, most importantly, spatial areas. As a result, system operators can determine the quality of DRT service across the service area and identify the most cost-effective ways to improve their service from a patron-perspective.

2.2 DATA USED TO DEVELOP THE TOOL

2.2.1 Data Source

The DRT Accessibility Tool was developed based on patron and trip data from the demand response transit system operating in Brownsville, Texas. Brownsville is located within Cameron County at the southern tip of Texas and borders Mexico. As a result, Brownsville serves as a major gateway for people and goods between the two countries. It is not surprising that over 91% of the population is Hispanic and that over 87% speaks a language other than English at home. The city has an area of 83 square miles and is home to close to 140,000 residents. (US Census Bureau, 2007)

Brownsville is an ideal location for developing a tool to evaluate DRT accessibility because the Brownsville Urban System (BUS) transit provider is widely considered to be one of the most advanced DRT systems in Texas and the United States. BUS has a paratransit fleet, 13 fixed transit routes, and 2 major terminals. BUS DRT serves all those residents that live within ¾ mile of the fixed-route transit network. Their DRT service is supported by RouteMatch scheduling software and in-vehicle GPS transponders. In

2002, BUS served over 1.6 million passengers in its fixed route bus service and over 54 thousand passengers in its demand response transit services. (US Census Bureau, 2007)

2.2.2 Data Summary and Formulation

The underlying models of the DRT Accessibility Tool were developed using a combination of spatial GIS data and actual recorded patron trip data. Because the tool utilizes both types of data, users are able to evaluate DRT accessibility at the patron-level and zone-based disaggregate scales (i.e. at the Traffic Analysis Zone (TAZ) or Census Block Group (CBG) level). Even though the data used in the tool is extremely detailed, the research team selected data sources that would be easy for transit system operators and planners to collect or replicate as well as be straightforward for non-technical planners to implement. The steps involved in formatting the spatial GIS and patron trip data are outlined in the following paragraphs.

Spatial GIS data was first collected from both the US Census Bureau and Brownsville Urban System (BUS), the transit provider within Brownsville, in the form of three main shapefiles, or digital map features, for roads, census block groups, and fixed-route transit routes. A number of steps were used to format and clean the shapefiles: First, these shapefiles were formatted and clipped to the area within the DRT service region, designated as "any place up to ¾ of a mile in any direction from a fixed (transit) route" (BUS, 2003). Second, sociodemographics data for each census block group were added from the census SF1 demographic library. Third, land uses for each census block group, in the form of zoning, were added. Land uses included manufacturing, commercial, retail, apartments, and general residential. Fourth, distances between every pair of census block group centroids, or center points, were calculated. Finally, the distance from each census block group centroid to the nearest fixed-route transit line was calculated.

The patron trip data, which consisted of a detailed list of patrons as well as a complete log of all completed trips over an 8 month period, was collected from BUS. The travel log contained all 28,751 DRT patron trips from June 1, 2006 to January 31, 2007. The list of patrons contained every patron ever recorded from 2001 to 2007. Duplicates were removed, and only those who had taken one of the trips during the 8 months of the travel log were selected. As a result, the final list contained 380 unique patrons, with gender, mobility, and home location data.

Finally, the spatial GIS and patron trip data were combined. In this last step, patron home locations and trip origins and destinations were geocoded (plotted on the map) in ArcGIS. By merging these files, the research team was able to graphically depict trip origins and destinations. This connection was a critical component in developing the system of models used to measure DRT accessibility, described in the following section.

2.3 METHOD FOR MEASURING DRT ACCESSIBILITY

Accessibility measures typically evaluate the number of travel opportunities and the ability to move between these travel opportunities. (Hanson and Giuliano, 2004) In demand response transit, travel opportunities and characteristics change every day depending on where and when patrons request service, making the measurement of accessibility difficult. In response, the DRT Accessibility Tool uses a system of models to simulate actual daily DRT travel patterns. The simulated travel characteristics are then used to measure DRT accessibility. Figure 1 outlines the system of models, which includes 3 main modules of collecting *Service Characteristics,* completing a *24hr Demand Responsive Transit Travel Simulation*, and calculating an *Accessibility Index.* These modules are discussed in detail in this section.
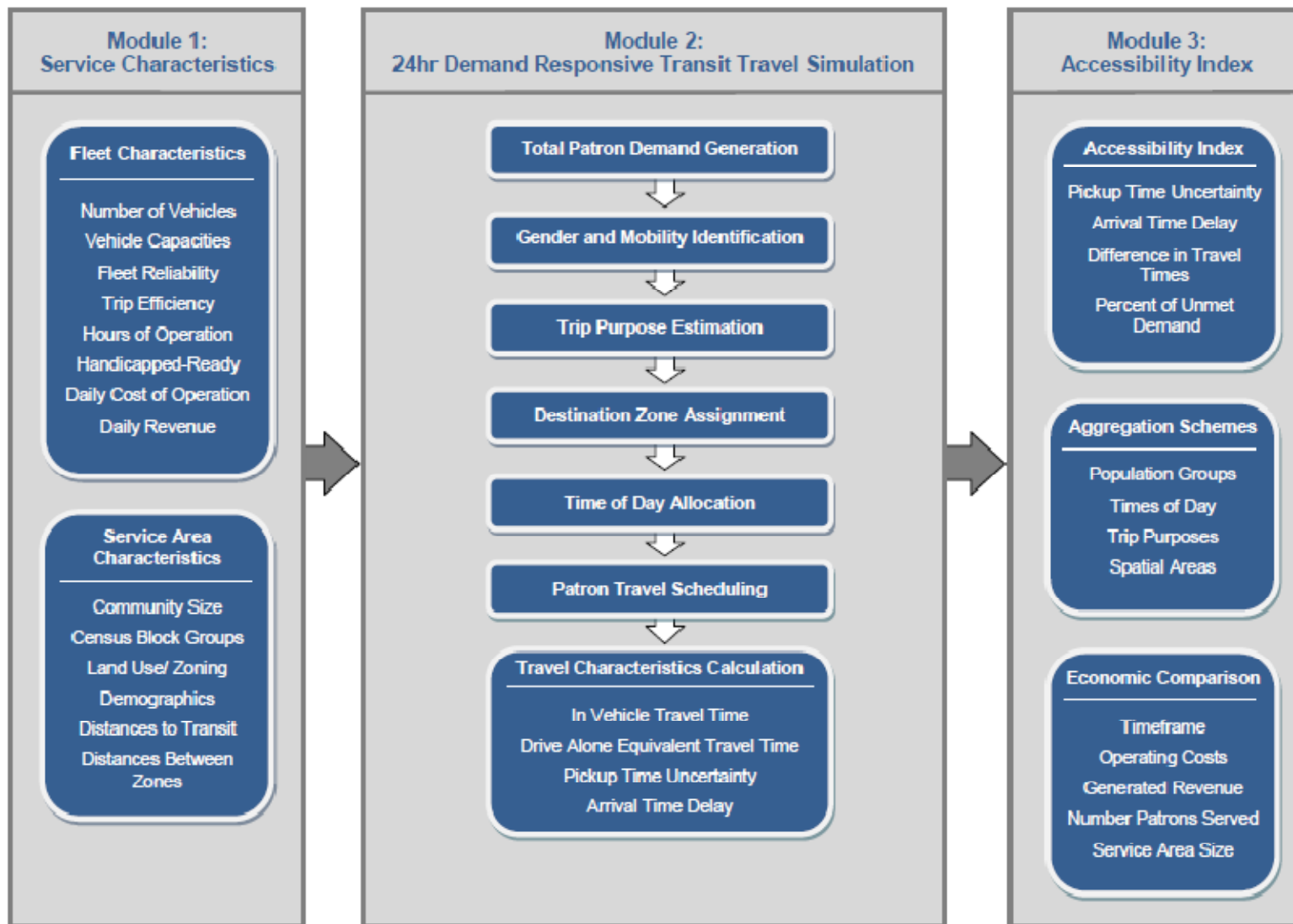
Figure 1: DRT Accessibility Tool Methodology

2.3.1 Service Characteristics

The first module collects the data required to run the analysis. This data consists of 1) a list of fleet vehicles, including capacity, service schedules, reliability (i.e. how often the vehicle will be out of service for repairs), efficiency (i.e. how many patrons this vehicle can pick up in an hour), hours of operation, whether they are wheelchair lift or ramp - equipped, daily cost of operation and revenue, and 2) a table of zones within the service area, including land uses/ zoning and population demographics, distance to transit, and distance between zones. This first module was designed with typical DRT system operators in mind and is flexible enough to allow for any fleet size or zoning scheme. The research team interviewed numerous DRT system operators from Tyler, Brownsville, Longview, and San Angelo, Texas, and found that these types of inputs were readily available and easily understood.

2.3.2 24-Hour Demand Responsive Transit Travel Simulation

The second module uses the service characteristics collected in the previous module to simulate patron travel over a 24-hour period. This module uses a series of probability models, linear models, and discrete choice models to simulate DRT patron characteristics and decisions. These models were estimated using the actual DRT trip data collected from Brownsville, Texas. By the end of this module, the tool generates a table of patrons to be served, their demographics, origin and destination zones, trip purpose and time of day, travel characteristics, and whether they are able to be accommodated on a particular day or not. Users also have the option of running multi-day simulations for higher precision. The series of seven specific models included in this module are:

Total Patron Demand Generation
The simulation begins with predicting the total number of patrons requesting a DRT trip from each service area zone based on the population demographics of the area. The explanatory variables in this model can be classified in two groups: percentages within

the specific census block group population, which describe the individual character of the service area zone, and percentages within the entire region, which describe the service area zone in reference to all other service area zones. The results indicate that service area zones that have larger total populations, older median ages, larger average household sizes, and are closer to fixed transit routes produce more DRT patrons. The impact of renters, married households with and without children, and different aged populations on patron generation are also significant, but the roles of these population factors varies greatly depending on spatial scale. More specifically, the effect that these population groups have on patron generation varies depending on whether these populations make up a significant percentage of the block group population, a significant percentage of the regional population, or both. For example, service area zones that have a high percentage of their population that rents produce fewer DRT patrons. However, if the service area zone contains most of the regional population of renters, it will produce more DRT patrons. These spatial interactions and variations suggest that although a large percentage of DRT patrons tend to be older and without access to a vehicle, DRT is also used by patrons of all ages and sociodemographic characteristics. This conclusion is similar to what Koffman et al. (2007) found in their regional DRT demand forecasting model. This linear regression, shown in Appendix A, was estimated from the geocoded BUS patron list and census block group characteristics.

Gender and Mobility Identification

The next model identifies whether each patron is either male or female and if he/she is mobile or mobility-impaired, i.e. requiring the use of an aid to get around, such as a cane or wheelchair. The simulation assigns these identities to the patrons based on probabilities derived from the BUS patron list. Patrons have a 33.04% probability of being a mobility-impaired female, 25.80% probability of being a mobile female, 24.06% probability of being a mobility-impaired male, and a 17.10% probability of being a mobile male.

Trip Purpose Estimation

Trip purposes are estimated in the third model of the simulation. In a method similar to the previous model, the simulation assigns trip purposes to patrons based on gender, mobility, and probabilities derived from the BUS travel log. The possible trip purposes include church/meeting, education/school, seeking recreation, medical/therapy, shopping, and work. Appendix B provides the trip purpose probabilities. Interestingly, most trips taken using DRT, regardless of the traveler's gender and mobility, are for medical/ therapy. Mobile patrons use DRT to travel for work considerably more than mobility-impaired patrons. Mobility-impaired patrons, on the other hand tend to use DRT for recreation-related travel more than mobile patrons.

Destination Zone Assignment

The simulation continues with a model of where each DRT patron is most likely to travel. This model was estimated from the BUS DRT travel logs and geocoded origin and destination locations. In this multinomial logit discrete choice model[2], each service area zone is treated as an independent destination alternative. As such, the model is applied to each service area zone in turn to calculate a patron's probability of choosing that service area zone. The probabilities of traveling to each possible destination are then used to assign each patron's destination. Both male and mobility-impaired patrons prefer destinations that are less populated and closer to their origin, relative to female and mobile patrons, respectively. These results suggest that not only do men and mobility-impaired patrons have less patience for traveling on transit, but that most of their trips are task-oriented, such as going to work or a medical appointment; they spend less time traveling to places to simply visit friends and family. Zoning land uses, categorized as residential, apartments, commercial (including public buildings and space), retail businesses, and manufacturing (including industrial), are important factors

---

[2] Multinomial logit discrete choice models predict the utility, or level of satisfaction, associated with various independent alternatives. It follows that individuals are most likely to choose the alternative with the largest utility, i.e. provides them with the most satisfaction. In this example, the different alternatives are the different destination zones.

in this model as well. Patrons traveling for different purposes are more likely to go to areas zoned to support that type of activity. For example, patrons traveling for recreation purposes are more likely heading to service area zones where outdoor spaces, school sports fields, and gyms are located, i.e. more commercial, retail, and apartment zoning. Similarly, patrons traveling in order to shop are considerably more likely to visit service area zones with high percentages of land area zoned for retail business. The full results of the model can be found in Appendix C. Interestingly, distances were not significant in this model, meaning that DRT patrons make destination decisions regardless of the distance they might have to travel to get there. This modeling process repeats for each individual patron until all patrons are assigned a destination service area zone. The δ_X variables included in this model, as well as many of the other models in the simulation, are indicator variables that take a 1 if the patron has the characteristic X and 0 otherwise. For example, δ_{Church} would equal 1 if the patron was traveling to church and 0 otherwise.

Time of Day Allocation

Patrons' choice of when to travel is simulated next using another multinomial logit discrete choice model. This model determines when each patron is most likely to travel, based on his/her demographics, trip purpose, and destination. The choices for this model are a) to travel out and return in the morning, b) to travel out in the morning and return in the afternoon, or c) to travel out and return in the afternoon. The probabilities of choosing to travel during these three times are calculated for each patron using the discrete choice model listed in Appendix D. The probabilities calculated for each time of day are then used to assign his/her travel time of day. Patrons are more likely to complete their travel during the morning if they are traveling farther distances, are mobile, and if they are traveling for task-oriented activities, such as work, education, or medical purposes. On the other hand, patrons are more likely to complete their travel during the afternoons if they are traveling longer distances, are mobility-impaired, and if they are traveling for leisure-oriented activities, such as church/meeting, recreation, or

shopping purposes. Mobility-impaired patrons are also likely to spread their travel across the entire day. However, this becomes more likely if they are traveling shorter distances but are pursuing longer activities, such as a church/meeting or recreation. This modeling process repeats for each individual patron until all patrons are assigned a time of day for travel. This discrete choice model was estimated using the BUS DRT travel log.

Patron Travel Scheduling

Once the patrons' demographics, trip purposes, and destination and time of day choices are completed, this model loads the patrons into the DRT vehicles by first randomly selecting patrons from the list to simulate a calling order. The maximum number of patrons able to be served during the specified timeframes is calculated from fleet size, vehicle capacities, probability a vehicle is out-of-service, number of patrons each vehicle can serve per hour, and DRT hours of operation. Mobility-impaired patrons are only able to be scheduled onto vehicles identified as being wheelchair lift or ramp - equipped. When a patron is randomly selected, the tool schedules them only if their travel time of day and mobility needs can be met; otherwise the tool will continue to select a new patron until either vehicle capacities are met or all unscheduled patrons' travel needs cannot be met. The model assumes that each trip consists of two legs: one from the home to the destination and the second from the destination to the home. This assumption is consistent with most DRT trips. In fact, close to 90% of the trips logged by BUS were exactly 2 legs.

Travel Characteristics Calculation

Finally, the simulation calculates travel characteristics for the scheduled DRT patrons by way of in-vehicle travel times, drive alone equivalent travel times, pickup time uncertainties, and arrival time delays. These travel characteristics are used in determining DRT travel accessibility.

- *In-Vehicle Travel Time*

  This model estimates the time, in minutes, it takes a patron to complete their DRT trip. It comes from research conducted by Schofer et al. (2003), and was estimated based on the 1995 NPTS.   It is a nonlinear regression based on community size and travel distances. The full model can be found in Appendix E.

- *Drive Alone Equivalent Travel Time*

  This linear regression model estimates the time, in minutes, it would take a patron to make their DRT trip if they were able to use a private vehicle and assuming an average 30 mile per hour speed for travel. The main predictors of drive alone equivalent travel time are the straight line distance and origin/destination census block group land areas. It was estimated using GIS straight census block group characteristics, straight line distance between census block group pairs, and shortest path travel times on the existing road network between census block group pairs. The full model can be found in Appendix F.

- *Pickup Time Uncertainty*

  This model estimates the difference in time, in minutes, between the scheduled and actual pickup times, regardless of whether it is early or late. It was estimated from the BUS travel logs. Patrons traveling across the entire day (from morning to afternoon) tend to experience less time uncertainty than those traveling only in the morning or only in the afternoon. Those traveling for church, education, or shopping also tend to experience less time uncertainty. Travel during the slowest seasons, summer and winter, has lower time uncertainty. The full model can be found in Appendix G.

> - *Arrival Time Delay*
>
>   This exponential regression model estimates the number of minutes a patron will arrive late at their destination. It was estimated from the BUS travel logs. The results of this model, which can be found in Appendix H, are generally similar to the previous one. Patrons traveling across the entire day (from morning to afternoon) tend to experience less delay than those traveling only in the morning; however, patrons traveling only in the afternoon are likely to experience more delay. Those traveling for church, medical, or shopping also tend to experience less delay. Travel during the slowest seasons, summer and winter, has lower delays.

2.3.3 Accessibility Index

Finally, the third module calculates and presents the DRT accessibility results, based on the aggregation scheme selected by the user. An accessibility value is calculated for each service area zone within the service region based on the following patron-level travel characteristics, developed from the literature review and a survey of DRT patrons in Tyler, Texas: the average number of minutes late patrons from this census block group are arriving at their destination (weighted 50%), the average number of minutes difference between when patrons from this census block group were scheduled to be picked up and when they actually got picked up (weighted 25%), the average difference in minutes between the time patrons spend in the DRT vehicle and the equivalent time it would have taken them if they were able to drive a personal vehicle (weighted 15%), and the percent of the patrons from this zone that were not able to be scheduled during this period (weighted 10%). The full model formulation can be found in Appendix I.

These accessibility values are scaled so that each service area zone is assigned a final relative accessibility index value between 0 and 1, with 1 representing high accessibility. Users have the option of calculating a general accessibility measure across all patrons,

times of day, and trip purposes within each service area zone or calculating a specific disaggregate accessibility measure for any combination of population groups, time of day, and trip purposes. For example, a user would be able to not only evaluate how accessible DRT is generally for patrons from each zone but also how accessible DRT is specifically for women going to work in the morning. If the user uses a specific disaggregate accessibility measure, the accessibility measure for each zone is averaged over only those patrons that meet the specific criteria (i.e. are women working in the morning).

3. DRT ACCESSIBILITY TOOL INTRODUCTION

This section provides an overview of the DRT Accessibility Tool interface and what is required to run the tool. Section 3.2 discusses processing requirements, including preferred system specifications and estimated run times. Section 3.3 thoroughly outlines the specific data required to run the tool, including what to include, how to structure it, and where to get it.

3.1 TOOL OVERVIEW

The DRT Accessibility Tool combines the three modules into an attractive, intuitive, and user-friendly Microsoft Access database package, seen in Figure 2. This platform was primarily selected because it was already familiar to all the DRT system operators interviewed during this research and it can be used without additional training. Equally important is the fact that the database format also allows the tool to be transferable, practical, and valuable for all small and medium-sized communities. In an effort to keep the tool intuitive, it is composed of three tabs based on the specific modules described in the previous section: Service Characteristics, DRT Travel Simulation, and DRT Accessibility Results. Users complete each tab in the order they are presented.

Users first enter fleet and service area characteristics in the appropriate tables of Figure 2. (Refer to the previous section for a more detailed explanation of this data.) Users have the option of entering the data for each vehicle and service area zone in this tab or by copying tables of data directly into the corresponding tables.
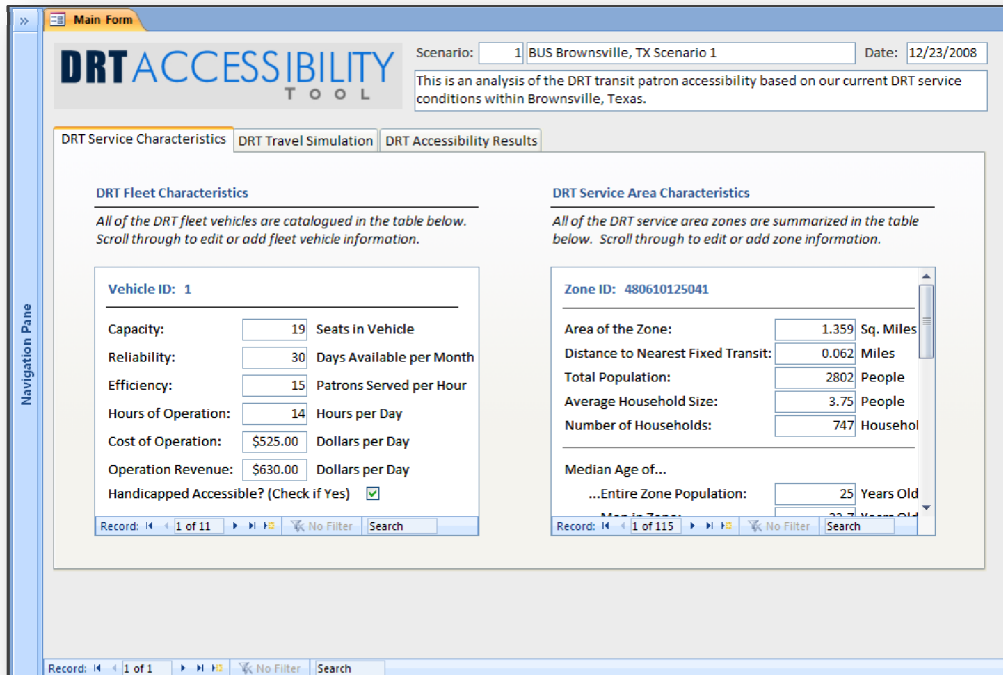
Figure 2: DRT Accessibility Tool: Service Characteristics Tab

Users then move to the second tab to run the travel simulation, shown in Figure 3. Before running the simulation, users must select a few final parameters that affect DRT travel patterns, including the size of the community (rural, town, second city, suburban, urban), timeframe (1 day, 2 days, 3 days, 1 week), and season (summer, fall, winter, spring). The parameter for community size is included within the in-vehicle travel time simulation calculation to reflect the differences in congestion and travel patterns across communities of various sizes. The parameter for season is included within the pickup time uncertainty and arrival time delay calculations to reflect the variation that occurs in these calculations based on seasonal changes. Simulations over longer timeframes offer more precision simply because there are more iterations to compare. General accessibility indices are consistent regardless of the selected timeframe, but this becomes more important for more specific accessibility measures. If a user will be calculating disaggregate accessibility measures, it is recommended that he/she

increases the timeframe. As the simulation runs, the status bar will change to indicate when each model is completed.
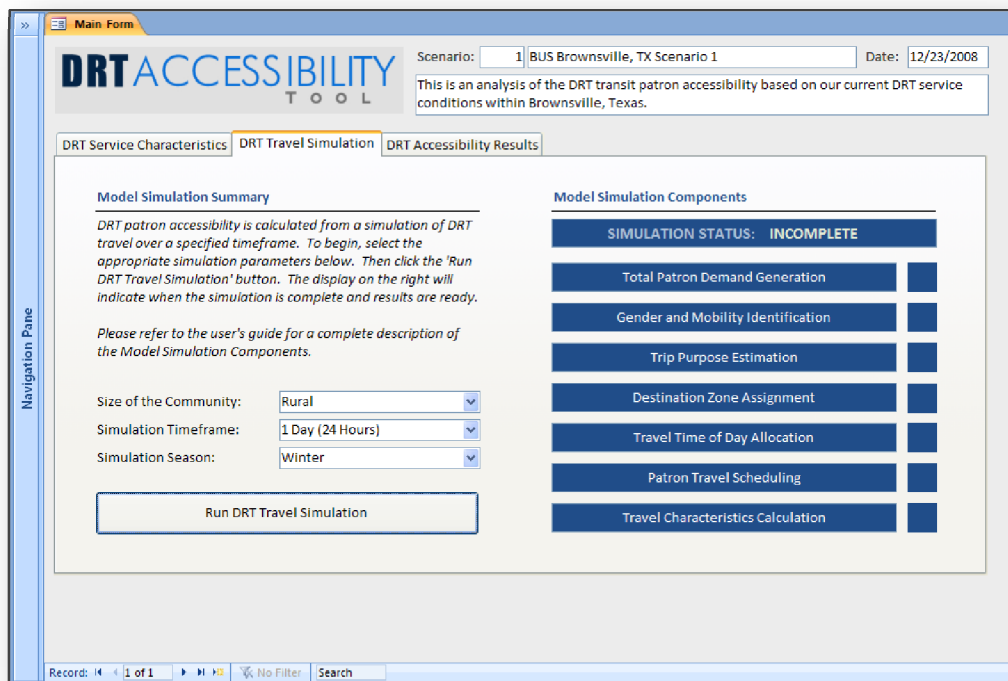
Figure 3: DRT Accessibility Tool: DRT Travel Simulation Tab

In the third tab, shown in Figure 4, users clearly define how they want to measure accessibility. First, users have the option to use the predefined accessibility model parameters or to overwrite them. DRT system operators requested this feature because they wanted the opportunity to use their judgment in controlling these factors. Next, users select the level of accessibility aggregation they want to measure. The tool is robust in that it allows users to measure accessibility for any combination of population groups, time of day, and trip purposes. This means that an operator can calculate accessibility from the general level all the way to any specific level of interest. The final results are queried based on the aggregation and presented in a pop-up table. This tab also features a list of economic details, such as operating costs, generated revenue, and total number of patrons served, that can be compared with the accessibility measure results.
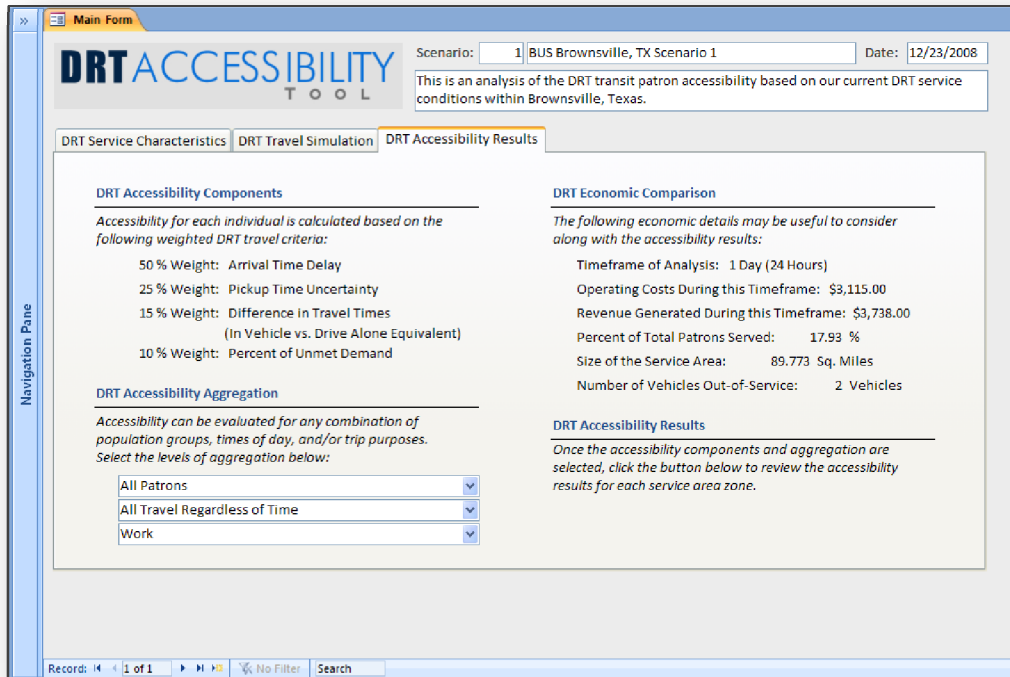
Figure 4: DRT Accessibility Tool: DRT Accessibility Results Tab

3.2 PROCESSING REQUIREMENTS

3.2.1 Preferred System Specification

The minimum computer specifications required to run the DRT Accessibility Tool are a 2 GHz Processor and 2 GB of RAM. Understandably, the faster the processor and the more RAM a computer has, the faster the program will run. Also, because the DRT Accessibility Tool is a database application that relies on functions found within Microsoft Access 2007, users will need to have the most recent version of Microsoft Office to open and run the tool. It is recommended that users are also familiar with Microsoft Access 2007, as this will aid in entering the data.

3.2.2 Estimated Run Times and Factors

The time it takes to run the DRT Accessibility Tool directly depends on the size of the service area used in the scenario. As a result, scenarios with larger service areas will take longer than scenarios with smaller service areas. The reason for this is because the

tool calculates the total number of patrons based on the service area zone characteristics, and service areas with larger populations will inherently generate more DRT patrons. More patrons, in turn, results in more calculations and longer running times. Still, running times are not excessive. For example, a typical service area within rural community or town of roughly 100 square miles will take about 15 minutes to run.

It is also important to recognize that the tool calculates DRT accessibility based on a number of estimated factors, including patron demographics and travel characteristics. Users have the option of improving the precision of these DRT accessibility measures by increasing the timeframe of the study from 1 day (24hrs) to 3 Days (72hrs) or 1 Week (7 Days), but at the cost of increasing the run time. If the user selects either 3 Days or 1 Week, the tool will increase the number of iterations and running time by magnitudes of 3 and 7 times, respectively. The accessibility values are then averaged out over these time frames. For example, if the timeframe for the typical service area within rural community or town of roughly 100 square miles is increased to 3 Days, the tool will take about 60 minutes to run but will provide more precise results. It is recommended that users increase the timeframe if they are interested in measuring accessibility at a very disaggregate level. More disaggregate analyses are, by definition, based on fewer patrons, and by increasing the timeframe the simulation is including more patrons in the simulation.

Once the tool has run, however, the results are permanently saved. This means that users do not need to run the simulation every time they want to review accessibility measures. Users can run the simulation, close the tool, and come back later to review the results. Because the tool saves results, planners can invest a larger amount of time in the beginning and then be able to come back to evaluate accessibility numerous times later.

3.3 DATA REQUIREMENTS

The DRT Accessibility Tool requires three tables of information in order to simulate and measure DRT accessibility. These tables include a service area characteristics table, a fleet characteristics table, and a zone distance table. The contents of these tables and possible data sources are outlined in the following sections.

3.3.1 Service Area Characteristics Table

The first data table describes the DRT service area, which is typically identified as either any area that falls within a specific radius (usually around 5 miles) from a central point or any area that falls within a specific distance (at least ¾ of a mile) from any fixed transit route. The tool requires that the service region be divided into zones, as it will calculate an accessibility measure (based on the specified aggregation scheme) for each of these zones. Users may use any type of zone system that exists for their region, such as traffic analysis zones (TAZs) or census block groups (CBGs). User should also select a zone scale such that calculating one accessibility measure for each zone will be appropriate and beneficial to the transit provider.

It is recommended that users first compile and generate the service area characteristics in ArcGIS. ArcGIS is especially helpful in calculating certain characteristics, such as 'Distance from Zone Centroid to Nearest Transit Line', and the ArcGIS zone database can be easily exported and edited. It is also recommended that users build the Service Area Characteristics Table in Microsoft Excel for ease in copying the data into the tool. It is also useful to have an ArcGIS map of the service area zones to incorporate and present the final accessibility measures.

The Service Area Characteristics Table should be setup so that each zone is a row, or record, and characteristics are listed as columns. The characteristics required for each zone, which can be treated as the column headings, are as follows (please note the footnoted additional comments below as well):

- Scenario ID [1]
- Zone ID [2]
- Total Number of Households Living within the Zone
- Total Number of People Living within the Zone
- Area of Zone, in Square Miles
- Population Density of Zone, in Number of People/ Square Mile [3]
- Distance from Zone Centroid to Nearest Transit Line [4]
- Median Age of Total Zone Population
- Median Age of Men within the Zone
- Median Age of Women within the Zone
- Average Household Size within the Zone
- Total Number of Households that Rent Within the Zone
- Total Number of Households that are Married with Children within the Zone
- Total Number of Households that are Married without Children within the Zone
- Total Number of People Living in Zone Aged 18-29
- Total Number of People Living in Zone Aged 30-49
- Total Number of People Living in Zone Aged 50-64
- Total Number of People Living in Zone Aged 65 or Older
- Percent of Area within the Zone Designated for Apartments [5]
- Percent of Area within the Zone Designated for Commercial (including Public Buildings and Space) [5]
- Percent of Area within the Zone Designated for Retail [5]
- Percent of Area within the Zone Designated for Manufacturing (including Industrial) [5]
- Percent of Area within the Zone Designated for Residential [5]
- Number of Patrons [6]

ADDITIONAL COMMENTS:

1. The 'Scenario ID' is one greater than the number of scenarios already saved in the tool. Every record (i.e. zone) MUST have the same 'Scenario ID'. This MUST be consistent among the three tables.
2. Users may use any numbering system to identify the zones, but this numbering system MUST be consistent with Zone Distances table. It MUST have unique IDs for each zone.
3. 'Population Density of Zone' = 'Total Number of People Living within the Zone'/' Area of Zone'
4. 'Distance from Zone Centroid to Nearest Transit Line' can be calculated in ArcGIS using the following general steps. If you do not have this information, just enter all zeros in this column.
   a. Convert zones into centroids.
   b. Join centroids with the transit route layer. Record distance value.
   c. Join centroids back to zones.
5. The sum of these 5 land use designations must equal 100% for each zone.
6. This column must be all blank. The number of patrons is calculated by the tool, but this column MUST be blank to start with.

The DRT Accessibility Tool was designed using census block groups as the service area zone system. As such, the model and table are designed around the census block group SF1 demographic data. Fortunately, the census block group shapefiles and demographic data are available for planners and transit system operators to download for free at http://arcdata.esri.com/data/tiger2000/tiger_download.cfm. If the user does not have an existing zone system for their service region, it is recommended that he/she use census block groups. To access the files follow these steps:

1. Go to http ://arcdata.esri.com/data/tiger2000/tiger_download.cfm (as seen in Figure 5)
2. Click on the US state your DRT Service is located.
3. Select the appropriate county from the Drop-down menu. Click 'Submit Selection'.
4. Check the box next to 'Block Groups 2000'.
5. Check the box next to 'Census Block Group Demographics (SF1)'.
6. Click 'Proceed to Download'.
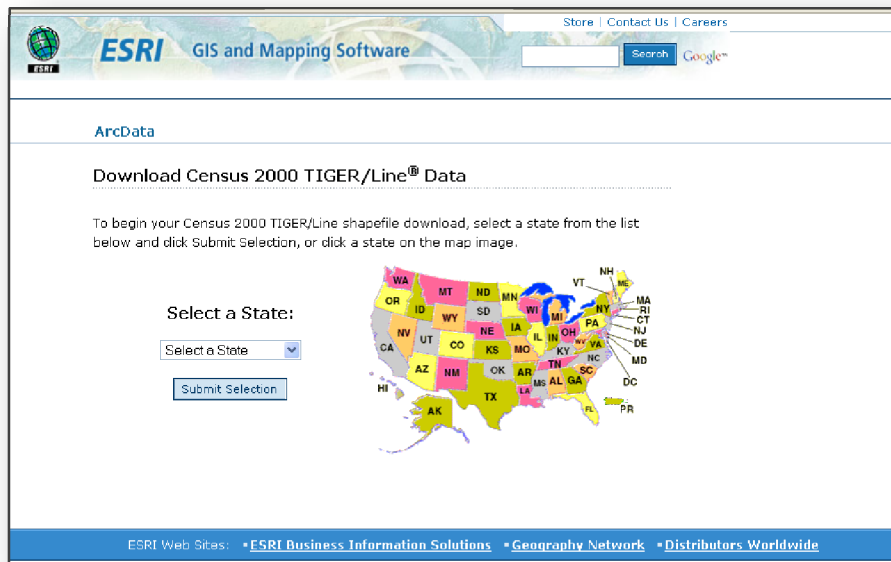
Figure 5: ESRI Census Data Website

3.3.2 Fleet Characteristics Table

The second data table describes the DRT fleet, which can be composed of any number of different paratransit vehicles. The tool is flexible to allow for a fleet of any size or composition, and incorporates readily available data describing each vehicle. It is recommended that users build the Fleet Characteristics Table in Microsoft Excel for ease in copying the data into the tool.

The Fleet Characteristics Table should be setup so that each vehicle is a row, or record, and characteristics are listed as columns. The characteristics required for each vehicle, which can be treated as the column headings, are as follows (please note the footnoted additional comments below as well):

- Scenario ID [1]
- Vehicle ID [2]
- Capacity, described as the maximum number of passengers the vehicle can hold
- Reliability, described as the number of days the vehicle is available on an average month
- Efficiency, described as the number of patrons the vehicle can typically serve in an hour
- Daily cost of vehicle operation, in dollars
- Daily revenue of vehicle operation, in dollars
- Number of hours vehicle is in service each day
- Whether or not the vehicle is able to support mobility-impaired patrons, designated as 'TRUE' or 'FALSE'

ADDITIONAL COMMENTS:

1. The 'Scenario ID' is one greater than the number of scenarios already saved in the tool. Every record (i.e. vehicle) MUST have the same 'Scenario ID'. This MUST be consistent among the three tables.
2. Users may use any numbering system to identify the vehicles, but this numbering system MUST have unique IDs for each vehicle.

3.3.3 Zone Distances Table

The final data table lists the straight line distance between the centroids of every possible pair of service area zones. This table is important to create spatial relationships between each of the zones. It is recommended that users first build the table in Microsoft Excel for ease in copying the data into the tool.

The Zone Distances Table should be setup so that there is one row, or record, for every pair of zones. It is important to note that order matters in this table because zones are being treated as 'Origins' and 'Destinations', so it needs to include reverse combinations as well. For example, even though the distances are the same, the table would need to include two separate records for travel from Zone 1 to Zone 2 and travel from Zone 2 to Zone 1. The column headings in this table are as follows (please note the footnoted additional comments below as well):

- Scenario ID [1]
- Origin Census Block Group ID [2]
- Destination Census Block Group ID [2]
- Distance Between Origin and Destination Census Block Groups, in Miles

ADDITIONAL COMMENTS:

1. The 'Scenario ID' is one greater than the number of scenarios already saved in the tool. Every record (i.e. zone pair) MUST have the same 'Scenario ID'. This MUST be consistent among the three tables.
2. Users MUST use the zone numbering system introduced in the Service Area Characteristics table.

4. USING THE TOOL STEP-BY-STEP

The purpose of this section is to provide step-by-step instructions for (1) opening the tool, (2) entering data, (3) measuring accessibility, and (4) presenting results in ArcGIS.

4.1 OPENING THE TOOL

STEP 1: Open DVD
1. Put DVD into computer, and open window to display contents.
2. Right-Click file entitled 'DRT Accessibility Tool.accdb'.
3. Select 'Copy'.

STEP 2: Copy DVD Contents
1. Navigate to and open the folder where you would like to store the tool file.
2. Right-Click any blank space in the folder.
3. Select 'Paste'.

STEP 3: Open Tool
1. Double-Click on the file you just pasted entitled 'DRT Accessibility Tool.accdb'. This will open the tool and Microsoft Access at the same time. (Alternatively, you may open Microsoft Access and navigate to the file you just pasted entitled 'DRT Accessibility Tool.accdb'.)
2. On the 'Security Warning', click the box labeled 'Options'.
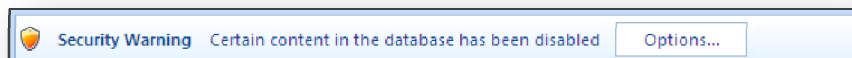
3. Select 'Enable this content'.
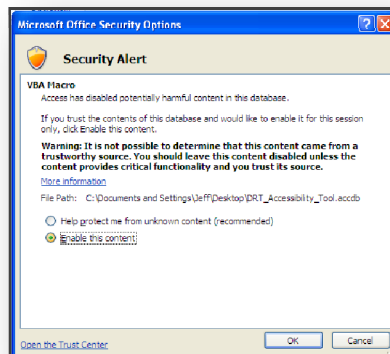
4. Click 'OK'.

5. The DRT Accessibility Tool database application is now open.
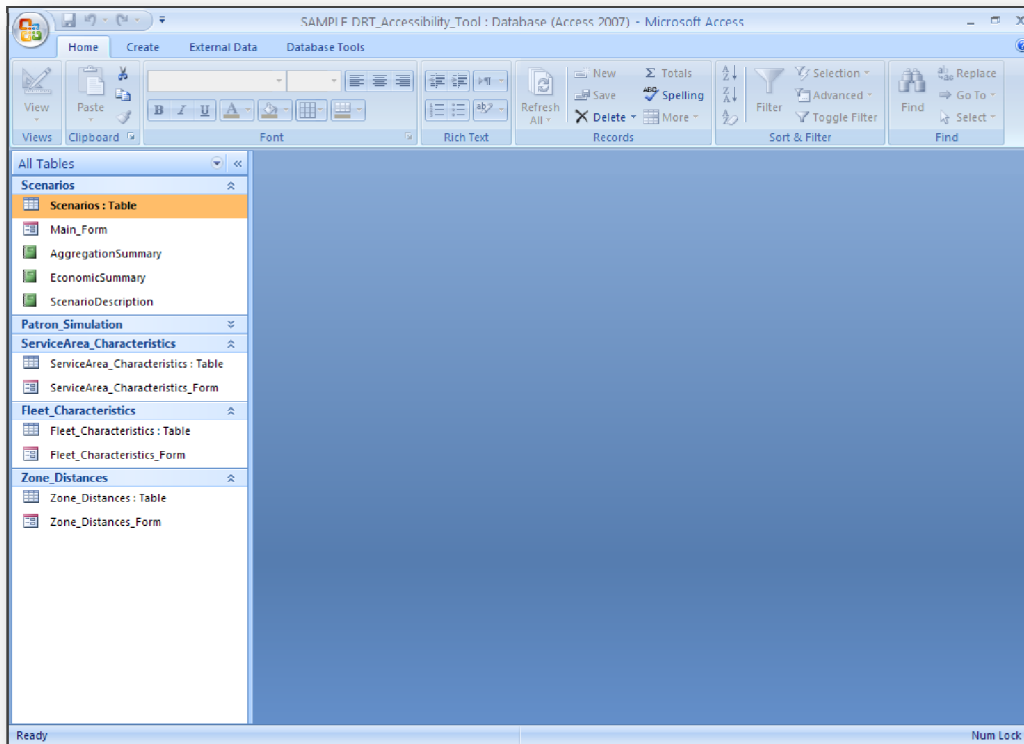
4.2 ENTERING DATA

STEP 1: Formulate Tables in MS Excel

1. Refer to Section 3.3 for descriptions of the three required tables of data: service region characteristics, fleet characteristics, and zone distances.
2. Organize the data tables in Microsoft Excel. It is recommended that you use add column names for each variables to ensure that all required variables are present and in the exact order presented in Section 3.3. It is further recommended that you use a separate tab for each table. In the service area characteristics table, each row should contain the information a different zone. In the fleet characteristics table, each row should contain information for a different vehicle. In the zone distances table, each row should contain the distance between a different pair of zones. It is critically important to follow the exact formulation presented in Section 3.3. Any blank records or fields will result in an error. The following figure illustrates an example of the zone distances table in Excel.

Scenario ID	Origin Zone	Destination Zone	Distance
1	1	2	0.5
1	1	3	3.4
1	2	1	0.5
1	2	3	10
1	3	1	3.4
1	3	2	10

STEP 2: Open Tool in MS Access

1. Refer to Section 4.1 if this is the first time the tool is being opened.
2. Otherwise, navigate to and double-click the file you saved entitled ''DRT Accessibility Tool.accdb'. This will open the tool.
3. If the 'Security Warning' appears, click the box labeled 'Options', select 'Enable this content', and click 'OK'.
4. Double-click the Form entitled 'Main_Form', under the 'Scenarios' header.
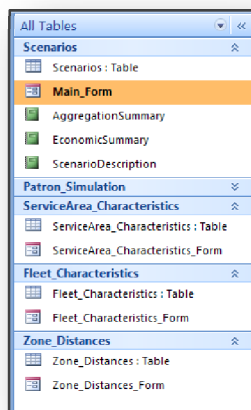
5. The Main Form is now open. The following figure illustrates what the Main Form will look like.
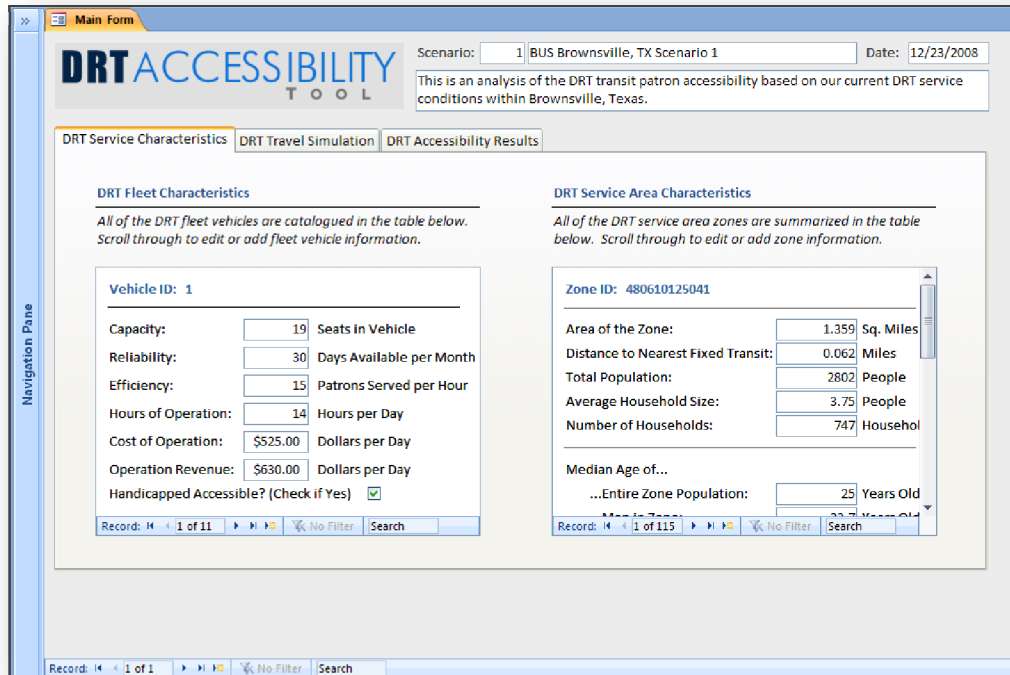
STEP 2: Create New Scenario

1. Start by going to the bottom of the Main Form to the 'Record' Toolbar. Click the icon highlighted in the red box in the following illustration. This opens a new scenario that you can edit. Confirm that the Scenario Number and Description are blank.

2. Start by entering some descriptive information about the scenario that can be used to identify this specific evaluation at the top of the Main Form. First, enter a number and name for the scenario. (The scenario number must be unique.) Confirm this scenario number is the same as the Scenario ID from the data you just compiled. Next, enter the current date. Finally, enter a description of the scenario. The name and description provided here will also appear on the final data report.
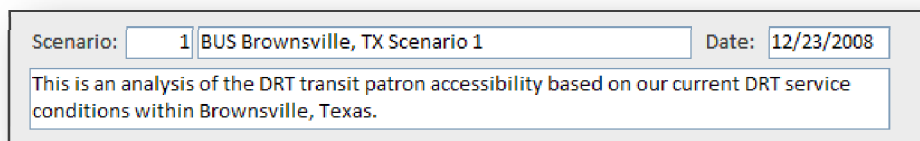
3. Close the Main Form.
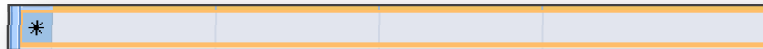
STEP 3: Copy Service Area Characteristics Data

1. Return to the Excel spreadsheet that contains the service area characteristics data table.
2. Highlight all the data within the table. Confirm that that all required variables are present and in the exact order presented in Section 3.3. Do not highlight the column names. Do not highlight any blank cells. In the example figure above, the data within the dark box is what should be selected.
3. Right-click the selection.
4. Click 'Copy'.

STEP 4: Paste Service Area Characteristics Data

1. Return to the DRT Accessibility Tool in MS Access.
2. Double-click the Table entitled 'ServiceArea_Characteristics : Table', under the 'ServiceArea_Characteristics' header on the Navigation Pane.
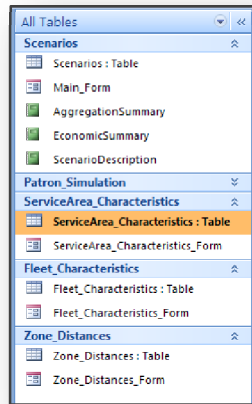
3. The Service Area Characteristics Table is now open.
4. Right-click on the asterisk located on the left of the last row in the table. The values in this row will be blank. If you have any scenarios already saved in the Tool, you will need to scroll past the service area records for the other scenario(s) to the bottom of the table to find the asterisk.

5. Click 'Paste'.
6. The service area characteristic data is now entered into the Tool. The following figure illustrates what the final table will look like.

7. Close the table.

## STEP 5: Copy Fleet Characteristics Data

1. Return to the Excel spreadsheet that contains the fleet characteristics data table.
2. Highlight all the data within the table. Confirm that that all required variables are present and in the exact order presented in Section 3.3. Do not highlight the column names. Do not highlight any blank cells.
3. Right-click the selection.
4. Click 'Copy'.

STEP 6: Paste Fleet Characteristics Data

1. Return to the DRT Accessibility Tool in MS Access.
2. Double-click the Table entitled 'Fleet_Characteristics : Table', under the 'Fleet_Characteristics' header on the Navigation Pane.
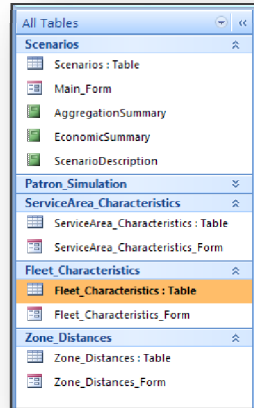
3. The Fleet Characteristics Table is now open.
4. Right-click on the asterisk located on the left of the last row in the table. The values in this row will be blank. If you have any scenarios already saved in the Tool, you will need to scroll past the fleet records for the other scenario(s) to the bottom of the table to find the asterisk.

5. Click 'Paste'.
6. The service area characteristic data is now entered into the Tool. The following figure illustrates what the final table will look like.

7. Close the table.

STEP 7: Copy Zone Distances Data

1. Return to the Excel spreadsheet that contains the zone distance data table.
2. Highlight all the data within the table. Confirm that that all required variables are present and in the exact order presented in Section 3.3. Do not highlight the column names. Do not highlight any blank cells.
3. Right-click the selection.
4. Click 'Copy'.

STEP 8: Paste Zone Distances Data

1. Return to the DRT Accessibility Tool in MS Access.
2. Double-click the Table entitled 'Zone_Distances : Table', under the 'Zone_Distances' header on the Navigation Pane.
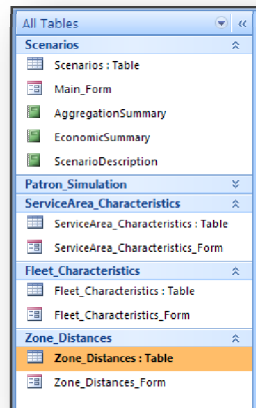
3. The Zone Distances Table is now open.
4. Right-click on the asterisk located on the left of the last row in the table. The values in this row will be blank. If you have any scenarios already saved in the Tool, you will need to scroll past the zone distance records for the other scenario(s) to the bottom of the table to find the asterisk.
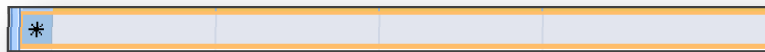
5. Click 'Paste'.
6. The zone distances data is now entered into the Tool. The following figure illustrates what the final table will look like.
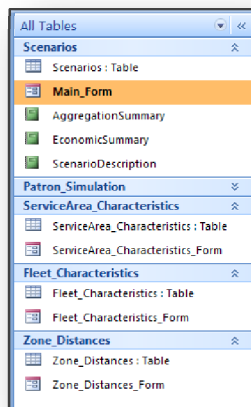
7. Close the table.

4.3 MEASURING ACCESSIBILITY

STEP 1: Open Tool in MS Access

8. Refer to Section 4.1 if this is the first time the Tool is being opened.
9. Otherwise, navigate to and double-click the file you saved entitled ''DRT Accessibility Tool.accdb'. This will open the Tool.
10. If the 'Security Warning' appears, click the box labeled 'Options', select 'Enable this content', and click 'OK'.
11. Double-click the Form entitled 'Main_Form', under the 'Scenarios' header on the Navigation Pane.

12. Minimize the Navigation Pane by clicking the arrow at the top of the Navigation Pane (Highlighted in red in the following illustration).
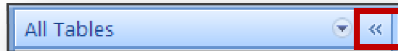
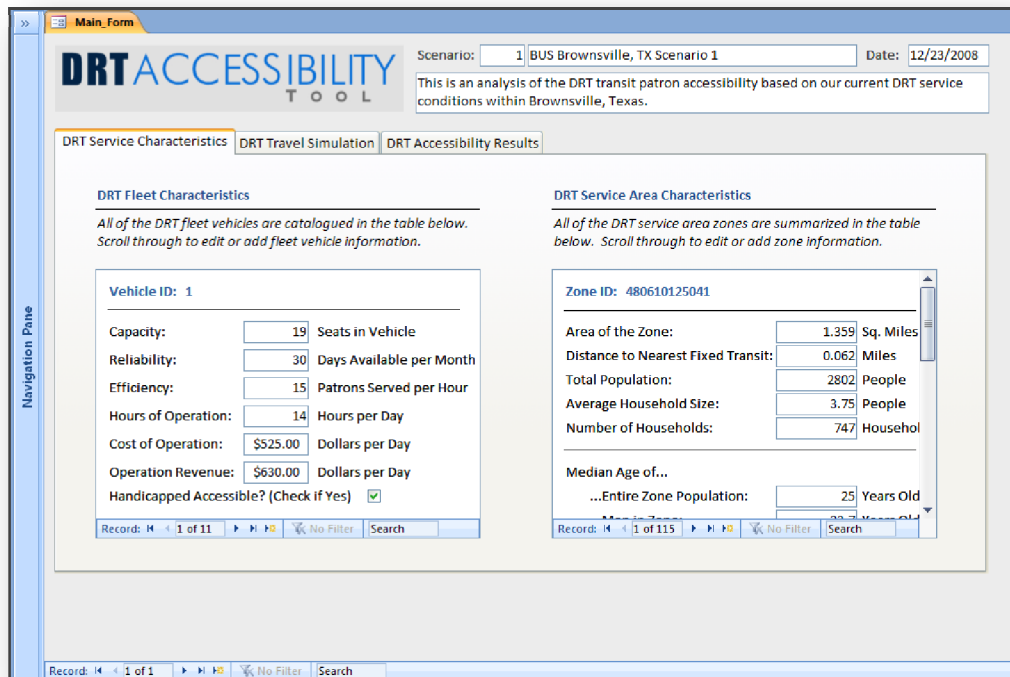13. The Main Form is now open. The following figure illustrates what the Main Form will look like. The form is organized with three main tabs below the scenario information. These tabs are based on the three modules described in the previous sections: Service Characteristics, DRT Travel Simulation, and DRT Accessibility Results.

STEP 2: Locate Scenario

1. Start by going to the bottom of the Main Form to the 'Record' Toolbar. Use the arrow buttons or search option to get to the preferred scenario. Use the scenario number, names, dates, and descriptions at the top of the Main Form to identify the correct scenario.
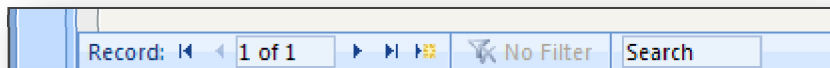
2. When the correct scenario is located, proceed to Step 3.

STEP 3: Confirm Data Is Entered
1. Click on the 'DRT Service Characteristics' tab if it is not already selected. You should see two subheadings in this tab: 'DRT Fleet Characteristics' and 'DRT Service Area Characteristics'. This tab presents the previously entered fleet and service area data in tables below the subheadings in a straightforward and easy-to-edit manner.

2. Confirm the DRT fleet and service area data are entered correctly by scrolling through all of the vehicles and zones using the arrow buttons on the 'Record' Toolbars imbedded in this tab. Additionally, you may use the scrollbar to review more details about each of the DRT zones. Particularly confirm the following facts:
    a. There are the correct number of vehicles
    b. There are the correct number of service area zones
    c. All of the data is present for each vehicle
    d. All of the data is present for each service area zone
3. If any data is missing or incorrect, either edit it or go back and review the steps in Section 4.2 to make sure the data was entered correctly.
4. When all the data is present and correct, proceed to Step 4.

STEP 4: Define Model Simulation Components
1. Click on the 'DRT Travel Simulation' tab. You should see two components in this tab: 'Model Simulation Summary' and 'Model Simulation Components'. In this tab you will simulate the DRT patron travel for which accessibility will be later measured. The 'Model Simulation Summary' tab allows you to control the simulation components, and the 'Model Simulation Components' tab tracks the progress of the simulation.
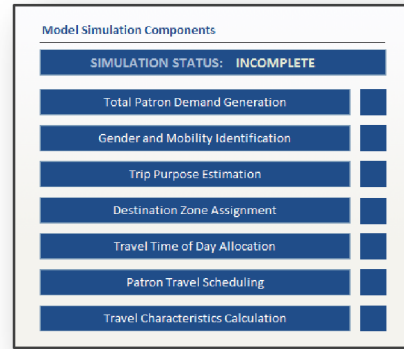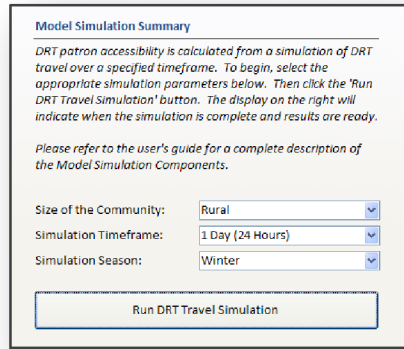
2. Choose the size of the community from the 'Size of the Community' drop-down list. The options include urban, suburban, second city, town, and rural. This designation is used to in the in-vehicle travel time calculation.

3. Choose the simulation timeframe from the 'Simulation Timeframe' drop-down list. The options include 1 Day (24 Hours), 3 Days (72 Hours), and 1 Week (7 days). This choice controls how many iterations the Tool will run: 1, 3 and 7 iterations, respectively. The more iterations the Tool performs, the higher the precision of the results. However, more iterations means that the Tool will take longer to run as well. Refer to Section 3.2.2 for more information on the implications of this decision.

4. Choose the season you would like to evaluate in this scenario from the 'Simulation Season' drop-down list. The options include spring, summer, winter, and fall. This designation is used in the pickup time uncertainty and arrival time delay calculations.

5. When the components are selected, proceed to Step 5.

STEP 5: Run DRT Travel Simulation

1. Continuing on the "DRT Travel Simulation' tab, click the 'Run DRT Travel Simulation' button. This starts the simulation. It is recommended that you close all other programs before running the simulation, and that you do not attempt to do anything else with the Tool while the simulation is running. This may take anywhere from a few minutes to more than half an hour, depending on the size of your service region, number of iterations, and the computer's processing speed.
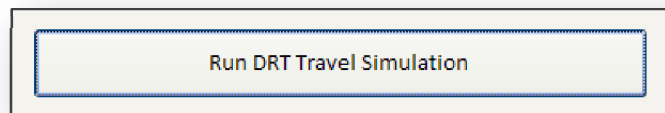
2. The Tool tracks the progress of the simulation under the 'Model Simulation Components' subheading. Initially, the 'SIMULATION STATUS' will read "INCOMPLETE". As the simulation runs, the 'SIMULATION STATUS' will read "PROCESSING". Similarly, the Tool will indicate when each simulation component is completed by turning the dark square next to that component green. Refer to Section 2.3.2 for a complete summary of

the simulation models. Once the simulation is started, there is no way to stop it except for closing down MS Access.

3. When the simulation is complete, the 'SIMULATION STATUS' will read "COMPLETE". The 'Model Simulation Components' subheading will look like the following illustration. It is important to recognize that the Tool always stores the results from the last simulation run. If you would like to run the simulation again, it will overwrite the current results. Either way, because the results are permanently stored, you can close the Tool and come back and view the results at any time.
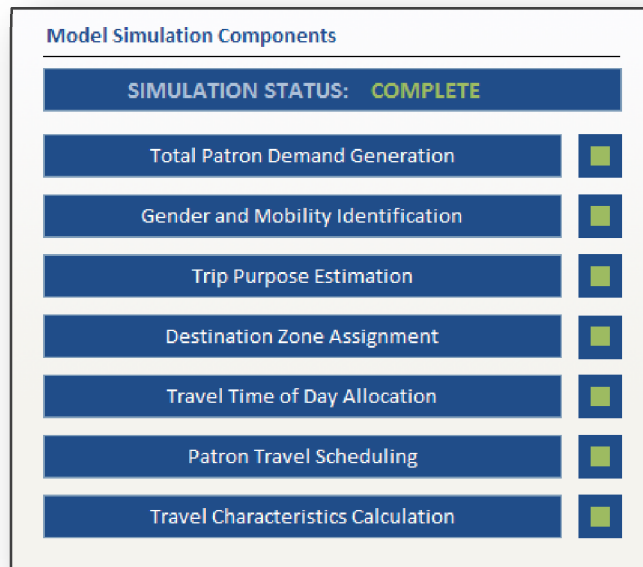
4. When the 'SIMULATION STATUS' reads "COMPLETE", proceed to Step 6.

STEP 6: Define DRT Accessibility Aggregation Scheme

1. Click on the 'DRT Accessibility Results' tab. You should see four components in this tab: "DRT Accessibility Components", "DRT Economic Comparison", which "DRT Accessibility Aggregation", and "DRT Accessibility Results". This tab summarizes accessibility, the scenario, and aggregation.

2. Accessibility for each individual is measured based on the weighted DRT travel criteria presented under the 'DRT Accessibility Components' subheading. These weights are predefined based on DRT patron survey results. If you would like to change the weights based on findings from your own area, you can edit them by clicking on each. If you are changing these weights, it is important to recognize that these weights need to sum to 100% for the accessibility measure to be accurate.

3. The 'DRT Economic Comparison' subheading provides context when reviewing the DRT accessibility results. These details are calculated as part of the simulation and reflect the simulated patron travel. These values cannot be changed.

DRT Economic Comparison

The following economic details may be useful to consider along with the accessibility results:

Timeframe of Analysis: 1 Day (24 Hours)

Operating Costs During this Timeframe: $3,258.00

Revenue Generated During this Timeframe: $3,402.00

Percent of Total Patrons Served: 16.32 %

Size of the Service Area: 89.773 Sq. Miles

Number of Vehicles Out-of-Service: 0 Vehicles

4. In order to review results, you must first select an aggregation scheme. You have the option of evaluating accessibility for the general population, a specific type of patron, a specific time of day, a specific trip purpose, or any combination thereof. Start by selecting the 'Population Aggregation' from the drop-down list. Options include male patrons only, female patrons only, mobile patrons only, mobility-impaired patrons only, mobile male patrons only, mobility-impaired male patrons only, mobile female patrons only, mobility-impaired female patrons only, and all patrons.

DRT Accessibility Aggregation

Accessibility can be evaluated for any combination of population groups, times of day, and/or trip purposes. Select the levels of aggregation below:

All Patrons

All Travel Regardless of Time

All Trip Purposes

5. Select the 'Time Of Day Aggregation' from the drop down list. Options include travel begun in the AM and ending in the AM, travel begun in the AM and ending in the PM, travel begun in the PM and ending in the PM, travel begun in the AM regardless of end time, travel ending in the PM regardless of start time, and all travel regardless of time.

6. Select the 'Trip Purpose Aggregation' from the drop-down list. Options include church/meeting, education/school, recreation, medical/therapy, shopping, work, and all trip purposes.

7. Only when all three aggregation levels are selected does the button to review results appear under the 'DRT Accessibility Results' subheading. When it is visible, click the button to review the results and proceed to Step 7.

Review DRT Accessibility Results

STEP 7: Review DRT Accessibility Results

1. The DRT accessibility results based on the aggregation scheme entered in the Main Form are presented in a report similar to the one presented in the following illustration. This report opens in a new Print Preview tab, and it includes the scenario description, aggregation scheme, economic comparison, and accessibility results for each service area zone. The accessibility results are structured so that there is one DRT Patron Accessibility Index value for each service area zone between 0 and 1, with 1 representing high accessibility. Service area zones are ordered in numerical order. Refer to Section 2.3.3 for a summary of how these Indices are calculated.

    a. If the index has a value between 0 and 1, this is the average accessibility for patrons matching the aggregation scheme within the zone.

    b. If the index is blank, this means that there are no patrons that match the aggregation scheme within the zone.

    c. If the index has a value of 0, this means that there are patrons that match the aggregation scheme within the zone but all of them were not able to be served.

2. You can navigate through the pages of the report by using the 'Page' Toolbar at the bottom of the report. Use the arrow buttons to get through the pages.

3. You can print the report by clicking the Print button at the top left corner of the page.

4. It is important to note that it is not possible to save this report since it is based on a temporary query. However, you can reopen it anytime by returning the Main Form, selecting the same aggregation scheme and opening the report. The simulation data for each scenario is saved in the Tool so you do not need to run the simulation every time you want to review results.

5. When you are done, close the report.

4.4 PRESENTING RESULTS IN ARCGIS

STEP 1: Retrieve Accessibility Results

1. Navigate to and double-click the file you saved entitled ''DRT Accessibility Tool.accdb'. This will open the Tool.
2. If the 'Security Warning' appears, click the box labeled 'Options', select 'Enable this content', and click 'OK'.
3. Double-click the Form entitled 'Main_Form', under the 'Scenarios' header on the Navigation Pane.
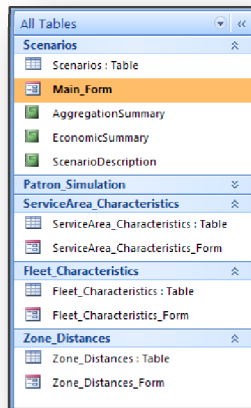
4. Minimize the Navigation Pane by clicking the arrow at the top of the Navigation Pane (Highlighted in red in the following illustration).
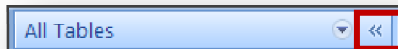
5. The Main Form is now open. The following figure illustrates what the Main Form will look like. The form is organized with three main tabs below the scenario information. These tabs are based on the three modules described in the previous sections: Service Characteristics, DRT Travel Simulation, and DRT Accessibility Results.
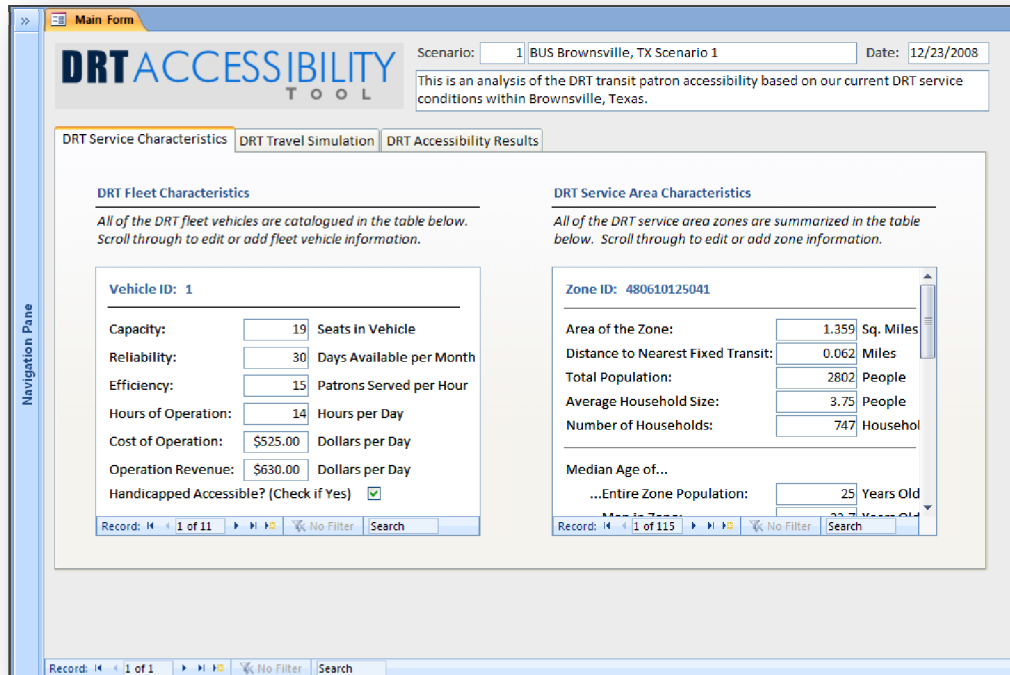
6. Click on the 'DRT Accessibility Results' tab. NOTE: You do not need to rerun the simulation to review results. Travel characteristics from the most recent simulation are saved in the Tool.

7. In order to review results, you must first select an aggregation scheme. You have the option of evaluating accessibility for the general population, a specific type of patron, a specific time of day, a specific trip purpose, or any combination thereof. Start by selecting the 'Population Aggregation' from the drop-down list. Options include male patrons only, female patrons only, mobile patrons only, mobility-impaired patrons only, mobile male patrons only, mobility-impaired male patrons only, mobile female patrons only, mobility-impaired female patrons only, and all patrons.

8. Select the 'Time Of Day Aggregation' from the drop down list. Options include travel begun in the AM and ending in the AM, travel begun in the AM and ending in the PM, travel begun in the PM and ending in the PM, travel begun in the AM regardless of end time, travel ending in the PM regardless of start time, and all travel regardless of time.

9. Select the 'Trip Purpose Aggregation' from the drop-down list. Options include church/meeting, education/school, recreation, medical/therapy, shopping, work, and all trip purposes.

10. Only when all three aggregation levels are selected does the button to review results appear under the 'DRT Accessibility Results' subheading. When it is visible, click the button to review the results and proceed to Step 7.

11. The DRT accessibility results based on the aggregation scheme entered in the Main Form are presented in a report similar to the one presented in the following illustration. This report opens in a new Print Preview tab, and it includes the scenario description, aggregation scheme, economic comparison, and accessibility results for each service area zone. The accessibility results are structured so that there is one DRT Patron Accessibility Index value for each service area zone between 0 and 1, with 1 representing high accessibility. Refer to Section 2.3.3 for a summary of how these Indices are calculated.

    a. If the index has a value between 0 and 1, this is the average accessibility for patrons matching the aggregation scheme within the zone.

    b. If the index is blank, this means that there are no patrons that match the aggregation scheme within the zone.

    c. If the index has a value of 0, this means that there are patrons that match the aggregation scheme within the zone but all of them were not able to be served.
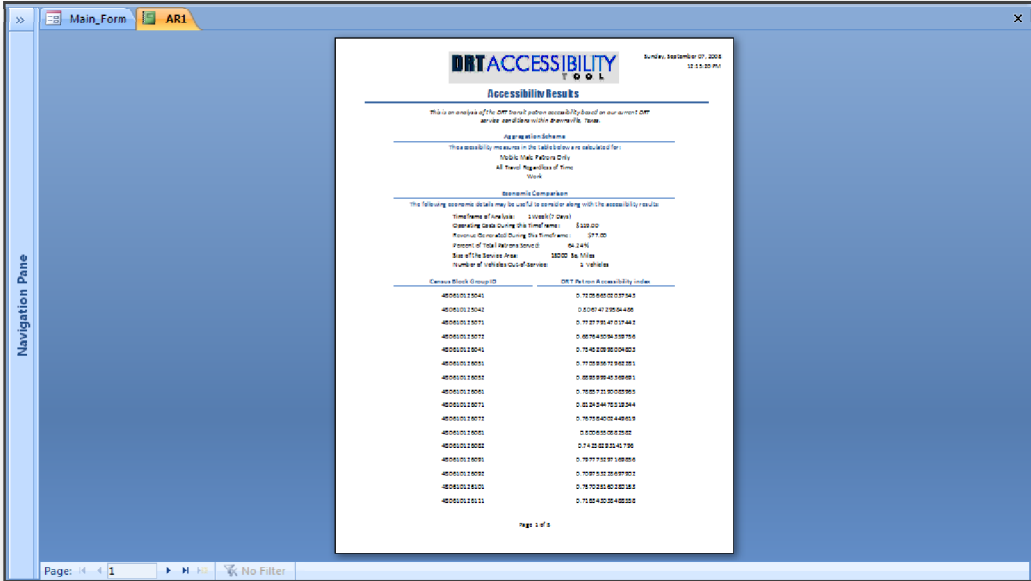
12. You can navigate through the pages of the report by using the 'Page' Toolbar at the bottom of the report. Use the arrow buttons to get through the pages.

13. Print the report by clicking the Print button at the top left corner of the page.

STEP 2: Create Map of Service Region

    1. Open ArcGIS.

2. If you already have a map created of the service area zones from when you created that data, open that existing map. Otherwise: Check 'A new empty map', Click 'OK', Click the Add Data button, and Navigate to and add the service area zones shapefile to the map.

STEP 3: Open Attribute Table
1. Right Click the service area layer/shapefile on the Layer List.
2. Click 'Open Attribute Table'.
3. This opens the attribute table for the service area zones.

STEP 4: Edit Data
1. Click the 'Options' button at the bottom of the attribute table.
2. Click 'Add Field…'.
3. Type "Accessibility" (without quotes) into the 'Name' space.
4. Choose 'Double' as the 'Type'.
5. Click 'OK'.
6. Right Click the field column name for the service area zone IDs.
7. Click 'Sort Ascending'.
8. Click 'Editor' button at the top of the screen.
9. Click 'Start Editing'.
10. On the attribute table, scroll to the new field labeled 'Accessibility'.
11. Refer to the printed report from the DRT Accessibility Tool. Enter the appropriate DRT Patron Accessibility Index value for each service area zone.
12. When all the values are entered, click 'Editor' button.
13. Click 'Stop Editing' and 'Yes' when it asks to save edits.

STEP 5: Create Color Theme
1. Right Click the service area layer/shapefile on the Layer List.
2. Click 'Properties…'.
3. Click the 'Symbology' tab.
4. Set 'Fields' 'Value' as 'Accessibility' and 'Normalization' as 'None'.
5. Set 'Classification' as 'Natural Breaks (Jenks)' with 4 Classes. This means that you will be dividing the service area zones into 4 quartiles based on accessibility measures.
6. Choose a color pattern from the 'Color Ramp'.
7. Edit the 'Label's so that the 'Range' closest to 1 is 'High Accessibility' and the 'Range' closest to 0 is 'Low Accessibility'. Label the two ranges in between as 'Average High Accessibility' and 'Average Low Accessibility'.
8. Click 'OK'. The map now presents the accessibility results ranked in four quartiles.

5. TOOL APPLICATIONS

Over 21% of the United States' population currently resides in small and medium sized communities (Northeast Midwest Institute, 2002), and these numbers are projected to increase as such areas continue to develop as nationally critical economic centers (Cambridge Systematics, Inc. et al., 2008). Unfortunately, DRT transit systems within small and medium sized communities already face many challenges that restrict how well they can serve their community, including limited funding, understaffing, aging fleets, a lack of technical support, a lack of quantification of level of service standards, and reduced modeling/planning practices. As populations within such regions grow these challenges will be amplified, resulting in potentially reduced mobility and stunted economic growth. Therefore, it is critically important that small and region communities take a proactive approach to transit planning. The DRT Accessibility Tool presented in this paper can be easily applied to DRT service regions of any size to assist transit system operators in these efforts. In fact, the Tool is specifically designed around practitioner needs and expertise. System operators can use the Tool for two main planning applications: First, they can evaluate their current accessibility levels for various combinations of population groups, service areas, and travel purposes. Second, the Accessibility Tool allows system operators to undertake "what if?" scenarios to evaluate changes in fleet characteristics (supply), population demographics (demand), and service areas (scope).

5.1 BENCHMARKING ACCESSIBILITY

The most straightforward application of the Tool is to evaluate current accessibility level for various combinations of population groups, service areas, times of day, and travel purposes. Much of the previous literature is focused on methods for benchmarking current practices, and the Tool provides such detailed benchmarking measures of accessibility that can be compared over time. By using the Tool in this capacity, system

operators can study current service needs or evaluate accessibility trends over time. Furthermore, system operators can measure accessibility spatially on a regional scale or focus on specific population groups/times/trip purposes to identify areas that need more reliable service or specific population groups that need to be targeted. Figure 5 illustrates an application of the DRT Accessibility Tool to study general DRT accessibility in Brownsville, Texas. Each census block group has been assigned an accessibility index value that measures how well patrons from that block group are being served based on overall travel needs. These accessibility index values are ranked into four equal-sized groups (or quartiles) that represent the four levels of accessibility within the service region. The lightest census block groups are in the quartile identified as best serving patrons needs. As the census block groups coloring gets darker, their level of patron accessibility diminishes. In this example, DRT service provides the best accessibility for patrons living in the areas along the main highway corridor where street networks and land uses are more densely developed. System operators and planners can use maps such as this one to locate areas where DRT service may need to be improved or further studied.

Benchmarking can be accomplished with the Tool by creating different scenarios for the DRT system over time. As users create scenarios it will be important to date and effectively describe each one. By having multiple scenarios (instead of just changing the data for a single scenario), users can compare accessibility for different aggregation schemes over time. Users can use the Tool to methodically document growth and identify accessibility trends. The ability to show benchmarks such as this will become increasingly important in the near future as funding relies more on these indicators.
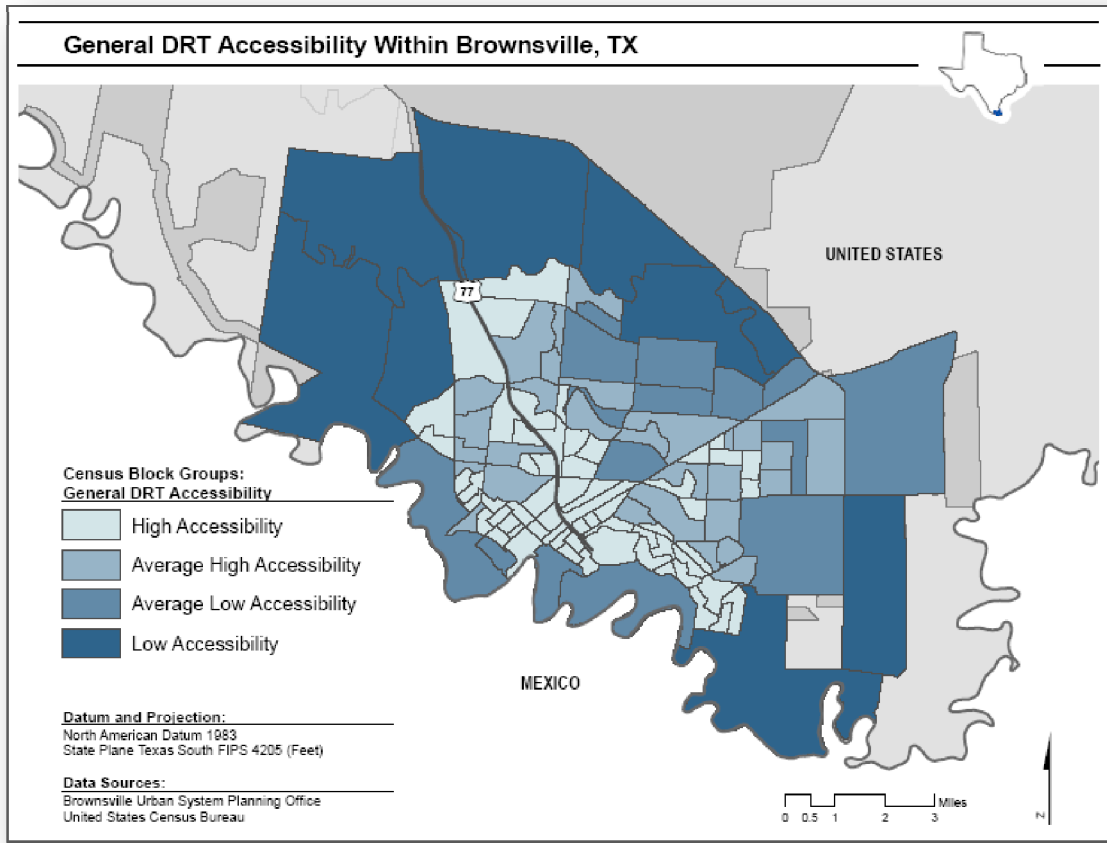
Figure 5: General DRT Accessibility Within Brownsville, TX

5.2 'What If?' SCENARIOS

More importantly, however, is the ability to conduct "what if?" scenarios to evaluate changes in fleet characteristics (supply), population demographics (demand), and service areas (scope). The Tool allows an operator to calculate the impact of adding an additional vehicle or expanding the service region on patron DRT accessibility. Similarly, system operators can predict (and anticipate) future needs of their riders by using the Tool to analyze changes in population demographics. System operators have the option of saving these scenarios for future comparison as well. These results have the potential to inform a range of public transportation planning, budgetary, and policy decisions. For example, purchasing an additional wheelchair lift or ramp - equipped vehicle might be justified if mobility-impaired patron accessibility levels show a

significant improvement with the addition of this vehicle. The Tool provides many such robust opportunities for the planner to see how any changes may impact transit operation. These "what if?" scenarios will become increasingly important as these small and medium-sized communities continue to develop.

To further assist system operators in evaluating "what if?" scenarios, the Tool provides economic information related to each scenario. This information, which is presented on the 'DRT Accessibility Results' tab and report, is calculated as part of the DRT travel simulation and offers context when reviewing the DRT accessibility results. When identifying the best alternative scenario, it is important to not only determine those scenarios that improve accessibility, but also those scenarios that are also economically feasible. For example, consider two scenarios that both improve overall patron accessibility roughly the same amount. However, based on the economic comparison, it is clear that one scenario increases operating costs, while the other scenario increases generated revenue. The second scenario should be the preferred alternative. This additional information, which includes timeframe, operating costs, generated revenue, percent of patrons served, size of the service area, and number of vehicles out of service, provides perspective and allows system operators to make more informed decisions regarding accessibility and changes in the system.

Figure 6 illustrates one such 'What If?' scenario: the impact that adding an additional vehicle to the fleet has on male DRT patron accessibility. In this example, adding an additional vehicle does not have a drastic impact on the entire service area zones' accessibility for male patrons. However, a significant number of zones increased their average accessibility measures for male patrons. A few zones decreased in accessibility as well, but since the accessibility measures are relative indices, there will always be a slight downward shift of accessibility in some zones down to balance out the upward shift of accessibility in other zones. In instances like this, though, the additional capacity had an overall positive effect as seen by the fact that the number of upward shifts

significantly outweighs the number of downward shifts. Users could continue the 'What If?' analysis by adding additional vehicles until there was little or no change to the accessibility measures. In doing this, system operators could identify the fleet size limit to which no more vehicles would improve accessibility. System operators could also conduct a similar 'What If?' analysis to determine the impact improved vehicle efficiency would have on male DRT patron accessibility. After identifying the most efficient scenario, they could then compare the economic factors for the increased fleet size and improved efficiency alternatives to find the best option. The Tool can conduct any possible 'What If?' scenarios system operators and planners would need.

The DRT Accessibility Tool is designed with 'What If?' scenarios in mind. Once users input the original service area and fleet data, they can then analyze the impact various changes in the fleet or service region will have on patron accessibility. It is recommended that users keep a copy of all original scenarios and create a new scenario (based on a copy of the original scenario) each time they conduct a 'What If?' analysis. This ensures that the original data is not inadvertently altered. In the new scenarios, users can use the 'DRT Service Characteristics' tab to make changes to the fleet or service area variables. It is important to recognize when doing 'What If?' scenarios that each time the Tool runs a simulation it overwrites the results from the previous simulation. (It however always saves the most recent simulation results so the user can come back to them without running that simulation again.) Because of this, users should either (1) print out the accessibility results for each iteration so they can save them for comparison or (2) create different scenarios for each 'What If?' test that they can return to later. Depending on the program configuration, some users may need to click the 'Refresh All' button for changes to take effect.

The DRT Accessibility Tool is, as the name states, a *tool* that DRT system operators can work with to improve their transit planning and DRT patron accessibility, rather than an independent program that 'spits out' generic results. Because of this, system operators

will be able to apply their knowledge of the service region, their patrons, and operations with the Tool to arrive at solutions that are meaningful and specific to their area. However, system operators should keep in mind the particulars of a tool such as this that calculates accessibility for each zone relative to the other zones within the service region. While this method allows system operators to identify those zones that stand out with relatively high and low accessibility, system operators will not be able to compare accessibility indices of two different service regions unless they evaluate both at the same time. This also means that there will always be zones with a relative high and low accessibility measures, although the difference may be only minor, regardless of any changes made to the system.

General DRT Accessibility Within Brownsville, TX

Census Block Groups:
General DRT Accessibility

High Accessibility
Average High Accessibility
Average Low Accessibility
Low Accessibility

Datum and Projection:
North American Datum 1983
State Plane Texas South FIPS 4205 (Feet)

Data Sources:
Brownsville Urban System Planning Office
United States Census Bureau

Figure 6: General Male DRT Accessibility Within Brownsville, TX

Before and After Adding an Additional Fleet Vehicle

6. ADDITIONAL INFORMATION

6.1 BROWNSVILLE SAMPLE DATA

The DVD contains two versions of the DRT Accessibility Tool. The actual Tool, entitled 'DRT Accessibility Tool', does not contain any initial data. The second version of the Tool, entitled 'SAMPLE Brownsville Tool', contains a complete set of data describing the Brownsville Urban System's fleet and service area. This sample tool can be used to test and explore the applications of the tool, become familiar with the process, and compare data as users build their own tables. The service area zone system used in the sample Brownsville Urban System data is census block groups.

6.2 TECHINCAL SUPPORT

The research team is available for:

- Feedback on how to improve the software
- Technical support in using the software
- Technical support in collecting required data
- General information

If you would like to contact the team, please do so by:

Email: Jeffrey.lamondia@gmail.com

Phone: (512) 471-4535

Fax: (512) 475-8744

BIBLIOGRAPHY

Bhat, Chandra, Stacey Bricka, Jeffrey LaMondia, Aarti Kapur, Jessica Guo, and Sudeshna Sen. (2006) *Metropolitan Area Transit Accessibility Analysis Tool.* Research Product Report 0-5178-P3. Texas Department of Transportation.

Blumenberg, Evelyn and Kimiko Shiki. (forthcoming) *How Welfare Recipients Travel on Public Transit, and Their Accessibility to Employment Outside Large Urban Centers.* Transportation Quarterly, Spring 57(2).

Brownsville Urban System (BUS). (2003) *Paratransit Ride Guide*. Brownsville, Texas.

Cambridge Systematics, Inc., Boston Logistics Group, Inc. and Alan E. Pisarski. (2008) *The Transportation Challenge: Moving the US Economy.* National Chamber Foundation, Washington, DC.

Conklin, Joana, Carol Schweiger, Buck Marks, William Wiggins, and Karen Timpone. (2003) *Rural Transit ITS Best Practices.* Federal Highway and US Department of Transportation, Washington, DC.

Davenport, Nathan S., Michael D. Anderson, and Philip A. Farrington. (2005) *Development and Application of a Vehicle Procurement Model for Rural Fleet asset Management.* Transportation Research Record, 1927: 123-127

Easter Seals Project ACTION. (2002) *Innovative Practices in Paratransit Services.* Washington, DC.

Fu, Liping. (2002) *A Simulation Model for Evaluating Advanced Dial-a-Ride Paratransit Systems.* Transportation Research Part 1, 36: 291-307.

Hanson, Susan and Genevieve Giuliano. (2004) *The Geography of Urban Transportation.* Third Edition. Guilford Press, New York, NY.

Kessler, David S. (2004) *TCRP Synthesis 57: Computer Aided Scheduling and Dispatch In Demand Responsive Transit Services.* Transportation Research Board, Washington DC.

KFH Group, Inc. (2002) *TCRP Report 79: Effective Approaches to Meeting Rural Intercity Bus Transportation Needs.* Transportation Research Board, Washington, DC.

KFH Group Inc. (2008) *TCRP Report 124: Guidebook for Measuring, Assessing, and Improving Performance of Demand-Response Transportation.* Transportation Research Board, Washington, DC.

KFH Group, Inc. and A-M-M-A. (2001) *TCRP Report 70: Guidebook for Change and Innovation at Rural and Small Urban Transit Systems.* Transportation Research Board, Washington, DC.

Kittelson & Associates, Inc., KFH Group, Inc., Parsons Brinckerhoff Quade & Douglass, Inc., and Katherine Hunter-Zaworski. (2003) *TCRP Report 100: Transit Capacity and Quality of Service Manual.* Transportation Research Board, Washington, DC.

Kittelson & Associates, Inc., Urbitran, Inc., LKC Consulting Services, Inc., MORPACE International, Inc., Queensland University of Technology, Yuko Nakanishi. (2003) *TCRP Report 88: A Guidebook for Developing a Transit Performance-Measurement System.* Transportation Research Board, Washington, DC.

Koffman, David, David Lewis, David Chia, Jon Burkhardt, and Mark Bradley. (2007) *TRCP Report 119: Improving ADA Complementary Paratransit Demand Estimation.* Transportation Research Board, Washington DC.

McIntyre, Robert J., Hani S. Mahmassani, C. Michael Walton, and Randy B. Machemehl. (1986) *Rural Public Transportation Demand: Characteristics and Estimation Methodology.* Technical Study Report 1080-1F. Texas Department of Transportation.

Northeast Midwest Institute. (2002) *Rural Population as a Percent of State Total By State, 2000.* http://nemw.org/poprural.htm Accessed on June 15, 2008.

Painter, Kathleen, Eric Jessup, Marcia Hill Gossard, and Ken Casavant. (2007) *Demand Forecasting for Rural Transit: Models Applied to Washington State.* Transportation Research Record, 2997:35-40.

Potts, John F. and Maxine A. Marshall. (2007) *TCRP Synthesis 71: Parataransit Manager's Skills, Qualifications, and Needs.* Transportation Research Board, Washington, DC.

Sandlin, Adam B. and Michael D. Anderson. (2004) *Serviceability Index to Evaluate Rural Demand-Responsive Transit System Operations.* Transportation Research Record, 1887: 205-212.

Schofer, Joseph L, Barry L Nelson, Ronald Eash, Mark Daskin, Ying Yang, Hong Wan, Jingfeng Yan, and Laszlo Medgyesy. (2003) *TCRP Report 98: Resource Requirements for Demand Responsive Transportation Services.* Transportation Research Board, Washington DC.

Simon, Rosalyn M. (1998) *Synthesis of Transit Practice 31: Paratransit Contracting and Service Delivery Methods.* Transportation Research Board, Washington, DC.

Southworth, Frank, David P. Vogt, and T. Randall Curlee. (2005) *Rural Transit Systems Benefits in Tennessee: Methodology and an Empirical Study.* Environment and Planning A, 37: 861-875.

Spielberg, Frank and Richard H Pratt. (2004) *TCRP Report 95: Traveler Response to Transportation System Changes, Chapter 6: Demand Repsonsive/ ADA.* Transportation Research Board, Washington DC.

Stommes, Eileen S. and Dennis M. Brown. (2005) *Moving Rural Residents to Work: Lessons from Eight Job Access and Reverse Commute Projects.* Transportation Research Record, 1903: 45-53.

US Census Bureau. (2007) *Fact Sheet: Brownsville, Texas.* http://factfinder.census.gov/ Accessed on December 1, 2007.

US Department of Transportation (2008) *Rural Transport Toolbox.* National Transportation Library. http://ntl.bts.gov/ruraltransport/Toolbox/ Accessed on December 1, 2007.

Victoria Transport Policy Institute. (2008) *Rural Transportation Management: Improving Transportation Efficiency and Diversity in Rural Areas.* http://www.vtpi.org/tdm/tdm87.htm Accessed on December 1, 2007.

Yim, YB. and J. Khattak. (2000) *Personalized Demand Responsive Transit Systems.* California PATH Research Report, August.

APPENDICES

Appendix A: Total Patron Demand Generation Model Specification

$$
\begin{aligned}
Total\ Number\ &of\ Patrons\ in\ Each\ Census\ Block\ Group\ (CBG)\ i\ = \\
&-4.25 + 0.01\ [Total\ Population\ Size\ within\ CBG_i] \\
&- 0.80\ [Median\ Age\ of\ All\ Residents\ within\ CBG_i] \\
&+ 0.46\ [Median\ Age\ of\ Male\ Residents\ within\ CBG_i] \\
&+ 0.76\ [Median\ Age\ of\ Female\ Residents\ within\ CBG_i] \\
&+ 2.32\ [Average\ Household\ Size\ within\ CBG_i] \\
&- 0.70\ [Distance\ from\ CBG_i\ Centroid\ to\ Nearest\ Transit\ Route, in\ Miles] \\
&- 0.08\ [Percentage\ of\ CBG_i\ Households\ that\ Rent] \\
&+ 1.80\ [Percent\ of\ Regional\ Renter\ Households\ within\ CBG_i] \\
&- 0.25\ [Percent\ of\ CBG_i\ Households\ that\ are\ Married\ with\ Children] \\
&+ 4.41\ [Percent\ of\ Regional\ Married\ Households\ with\ Children\ within\ CBG_i] \\
&- 4.55\ [Percent\ of\ Regional\ Married\ Households\ without\ Children\ within\ CBG_i] \\
&+ 0.43\ [Percent\ of\ CBG_i\ Population\ Aged\ 18-29] \\
&- 11.81\ [Percent\ of\ Regional\ Population\ Aged\ 18-29\ within\ CBG_i] \\
&- 8.67\ [Percent\ of\ Regional\ Population\ Aged\ 30-49\ within\ CBG_i] \\
&- 0.48\ [Percent\ of\ CBG_i\ Population\ Aged\ 50-64] \\
&+ 4.38\ [Percent\ of\ Regional\ Population\ Aged\ 50-64\ within\ CBG_i] \\
&- 0.77\ [Percent\ of\ CBG_i\ Population\ Aged\ 65\ or\ Older] \\
&+ 5.07\ [Percent\ of\ Regional\ Population\ Aged\ 65\ or\ Older\ within\ CBG_i]
\end{aligned}
$$

Appendix B: Trip Purpose Estimation Model Specification

	Church/Meeting	Education/School	Recreation	Medical/Therapy	Shopping	Work
Mobile Males	6.38%	4.95%	12.19%	41.03%	3.02%	32.43%
Mobility-Impaired Males	8.06%	6.17%	19.63%	52.26%	8.73%	5.15%
Mobile Females	5.60%	6.03%	10.96%	40.78%	3.36%	33.27%
Mobility-Impaired Females	8.15%	5.71%	20.42%	52.55%	8.79%	4.38%

Appendix C: Destination Zone Assignment Model Specification

$$Probability\ of\ Choosing\ Zone\ i\ = \frac{e^{U_i}}{\sum_{j=1}^{I} e^{U_j}}$$

Where:

$$U_i = \delta_{Mobility-Impaired} \begin{Bmatrix} -0.16\ [Population\ Density\ of\ CBG_i] \\ -1.70\ [Distance\ from\ CBG_i\ Centroid\ to\ to\ Nearest\ Transit\ Route, in\ Miles] \end{Bmatrix}$$
$$+\delta_{Male} \begin{Bmatrix} -0.07\ [Population\ Density\ of\ CBG_i] \\ -0.37\ [Distance\ from\ CBG_i\ Centroid\ to\ Nearest\ Transit\ Route, in\ Miles] \end{Bmatrix}$$
$$+\delta_{Church} \begin{Bmatrix} 0.73\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Apartments] \\ +0.20\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Commercial] \\ +0.92\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Retail] \end{Bmatrix}$$
$$+\delta_{Education} \begin{Bmatrix} -6.68\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Apartments] \\ +1.02\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Commercial] \\ -2.08\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Manufacturing] \\ +1.46\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Retail] \end{Bmatrix}$$
$$+\delta_{Recreation} \begin{Bmatrix} 1.97\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Apartments] \\ +1.45\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Commercial] \\ +1.09\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Retail] \end{Bmatrix}$$
$$+\delta_{Medical} \begin{Bmatrix} 1.80\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Apartments] \\ +0.21\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Commercial] \\ -0.36\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Manufacturing] \end{Bmatrix}$$
$$+\delta_{Shopping} \{0.60\ [Percent\ of\ CBG_i\ Area\ Zoned\ for\ Retail]\}$$

Appendix D: Time of Day Allocation Model Specification

$$Probability\ of\ Choosing\ to\ Travel\ Out\ in\ the\ AM\ and\ Return\ in\ the\ AM\ = \frac{1}{1 + e^{U_2} + e^{U_3}}$$
$$Probability\ of\ Choosing\ to\ Travel\ Out\ in\ the\ AM\ and\ Return\ in\ the\ PM\ = \frac{e^{U_2}}{1 + e^{U_2} + e^{U_3}}$$
$$Probability\ of\ Choosing\ to\ Travel\ Out\ in\ the\ PM\ and\ Return\ in\ the\ PM\ = \frac{e^{U_3}}{1 + e^{U_2} + e^{U_3}}$$

Where:

$$U_2 = -0.02\ [Distance\ Between\ Origin\ and\ Destination\ CBG\ Centroids, in\ Miles] + 0.30\ \delta_{Church}$$
$$- 0.91\ \delta_{Education} + 1.35\ \delta_{Recreation} - 1.32\ \delta_{Medical} - 0.79\ \delta_{Shopping} + 0.36\ \delta_{Mobility-Impaired}$$

$$U_3 = 1.68\ \delta_{Church} - 1.68\ \delta_{Education} + 0.55\ \delta_{Recreation} - 0.18\ \delta_{Medical} + 0.66\ \delta_{Shopping} + 1.01\ \delta_{Mobility-Impaired}$$

Appendix E: In-Vehicle Travel Time Model Specification

$$In\ Vehicle\ Travel\ Time_n, in\ Minutes = \alpha D + \beta D^{1-\gamma}$$

$$Where\ \alpha = \begin{cases} 1.0\ if\ Urban\ Area \\ 0.6\ if\ Suburban\ Area \\ 0.8\ if\ Second\ City\ Area \\ 1.0\ if\ Town\ Area \\ 1.1\ if\ Rural\ Area \end{cases} \quad \beta = \begin{cases} 6.3\ if\ Urban\ Area \\ 5.4\ if\ Surburban\ Area \\ 5.7\ if\ Second\ City\ area \\ 4.4\ if\ Town\ Area \\ 4.0\ if\ Rural\ Area \end{cases} \quad \gamma = \begin{cases} 0.7\ if\ Urban\ Area \\ 0.6\ if\ Surburban\ Area \\ 0.7\ if\ Second\ City\ area \\ 0.7\ if\ Town\ Area \\ 0.7\ if\ Rural\ Area \end{cases}$$

Appendix F: Drive Alone Equivalent Travel Time Model Specification

$$Drive\ Alone\ Equivalent\ Travel\ Time_n, in\ Minutes =$$
$$1.37 + 1.68\ [Distance\ Between\ Origin\ and\ Destination\ CBG\ Centroids, in\ Miles]$$

Appendix G: Pickup Time Uncertainty Model Specification

$$Difference\ in\ Time\ Between\ Scheduled\ and\ Actual\ Pickup_n, in\ Minutes =$$
$$e^{(2.37 - 0.29\ \delta_{AM-PM} - 0.31\ \delta_{Church} - 0.19\ \delta_{Education} - 0.13\ \delta_{Shopping} + 0.22\ \delta_{Mobility-Impaired} - 0.15\ \delta_{Summer} - 0.07\ \delta_{Winter})}$$

Appendix H: Arrival Time Delay Model Specification

$$Minutes\ Late\ Arriving\ at\ Destination =$$
$$e^{(1.58 - 0.25\ \delta_{AM-PM} + 0.12\ \delta_{PM-PM} - 0.32\ \delta_{Church} - 0.20\ \delta_{Medical} - 0.19\ \delta_{Shopping} + 0.17\ \delta_{Mobility-Impaired} - 0.05\ \delta_{Male} - 0.20\ \delta_{Summer} - 0.27\ \delta_{Winter})}$$

Appendix I: Accessibility Index Model Specification

$$Accessibility\ Value\ for\ CBG\ i =$$
$$0.50\ [Average\ Patron\ Arrival\ Time\ Delay] + 0.25\ [Average\ Patron\ Pickup\ Time\ Uncertainty]$$
$$+0.15\ [Average\ Patron\ Difference\ Between\ In\ Vehicle\ and\ Drive\ Alone\ Equivalent\ Travel\ Times\ ]$$
$$+0.10\ [Percent\ of\ Unmet\ Demand\ in\ CBG_i]$$