PREDICTING POTENTIAL DEMAND

Demand Response Transit Ridership
In Brownsville, Texas

Report Prepared for
Dr. Bjorn Sletto, Introduction to GIS

Report Prepared by
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Executive Summary

Demand Response Transit (DRT) is a critical form of transportation for handicapped, low income, and small/medium sized communities. This type of service, which transports riders through an on-demand basis, is commonly used in communities that are not dense enough to support a fixed route transit system. 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 minimal modeling/planning practices. This research uses GIS to evaluate the demographic and economic development characteristics of census block groups in order to predict potential demand response travel demand. The results provide insight into those factors that are good indicators of where to find these DRT patrons. Previous research in DRT demand does not consider either the spatial component (i.e. where patrons are located) or the specific patron types (i.e. whether patrons are mobile, handicapped, etc.). This research combines both of these factors, while focusing the study on census variables that can be easily reproduced by transit operators. The findings indicate that DRT has evolved from its inception to now support everyone in a community. In fact, Brownsville demonstrates this by no longer having any selection criterion; essentially anyone who needs to use demand response transit is provided it. The characteristics considered in this research, which included ages groups, densities, households sizes and other factors, were significant in predicting demand. However, it is clear that there are other spatial factors that cannot be captured by census data, such as outreach and awareness across neighborhoods, which combine with these characteristics to influence the number of patrons that come from various areas. Operators can use this information in two ways: they can improve their current service to best support the current potential ridership and they can better anticipate the impact on their DRT system when annexing new service areas.
Introduction

Demand response transit (DRT), also known as paratransit, is a critical form of transportation for handicapped, 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 DRT service must call their transit operator, usually at least 24 hrs ahead of time, to schedule their trip. As trips are scheduled, transit 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 been long established due to numerous repeat patrons. (2004)

There are many variations of DRT service, depending on the needs of the area. Some 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. (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 paratransit operators were serving these patrons in 1998. (2000) Regardless of their differences, however, all of these DRT systems 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.

The Texas Department of Transportation (TxDOT) recently recognized the importance of improving demand response transit (DRT) systems and funded a DRT accessibility study though the University of Texas at Austin. Through this larger study, I am developing a tool that determines how well a DRT system currently serves its riders and the most efficient ways to improve this service. This report deals with one of the most important pieces of the overall research objective, which is to identify potential ridership (i.e. demand) in the service region. The lack of information and models on this topic consistently came up during my interviews with DRT operators in Brownsville, Tyler, Longview, and San Angelo, Texas.

Much of the previous work within demand response transit operation focuses on fleet distribution and scheduling. Even since the 1970s, when computer-aided scheduling
software was introduced, operators focused on how to reduce costs, combine routes, increase pick-up time, and other supply sided questions. (Kessler 2004) However, they do not consider the customer’s perspective: Where would a patron live if they needed to take DRT? How long will someone wait for DRT? How long will it take to get to their destination? How often do they have to negotiate a suitable time due to high demand? Predicting potential demand is the critical first step in any analysis of all these questions, including patrons’ accessibility with demand response transit. A few studies have taken the initial steps towards developing such a framework, and these methods are discussed in the following paragraphs.

Schofer et al developed a tool for determining optimal fleet size for a demand response transit system. While this program focused on service attributes, it included a unique trip simulation component. A user would input the average number of weekday trips and the program would then use census data to estimate traveler characteristics, origin and destination locations, and trip characteristics. This is incredibly forward thinking but still requires the user to input the level of demand. (2003)

Spielberg and Pratt outlined one factoring method for predicting rural program paratransit trips, for example Group Home or Job Training services, and they calculate program participants as part of this method. “The best estimator of the number of trips associated with a social service program is the number of program participants. In general there is a direct linear relationship between the number of individuals eligible for and participating in a given social service program such as senior nutrition, and the demand for passenger transportation.” (2004) Unfortunately this demand prediction is done on the regional scale, and predicts the total number of paratransit trips within a region. It is not concerned with where patrons are specifically coming from or going, which is an important factor when considering accessibility.

Most recently, Koffman et al developed an ADA Complementary paratransit Demand Estimation Tool. This tool incorporates six factors (population size, base fares, conditional eligibility, conditional trip determination, poverty level, and effective window) to calculate the annual number of DRT patrons. Again, this method is focused on the region as a whole and not identifying where individuals are coming from. Interestingly, they found that the most commonly believed factors influencing demand, namely “population of older age groups, incidences of disability, and availability and quality of accessible fixed route transit”, were not included in the tool. (2007)

This research develops linear models to predict the potential ridership demand of a census block group based on a number of readily available characteristics, including demographics, economic development, and other spatial characteristics. Operators consistently emphasized that models and tools for demand response transit need to be intuitive and easy to use. Most operators are familiar with GIS and census information, so developing linear models using these resources is realistic. Operators can use this information in two ways (in addition to supplementing the tool): they can improve their current service to best support the current potential ridership and they can better anticipate the impact on their DRT system when annexing new service areas.
This research focuses on the demand response transit system within Brownsville, Texas. Brownsville is located within Cameron County at the southern tip of Texas, bordering with Mexico, seen in City of Brownsville Within Cameron County, Texas. In fact, 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% speak 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 linear model to predict the potential ridership because the Brownsville Urban System (BUS) transit provider is widely considered to be one of the most advanced DRT systems in Texas. BUS has a paratransit fleet, 13 fixed-transit routes, and 2 major terminals. BUS DRT serves all those residents that live within a half-mile of the fixed-route transit network, seen in Demand Response Transit Service Area Within Brownsville, Texas. Their DRT service is supported by RouteMatch scheduling software and in-vehicle GPS transponders. According to BUS operators, “they serve more than 1.5 million passengers a year. In 2002, BUS served 1,631,349 passengers in its fixed-route bus service and 54,526 passengers in its paratransit services.” (Wikipedia 2007)
City of Brownsville Within Cameron County, Texas

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

Author: Jeff LaMondia
Date: November 17, 2007
Demand Response Transit Service Area Within Brownsville, Texas

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

Author: Jeff LaMondia
Date: November 17, 2007

Fixed Transit Routes
DRT Service Area (1/2 mi Buffer)
Census Block Groups Served by DRT
Brownsville City Limits
Cameron County
US - Mexico Border

MEXICO
UNITED STATES

0 0.5 1 2 3 Miles
Roads Within DRT Service Area of Brownsville, Texas

Author: Jeff LaMondia
Date: November 17, 2007

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
Problem Statement

The lack of practical modeling and planning practices for demand response transit puts it at a disadvantage not only when seeking new funding but also when trying to allocate their existing funds. This research deals with this problem by:

- Conducting a spatial analysis of the impact demographics and economic development has on creating DRT patrons.
- Developing a linear model to predict the potential ridership of a census block group based on a number of characteristics, including sociodemographics and relative accessibility.

By definition, demand response transit is designed to support areas that have high numbers of elderly, low density, low economic vitality, and far from fixed route transit. I expect census block groups with these characteristics to correspond to more DRT patrons.

Research Questions

The primary research questions are:

- How many people in a census block group will use DRT if it is available?
- What sociodemographics and relative accessibility characteristics can be used to estimate this potential DRT ridership?
- Are linear models successful at predicting potential DRT ridership? If so, which variables are relatively more important?

Methodology

Data Collection
This research is a continuation of a transit accessibility project I did that dealt with fixed-route transit systems in Texas. During that project I made a number of contacts within the Texas transit operator community who I spoke to when developing this research. I found that demand response transit systems are operationally completely different from fixed route systems, and therefore I needed a different set of techniques for this research than the ones developed in the previous work. Initially, the research team wanted to utilize the RouteMatch scheduling software, but it is not universally used (which means that our tool could not be universally distributed) and the software was not designed to support the applications we wanted. The research team decided to develop the tool using ArcGIS and Microsoft Access after realizing that most planners had the files and experience to handle work using these programs. Brownsville Urban System (BUS) in Brownsville, Texas, volunteered to assist in this research by allowing us to tour their facilities and by sharing their GIS and trip data files. All names were replaced with identification numbers in the files we received from BUS. In some cases the files were too specific and could not be replicated by other operators, so I returned to the census bureau to download the remaining data files.
Throughout this entire development process, I was careful to select data sources that other operators would already have or could easily access. At the conclusion of this stage, I had the following files:

- 2000 Roads shapefile, 2000 Census Block Groups shapefile, and SF1 Demographic data, downloaded from the US Census Bureau website. (I initially started working with census blocks, but this unit of spatial measure was too small so I increased it to census block groups.)
- Transit Routes shapefiles, Transit Patron Address List database and Transit Travel Log database, collected from the Brownsville BUS data files.

**Data Formulation**
In this next stage I compiled and cleaned all of the data in order to run the analyses. This stage included a number of steps:

- **Create a complete patron list database.** I deleted the duplicate records from the transit patron address list and merged this database with the transit travel log database to identify only those individuals that traveled during the last six months. This was done for two reasons: First, I only had personal demographics for those who traveled within the past six months since that information was attached to the travel log database. Second, I knew that the patron address list database I was working with was old and contained many people who didn’t use transit anymore; this was a way to factor out the extraneous patrons. This resulted in a list of 380 patrons (including their addresses and demographics) that I could later geocode.

- **Create a complete transit service area shapefile.** I combined the census block groups shapefile and the transit routes shapefiles in ArcGIS. I buffered each transit route with a ½ mile buffer, Brownsville’s spatial limit for defining whether a person is allowed to ride the demand response transit, and unioned each of these buffered transit routes together. This resulted in a cumulative transit route buffer shapefile. I then identified the transit service area by selecting those census block groups that had any part of the buffer within it. Finally, I joined the SF1 demographic data to the census block group service area shapefile. This resulted in the creation of the complete transit service area shapefile that contained 115 census block groups.

- **Create a transit service area roads shapefile.** I clipped the roads shapefile to within the census block group service area to create the transit service area roads shapefile.

**Service Area Characteristics**
In this stage I developed the census block group characteristics that were used in the model estimation. This stage included a number of steps:

- **Geocode patron addresses.** I geocoded the 380 patron addresses both automatically and interactively. In doing the conversion, two street names consistently used in the database did not match those of the census roads. I changed ‘N Expressway’ to ‘United States Highway 77’ and ‘FM#’ to ‘Farm-To-Market Road #’. One patron was outside the service area and had to be deleted. At the end of this step, 345 of the 380 patrons (or 91%) were matched.
• **Separate four types of patron files.** I broke up the various patrons into the four categories being studied. I created four separate shapefiles for the following categories:
  o mobile male patrons (59 patrons)
  o mobile female patrons (89 patrons)
  o handicapped male patrons (83 patrons)
  o handicapped female patrons (114 patrons)

• **Calculate the distance from the centroid of each census block group to the nearest transit line and census block group area.** At this point, I reprojected all of the shapefiles so the coordinate system had a unit of measurement in feet. They were in the same coordinate system previous to this step, but the unit of measurement in that projection was decimal degrees. I then converted census block group polygons to centroids points using the XtoolsPro GIS extension. I joined the census block group centroids to the transit route polygon layer. This step added the distance from the centroid to the nearest transit route into the attribute table. I finally joined the census block group polygons to the census block group centroids to transfer this data. Lastly, I added the census block group area to the attribute table, which I calculate using visual basic code.

• **Count number of patron points within each census block.** I started with joining the four patron point shapefiles to the census block group layer, to record the polygon that each point fell within. I tried doing the ‘count joining method’, but this recounted any points that fell on roads that formed a border between two census block groups. I then used SPSS to calculate the number of patron points (for all four categories) within each census block group. I joined this database back to the census block group shapefile, which resulted in 4 new variables in the census block group attribute table – a count for each of the four patron types.

**Predicting Demand**

In this stage I created various maps and models that I used to evaluate potential demand. This stage included a number of steps:

• **Create maps.** I developed a number of maps that analyzed the distributions of census block group demographics, economic development, and DRT patron distributions. These maps are presented and analyzed in the following sections.

• **Estimate linear regression models.** Using SPSS, I ran four linear regressions to predict the number of male mobile, female mobile, male handicapped, and female handicapped patrons within each census block group. I included the various demographics, economic development, and general dependent variables. These models are presented and analyzed in the following sections.
Findings

Demographics Maps
The following maps were made to analyze the service area demographics, which can be seen within the following pages:

- Hispanic Population Within DRT Service Area of Brownsville, Texas. This map was created to confirm the predominance of the Hispanic population.
- Male Population Within DRT Service Area of Brownsville, Texas. These two maps were created to understand the distribution of men and women within the service area.
- Elderly Population Within DRT Service Area of Brownsville, Texas. These two maps were created to understand the distribution of the elderly within the service area.

Economic Development Maps
The following maps were made to analyze the service area economic development, which can be seen within the following pages:

- Population Density Within DRT Service Area of Brownsville, Texas. This map was created to identify areas that are most density populated.
- Household Density Within DRT Service Area of Brownsville, Texas. This map was created to identify areas that are most density populated.
- Home Ownership Within DRT Service Area of Brownsville, Texas. This map was created to identify wealthier areas where residents own their homes.
- Average Household Size Within DRT Service Area of Brownsville, Texas. This map was created to identify areas that have various family sizes.

DRT Patron Distribution Maps
The following maps were made to analyze the existing service area patron distribution, which can be seen within the following pages:

- Female Mobile Patrons Within DRT Service Area. This map locates and scales the area to identify where female mobile patrons live.
- Female Handicapped Patrons Within DRT Service Area. This map locates and scales the area to identify where female handicapped patrons live.
- Male Mobile Patrons Within DRT Service Area. This map locates and scales the area to identify where male mobile patrons live.
- Male Handicapped Patrons Within DRT Service Area. This map locates and scales the area to identify where male handicapped patrons live.
Hispanic Population Within DRT Service Area of Brownsville, Texas

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
Male Population Within DRT Service Area of Brownsville, Texas

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

Census Block Groups:
Number of Male Residents
145 - 607
608 - 1061
1062 - 2103

Highway 77
Brownsville City Limits
Cameron County
US - Mexico Border

Author: Jeff LaMondia
Date: November 17, 2007
Male Population Within DRT Service Area of Brownsville, Texas

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
Elderly Population Within DRT Service Area of Brownsville, Texas

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
Elderly Population Within DRT Service Area of Brownsville, Texas

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

Author: Jeff LaMondia
Date: November 17, 2007
Population Density Within DRT Service Area of Brownsville, Texas

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
Household Density Within DRT Service Area of Brownsville, Texas

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

Census Block Groups:
Household Density
27 - 958 Households/ Sq. Mile
959 - 2321 Households/ Sq. Mile
2322 - 5164 Households/ Sq. Mile
Home Ownership Within DRT Service Area of Brownsville, Texas

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

Census Block Groups:
Percentage of Owned Homes
10% - 38%
39% - 66%
67% - 92%
Average Household Size Within DRT Service Area of Brownsville, Texas

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
Female Mobile Patrons Within DRT Service Area

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
Female Handicapped Patrons Within DRT Service Area

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

Census Block Groups:
Number of Female Handicapped Patrons
- 0 Patrons
- 1 Patrons
- 2 Patrons
- 3 Patrons
- 4 Patrons

Patron Location
US - Mexico Border
Highway 77
Brownsville City Limits
Cameron County

Author: Jeff LaMondia
Date: November 17, 2007
Male Mobile Patrons Within DRT Service Area

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

Census Block Groups:
Number of Male Mobile Patrons
- 0 Patrons
- 1 Patrons
- 2 Patrons
- 3 Patrons
- 4 Patrons

Patron Location
US - Mexico Border
Highway 77
Brownsville City Limits
Cameron County
Male Handicapped Patrons Within DRT Service Area

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

Census Block Groups:
Number of Male Handicapped Patrons
- 0 Patrons
- 1 Patrons
- 2 Patrons
- 3 Patrons
- 4 Patrons

Patron Location
US - Mexico Border
Highway 77
Brownsville City Limits
Cameron County
Analysis

Analyzing Maps
The collection of demographic, economic development, and DRT patron distribution maps are introduced in the previous section.

The demographic oriented maps thoroughly describe the service area populations. The first map highlights how the majority of Brownsville’s population is Hispanic, especially along the southern border with Mexico. Unfortunately the high concentrations do not provide any variability for an ethnicity characteristic in the model, so we cannot use it. The male population maps reveal an even split between men and women within the service region. A few areas to the east have higher percentages of male population, but in the larger picture do not have large overall. Census block groups that have larger numbers and percentages of males seem to have more male DRT patrons. Ironically, those census block groups that have smaller numbers of females seem to have more female DRT patrons. Elderly populations are generally located in the least dense areas. As the elderly population increases in an area, the number of male and female mobile patrons increases. However, areas with fewer percentages of elderly seem to have more patrons overall. This could imply that it is not just the elderly taking the demand response transit.

The economic development maps capture the vitality and affluence of areas through census data. Denser areas (either by population or number of households) are usually more developed and urban. Areas that have a higher percentage of home ownership are usually more affluent. Areas with smaller households represent those places were single people tend to live. All of these characteristics can be used to predict the number and types of DRT patrons. The areas of densest total populations and households are clustered at the southern end of Highway 77, which tends to be in the center of the service region. They also tend to correspond to the smaller census block groups, which is not surprising because census blocks are generally developed based on the population size within then. Both densities are similar in scale and match most with areas that have more handicapped male and female patrons. Home ownership, a proxy for income and affluence, occurs outside of downtown. As home ownership increases in areas, so does the number of male mobile patrons. In these areas there are also fewer female handicapped patrons. Finally, areas with smaller household sizes are surprisingly not located in the downtown, but more to the southwest and southeast of the service region. One can loosely connect increased household sizes with increased mobile patrons, both male and female.

In general there were no standout indicators of DRT patrons among the demographic or economic development features analyzed. Brownsville is a well-mixed area of young and old, single resident households and large families, and owners and renters. It is therefore important to conduct a statistically study to further evaluate these characteristics.
Analyzing Models
The linear models developed to predict the number of DRT patrons (for male mobile, male handicapped, female mobile, and female handicapped patrons) in a census block group based on demographic and economic development characteristics can be found on the following page, in Table 1. The results not only tend to mimic those trends found in the previously reviewed maps but also are intuitive and insightful.

There are a number of significant parameters affecting the number of female DRT patrons in a census block group. First, there is an inherent predisposition for female handicapped to come out of any census block group. The number of female handicapped patrons in a census block group increases as the median female age increase. The number of female handicapped patrons decreases as the percent of males in the census block group increases, as the percent of people aged 65 or older increases, as the percent of people who own their home increases, and as the household density increases. The number of female mobile patrons increases with an increase in the median female age, the number of people aged 65 or older, the percent of single resident households, and the average household size. The number of female mobile patrons decreases as the median male age increases, the percent of people aged 65 or older increases, and as the percentage of owners increases. Most interesting is that the coefficients on the percent of resident aged 65 or older is so negatively large. This implies that more female DRT patrons are either younger or in fact elderly, but live in an area that not many other elderly people live in as well.

The models predicting male DRT patrons contain a number of significant parameters as well. First, there is an inherent predisposition for male mobile patrons to come out of any census block group. It then follows that the number of male mobile patrons increase further as the total number of males, the number of people aged 65 or older, the percent of single resident households, percent of home owners, household density, and area increase. The number of patrons decreases when there are more percent of males, there are large average household sizes, there are more total households, and the census block group is further from the nearest transit route. The male handicapped prediction model is much simpler: the number of patrons increases with more elderly residents, higher percentages of single resident households, and larger average household size; the number of patrons decreases the farther one gets from the neatest transit route. There are two especially interesting results from these models. First, more male handicapped patrons come from areas where there are proportionally more single resident households but larger average household size. This means that handicapped male patrons are most likely to come from mixed development. Second, mobile male patrons come from areas that have fewer percentages of men.

In general these results provide more depth to the basic assumptions about DRT patrons. Some of the statistics support the philosophy that DRT patrons are older, single, less wealthy, and remotely located. Other statistics, however, reveal that mobile patrons tend to be younger, from more affluent areas, and from larger households. These results follow Koffman’s work in which he concluded that commonly assumed factors influencing demand, namely populations of older age groups and accessibility to fixed transit routes, are not significant predictors. The findings presented in this paper show that the variables Koffman
mentioned have some minor effects, but there are many further local area characteristics that can be used to predict demand, including single residents, household density, and household sizes.

While each model is populated with a number of significant variables, the R-squared values for each are extremely low. By definition, low R-squared values indicate that the variables do not capture the variation among the sample. There is a considerable amount of ‘noise’ within these models for a number of reasons, including small sample size, limited variables, and low variation in the dependent and independent variables, that causes this to happen. Still, the results are interesting and informative, and offer a unique perspective to predicting demand response transit patron ridership. The implications and uses of these models will be further explored in the next section.
### Table 1: Census Block Group Characteristic Parameter Estimates

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<th>Female</th>
<th></th>
<th>Male</th>
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<td>T-Stat</td>
<td>Coefficient</td>
<td>T-Stat</td>
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<td>Number of Males</td>
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<td>-</td>
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<td>Percent of Males</td>
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<td>Median Male Age</td>
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<td>-</td>
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<td>Percent Aged 65 or Older</td>
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<td>-3.624</td>
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<td>Percent Single Resident Households</td>
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<td><strong>Economic Development</strong></td>
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<td>Average Household Size</td>
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<td>Household Density (per Sq. Mile)</td>
<td>-0.002</td>
<td>-4.235</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Number of Households</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area (in Sq. Miles)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Distance from Census Block Group</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Centroid to Nearest Transit Route (in Miles)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.326</td>
<td>0.165</td>
<td>0.123</td>
<td>0.233</td>
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</table>
Conclusions

This research uses GIS to evaluate the demographic and economic development characteristics of census block groups in order to predict potential demand response travel demand. The results provide insight into those factors that are good indicators of where to find these DRT patrons. Previous research in DRT demand does not consider either the spatial component (i.e. where patrons are located) or the specific patron types (i.e. whether patrons are mobile, handicapped, etc.). This research combines both of these factors, while focusing the study on census variables that can be easily reproduced by transit operators. The findings indicate that DRT has evolved from its inception to now support everyone in a community. In fact, Brownsville demonstrates this by no longer having any selection criterion; essentially anyone who needs to use demand response transit is provided it. The characteristics considered in this research, which included ages groups, densities, households sizes and other factors, were significant in predicting demand. However, it is clear that there are other spatial factors that cannot be captured by census data, such as outreach and awareness across neighborhoods, which combine with these characteristics to influence the number of patrons that come from various areas.

There are many extensions to this research that could improve on the limitations of the existing data. It could be helpful to have data for a longer period than the six months in this study and to have data from more areas. More complicated modeling techniques can also be used to help predict ridership. Finally, it might be more conclusive to model with census tracts and/or with all the patrons grouped into one general category.

Operators can use this information in two direct ways: they can improve their current service to best support the current potential ridership and they can better anticipate the impact on their DRT system when annexing new service areas. As noted earlier, this paper is part of a much larger DRT accessibility framework and tool that a research group at the University of Texas at Austin is working on. The tool determines how well a DRT system currently serves its riders and the most efficient ways to improve this service through three components. The first component is associated with operator input of service characteristics (including vehicle fleet and service area information). The second component, in which this research plays a part, is a system that simulates travel over the desired days using a series of linear and discrete choice models. Finally, the third component evaluates the accessibility of selected service regions based on the difference between scheduled and actual pickup times, the difference between driving alone and DRT travel times, and the percent of demand from the region not able to be served on the day of service request.

The DRT accessibility tool is designed to be transferable, practical, and valuable for all small and medium communities. The tool utilizes service fleet and region information that all operators already have, and it is designed to be applicable to demand response systems of any size and location. Working with DRT operator input, we designed the tool to not only be easy to use and intuitive, but also to allow for operator judgment in controlling results. Ultimately, DRT operators can use the accessibility tool in two robust ways. First, they can evaluate their current accessibility provision for various combinations of population groups,
service areas, and travel purposes. For example, an operator has the option of evaluating accessibility over the entire system or focusing in on accessibility for elderly women traveling for shopping. Second, the accessibility tool allows operators to undertake “what if?” scenarios to evaluate changes in fleet characteristics (supply), population demographics (demand), and service areas (scope). For example, an operator can calculate the impact of adding an additional vehicle or expanding the service region on overall DRT accessibility. Similarly, operators can predict (and anticipate) future needs of their riders by using the tool to analyze changes in population demographics. These results have the potential to inform important public transportation planning and policy decisions.
References


Appendices

Data Sources and Contacts

Step By Step Guide
Data Sources and Contacts

Norma Zamora, Tom Logan, and Rebeca Castillo from Brownsville Urban System (BUS) sent me a number of GIS files on a DVD that I will be working with. These are the files that they use on a daily basis in planning their demand response transit system. The original files include:

1. Census Block Groups (and SF1 data)
   a. Format: Polygon Shapefile
   b. Includes: Areas, Demographics, Ethnicities, Ages, Households, etc…
   c. Coordinate System: GCS_WGS_1984; D_WGS_1984; Greenwich, Degree
   d. Details: This layer came from the 2000 Census/TIGER files, as was the 2000 SF1 survey information. Also includes a selection set of census block groups served by the DRT transit, determined by those census blocks that are at least partially within a 1/2-mile radius of the fixed route network.

2. Transit Network
   a. Format: Multiple Line Shapefiles; one for each route
   b. Coordinate System: GCS_WGS_1984; D_WGS_1984; Greenwich, Degree
   c. Details: This layer overlaps with the street layer, and is used to create the service area selection set.

3. Streets
   a. Format: Line Shapefile
   b. Includes: Segment lengths, Segment start and end point coordinates, Address Markers
   c. Coordinate System: GCS_WGS_1984; D_WGS_1984; Greenwich, Degree
   d. Details: This is a basic street layer. It is very similar to the census block boundaries. It also contains all the information needed to create an address locator file.

4. Patron Address List
   a. Format: Excel Spreadsheet
   b. Data: Addresses, Cities, Zip codes, Mobility, and Gender
   c. Details: This spreadsheet contains records for all the current DRT patrons within Brownsville, Texas. It will be imported and formatted in SPSS. The addresses were input by hand, so many of them will need to be interactively matched in the geocoding process.

Source Information: Brownsville Urban System, 700 Jose Colunga Jr. Street, Brownsville, TX 78521. Phone (956) 574-6672, Fax: (956) 544-7603
Step by Step Guide

Part 1: Compiling, Cleaning, and Formulating Files

Goals/Products:
- The following shapefiles, databases, and maps can be used in the subsequent Parts:
  - complete patron list database
  - complete travel log database
  - transit service area shapefile
  - service area roads shapefile

Procedure:
1. Compile files from various sources
   a. Download 2000 Roads, 2000 Census Block Groups, and SF1 Demographic data from the US Census Bureau website [I initially started working with census blocks, but this unit of spatial measure was too small so we increased it to block groups.]
      i. 2000_Roads.shp
      ii. 2000_CensusGroups.shp
      iii. 2000_CensusGroups_SF1.dbf
   b. Collect Transit Routes data from the Brownsville BUS GIS dvd
      i. route1.shp etc...
   c. Collect Transit Patron List and Transit Travel Log from the Brownsville BUS GIS dvd
      i. ADA_Paratransit_Services_Patron_List.xls
      ii. ADA_Paratransit_Log_(BUS).xls
2. Create a complete patron list database
   a. Open original Paratransit Patron List (2021 records)
      i. ADA_Paratransit_Services_Patron_List.xls
   b. Convert the file to SPSS format (2021 records)
      i. Patron_List.sav
   c. Delete duplicate records, based on matching address and mobility (1673 records)
      i. Patron_List_Cleaned2.sav
   d. Merge the patron list with the travel log (see step 3.e) to identify only those individuals that traveled during the last six months [This is done for two reasons: First, we only have personal demographics for those who traveled within the past six months since they are attached to the travel logs. Second, we know that the patron list we are working with is old and contains many people who don’t use transit anymore; this was a way to factor out the extraneous patrons.] (927 records)
      i. Patron_List_Cleaned2_and_Merged.sav
   e. Delete those records from the previous file that are destination locations [Since all the trips are unchained, i.e. from origin to destination and back to destination, we
only want/need the origin home locations for the patrons. When we merged the files in the previous step, both the origins and destinations from the travel log were combined, and essentially we are just reverting back to the original form of patron home addresses. The final database includes home address, city, zipcode, purpose, language, ethnicity, gender, and mobility] (380 records)

i. Patron_List_Cleaned2_and_Merged_OnlyHomes.sav

f. Convert SPSS file to database
   i. Patron_List_GIS.dbf

3. Create a complete travel log database
   a. Open original Paratransit Travel Log (36135 records)
      i. ADA_Paratransit_Log(BUS).xls
   b. Calculate important trip details, including Pickup Delay, Dropoff Delay, Time of Trip (AM/PM), Travel Time, Trip Purpose and Mobility [Delays are calculated by taking the difference between scheduled and actual times. The final database includes origin address, destination address, pickup delay, dropoff delay, am/pm, travel time, language, ethnicity, gender, trip purpose, and mobility.] (36135 records)
      i. ADA_Paratransit_Log(BUS)_Expanded.xls
   c. Convert the file to SPSS format (36135 records)
      i. Travel_Log_Cleaned.sav
   d. Delete blank records [For some reason, Excel and SPSS identified a considerable number of blank records at the end of the file as if they were part of the dataset. I simply removed those.] (28751 records)
      i. Travel_Log_Cleaned_Final.sav
   e. Create a simplified version of the previous file to use in merging with the travel log (see step 2.d) (28751 records)
      i. Travel_Log_Simplified_for_Merging.sav

4. Create a transit service area shapefile
   a. Open ArcGIS and create a map that contains census block groups and transit route shapefiles
      i. Original_Explore.map
   b. Buffer each transit route with a ½ mile buffer [This step converts the routes from lines to polygons, which is required to dissolve them together. This is Brownsville’s spatial limit for defining whether a person is allowed to ride the demand response transit.]
      i. BufferRoute1.shp etc...
   c. Union each of these buffered transit routes together to create a cumulative transit route shapefile
      i. DRT_Service_Area.shp
   d. Select census block groups if any part of the buffer is within it (based on spatial location) [These are the census block groups within the service area.] (115 block groups)
      i. CensusBlockGroupServiceArea.shp
   e. Join Add SF1 demographic data to census block groups service area shapefile
      i. CensusBlockGroupServiceArea_withSF1Data.shp
5. Create service area roads shapefile
   a. Clip roads shapefile to within the census block groups service area
      i. ServiceAreaRoads.shp

Part 2: Estimating Potential Demand

Goals/Products:
- Linear models that use census block socioeconomic and land use variables to predict the number of:
  - potential male mobile DRT users.
  - potential female mobile DRT users.
  - potential male handicapped DRT users.
  - potential female handicapped DRT users.
- SPSS tables in case format where each record is a census block in Brownsville DRT Service Area, and variables include socioeconomic and land use characteristics as well as the number of actual male/female mobile/handicapped DRT users in each census block.

Procedure:
1. Create an ArcGIS map to work from
   a. Open ArcGIS and create a map that contains service census block groups, cumulative transit routes, service area roads, and census roads shapefiles [All files added and created in this map are of the same coordinate system: GCS_WGS_1984; D_WGS_1984; Greenwich, Degree.]
      i. Geocoded_Patrons.map

2. Geocode addresses to map
   a. Add database of transit patron addresses to the map (380 records)
      i. Patron_List_GIS.dbf
   b. Create an address locator file
      i. Patron List Address Locator
   c. Geocode addresses automatically, with spelling sensitivity of 60, the minimum candidate score of 10, and a minimum match score of 40 [In doing the conversion, two street names consistently used in the database did not match those of the census roads. We changed 'N Expressway' to 'United States Highway 77' and 'FM#' to 'Farm-To-Market Road #'.]
   d. Geocode addresses interactively [By the end of this step, 346 of the 380 were matched or 91%.
   e. Export the layer of patron’s home address (PHA) points (346 records)
      i. Geocoded_Patrons.shp
   f. Select only those matched PHA points that are within the service area (345 records)
      i. GeocodedPatrons_Cleaned.shp
   g. Select and export those PHA points that correspond to mobile male patrons (59 records)
i. **Patrons_MaleMobile.shp**

h. Select and export those PHA points that correspond to mobile female patrons (89 records)
   i. **Patrons_FemaleMobile.shp**

i. Select and export those PHA points that correspond to handicapped male patrons (83 records)
   i. **Patrons_MaleHandicapped.shp**

j. Select and export those PHA points that correspond to handicapped female patrons (114 records)
   i. **Patrons_FemaleHandicapped.shp**

k. Add these layers back to the ArcGIS map
   i. **Geocoded_Patrons.map**

3. Calculate the distance from the centroid of each census block group to the nearest transit line

   a. Open ArcGIS and create a new map that contains service census block groups and transit routes shapefiles [All files added and created in this map are converted to the same coordinate system: NAD 1983 State Plane Texas South FIPS 4205.]
      i. **Reprojected_Geocoded_Patrons.map**

   b. Reproject census block group service area shapefile into a coordinate system that can handle distances and areas [We used NAD 1983 State Plane Texas South FIPS 4205.]
      i. **CensusBlockGroupServiceArea_Reproject.shp**

   c. Buffer each transit route with a 1-foot buffer [This step converts the routes from lines to polygons, which is required to union them together.]

   d. Union and Dissolve “polygon” transit routes together
      i. **Routefile_Dissolve.shp**

   e. Reproject “polygon” transit routes shapefile into a coordinate system that can handle distances and areas [We used NAD 1983 State Plane Texas South FIPS 4205.]
      i. **Routefile_Dissolved_Reproject.shp**

   f. Convert census block group polygons to centroids using the XtoolsPro GIS extension
      i. **CensusBlockGroupServiceArea_Reproject_Centroids.shp**

   g. Join the census block group centroids to the transit route polygon layer [Use the ‘join data from another layer based on spatial location’ and from ‘polygons to points’ and select option for ‘closest polygon and distance’. This adds the distance from the centroid to the nearest transit route into the attribute table.]

   h. Simplify the attribute table for the census block group centroids to only include ID and distance to transit
      i. **CensusBlockGroupServiceArea_Reproject_Centroids_withRouteDist.shp**

   i. Join census block group polygons to the census block group centroids [Use the ‘join data from another layer based on spatial location’.]

   j. Add X and Y coordinates of the census block group centroid to the attribute table [Calculate with the visual basic code provided in the ArcGIS manual.]
k. Add census block group area to the attribute table [Calculate with the visual basic code provided in the ArcGIS manual.]
   i. \texttt{CensusBlockGroupServiceArea\_Reproject\_withTransDist.shp}

4. Count number of these PHA points within each census block
   a. Reproject the four PHA point shapefiles
   b. Add the reprojected shapefiles to the map
      i. \texttt{Reprojected\_Geocoded\_Patrons.map}
   c. Make sure unmatched addresses are removed from the four PHA point shapefiles
      i. \texttt{Patrons\_MaleMobile\_Reproject.shp}
      ii. \texttt{Patrons\_FemaleMobile\_Reproject.shp}
      iii. \texttt{Patrons\_MaleHandicapped\_Reproject.shp}
      iv. \texttt{Patrons\_FemaleHandicapped\_Reproject.shp}
   d. Join the four PHA point shapefiles to the census block groups layer [Use the \texttt{join data from another layer based on spatial location} and from \texttt{polygons to points} and select option for \texttt{closest polygon and distance}. I tried doing the \texttt{Count} method, but this method recounted any points that fell on roads that formed a border between two census block groups.]
      i. \texttt{Patrons\_MaleMobile\_Reproject\_withCBG\_ID.shp}
      ii. \texttt{Patrons\_FemaleMobile\_Reproject\_withCBG\_ID.shp}
      iii. \texttt{Patrons\_MaleHandicapped\_Reproject\_withCBG\_ID.shp}
      iv. \texttt{Patrons\_FemaleHandicapped\_Reproject\_withCBG\_ID.shp}
   e. Export the point shapefiles to databases
      i. \texttt{MaleMobile\_Database.dbf}
      ii. \texttt{FemaleMobile\_Database.dbf}
      iii. \texttt{MaleHandicapped\_Database.dbf}
      iv. \texttt{FemaleHandicapped\_Database.dbf}
   f. Use SPSS to calculate frequencies for number of PHA points of each category in each census block
      i. \texttt{CBG\_Patron\_Frequencies.xls}
   g. Save the four sets of patron frequencies as databases
      i. \texttt{CBG\_FH\_Frequencies (69 records)}
      ii. \texttt{CBG\_FM\_Frequencies (54 records)}
      iii. \texttt{CBG\_MH\_Frequencies (56 records)}
      iv. \texttt{CBG\_MM\_Frequencies (39 records)}
   h. Add databases to the map
      i. \texttt{Reprojected\_Geocoded\_Patrons.map}
   i. Join the census block group shapefile with the four frequencies databases [Use the \texttt{Join attributes from a table}. This results in 4 new variables in the census block group attributes table- a count for each of the various patron types.] (155 records)
      i. \texttt{CensusBlockGroupServiceArea\_Reproject\_withTransDist\_andPatronCounts.shp}
j. Save final census block group shapefile [This step combines the joins into one clean file.] (115 records)
   i. CensusBlockGroupServiceArea_Reproject_withTransDist_andPatronCounts_final.shp

5. Develop a number of maps that analyze the distributions of
   a. Census block group populations
      i. Ethnicities
      ii. Ages
   b. Census block group households
      i. Average Size
      ii. Number of Occupied Household Units
      iii. Number of Vacant Units
      iv. Number of Renters
      v. Number of Owners
   c. Number of PHA points per census block group

6. Develop linear regression models to predict the number of PHA points in a census block group
   a. Export the complete census block group database
      i. Complete_CensusBlockGroup_Database.dbf
   b. Convert the four complete census block group databases into SPSS
      i. Complete_CensusBlockGroups.sav
   c. Run 4 linear regressions for male/female mobile/handicapped patrons using the following independent census block variables:
      i. area in square miles,
      ii. total population,
      iii. genders (male/female),
      iv. ages (under 5, 6-17, 18-29, 30-49, 50-64, 65 and older),
      v. households (total, average size),
      vi. families (total, average size),
      vii. housing units (total, vacant, rented, owned), and
      viii. distance from centroid to nearest bus route