Characterizing Public Transit Use in Austin, Texas

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EXECUTIVE SUMMARY

Public transportation has been identified in many regional and local plans for Austin, Texas as a critical means to address congestion and mobility challenges. It will be essential to ensuring economic competitiveness, reducing environmental impacts and providing mobility with the continuing growth in population. The purpose of this study is to use geographic information systems (GIS) to determine the locations within the existing fixed-route bus service area that have the most transit usage, and characterize these areas based demographic and socioeconomic data. Data from 2010 is used with traffic analysis zones as the unit of analysis. The three areas with the most significant ridership are identified as The University of Texas (UT) campus, East Riverside Drive and North Central Austin. These areas are further studied, looking at population density, employment density, median household income, auto ownership and adjacent land use. Linear regression is used to quantity the effects of these variables on transit use. Higher population and employment densities, lower incomes, lower auto ownership and mixed-land use are all exhibited in the study areas to varying degrees. This provides insight into what future transit-friendly development might look like for Austin. Furthermore, areas in most need of public transit service are identified based on proxies for demand and supply. The areas with the greatest transit gap are the UT campus, North Austin, East Riverside, Onion Creek, Pflugerville and Round Rock, however there are limitations to the methodology used. Further work should be done to investigate the areas with a transit gap to evaluate existing quality of service (if any) and determine if existing characteristics are favorable to transit. Overall, the results are useful for guiding future development of transit friendly areas and investment in public transportation.
INTRODUCTION

Urban transportation systems face a wide range of challenges including increasing demand and congestion, limited funding and inadequate public transportation systems. The fast growing Austin, TX is no exception, with some of the worst congestion in the country and its high car dependency. The 11th largest city in the United States is attracting an estimated 110 new residents a day (Austin Transportation Department, 2014). The change in population and number of commuters of the urban area1 is shown in Figure 1; from 2000 to 2011 there was a 45% and 59% change in population and commuters, respectively (Texas A&M Transportation Institute, 2012). This influx of people, jobs and cars is straining the current transportation system. In fact, the traffic in Austin grew more than 30 percent faster than the growth in road capacity over the past 25 years (Austin Transportation Department, 2014). Figure 2 shows the increase of miles traveled for vehicles and transit passengers from 2000 to 2011; there was a 43% increase in vehicle miles traveled but only a 29% increase in transit passenger miles traveled during that time (Texas A&M Transportation Institute, 2012). Austin is accordingly known as the 4th most congested metropolitan area in the United States (INRIX, 2014).

Figure 1: Austin, TX urban population trends.

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1 Urban area is defined as developed area with population density greater than 1,000 persons per square mile
Public transit is part of the solution to the problem. It has been identified as a critical component to several regional and local plans. The city’s comprehensive plan, Imagine Austin, focuses on a compact and connected approach to future development (City of Austin, 2012). This interconnected development pattern would support public transit and more transportation options. The 2014 Strategic Mobility Plan emphasizes the need for shared solutions and investments in both roadways and high capacity transit. An integrated, multi-modal system is needed to efficiently move people and goods. The Capital Area MPO’s (CAMPO) long range transportation plan also calls for high capacity transit as a critical part of the solution to Central Texas’s mobility problem. Recently, a
cohesive transit plan for the region, Project Connect, was developed; a mix of express buses, bus rapid transit, urban rail, commuter rail and regional rail are included.

The Capital Metropolitan Transit Authority (Capital Metro) is the regional public transit provider, whose system served 113,425 weekday boardings in FY2014 (Capital Metro, 2014). While a passenger rail line is currently part of Austin’s transit system, most users are served by the expansive bus system. Unfortunately, Austin lacks certain characteristics needed for great public transit, for example high density. The historical prioritization of highway construction has resulted in sprawling development away from the urban core and has slowed the development of transit. However, Austin will continue to change the focus of its transportation policies, and investments in public transit will almost certainly be part of the plan. It is important to understand what the characteristics are of areas with the highest transit usage when planning for Austin’s future growth and development so smart investments can be made when expanding the service. Likewise, recognizing the areas in most need of service can guide future investment and improvement in transit service. These two tasks are the main focus of this work.

Several related studies have been conducted, some utilizing geographic information systems (GIS) and others not. Dill et al. (2013) investigated the influence of transit service characteristics and urban form on transit ridership at the stop level for cities in Oregon. Their models indicated that transit service characteristics (e.g. headway, stops, park and ride) play the most significant role, however built environment characteristics also matter. Socio-demographic characteristics were also found to have a large effect on ridership in urban areas. Taylor et al. (2008) found that the most variation in transit ridership in urban areas can be explained by factors outside of the control of public transit systems such as population, income and carless households. Still, transit policies such as fare and frequency were found to be significant. Their study used urban areas as a whole as the unit of analysis (265 in total). In another study, both internal (controlled by transit operator) and external (not controlled by transit operator) were found to influence ridership in college towns (Oldread, 2011). The study used block groups as the unit of analysis and found direction of travel, level of service, percent of college age students and population density to be the highest indicators of ridership.

GIS has been used in several other studies to identify factors affecting transit use, access and performance. Zhao et al. (2002) used GIS for data compilation and spatial analysis of factors influencing transit use; transit supply variables, population and employment density and land use mix were all identified as strong indicators. Rizkiya (2012) used GIS to analyze the walking distance coverage of the transit system in Istanbul and the effect of population density, income level and car availability on sustainable transportation uses (e.g. public transit). The results were used to identify areas of the city that could be improved with transit access. Peng et al. (2006) developed a step-by-step guide for using GIS for performance assessment of transit systems and routes. They also show how actual walk buffer (i.e. following streets) and a straight line buffer from transit stops can differ significantly when determining service area. Finally, Jiao and Dillivan (2013) develop a GIS method for calculating and quantifying gaps between transit supply and demand. Their study identifies these “transit deserts” in four major U.S. cities.
This report builds upon several of these previous studies with the fixed-route bus system of Austin being the focus. Numerous data sources are utilized with GIS to analyze the existing transit service area, characteristics of areas with the highest transit utilization, and gaps between transit supply and demand. The following two reference maps are included to orient the reader with the overall study area. The Capital Metro system from 2010 is used, which services Travis County and part of southern Williamson County.

Map 1: Reference map.

TRAVIS AND WILLIAMSON COUNTIES
Reference Map

By: Tyler Beduhn | November 16, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: COA (Roads, Municipalities), TSDC (Counties, Water)
Map 2: Austin bus system overview.

FIXED-ROUTE BUS SYSTEM
Austin, Texas

By: Tyler Beduhn | November 16, 2014
Projected Coordinate System: NAD 1983 State Plane Texas
Central FIPS 4203 Feet
Sources: CMTA (Routes, PnR), COA (Roads), TSDC (Counties, Water)

Bus Routes (2010)
Express  Feeder  Park and Ride
Flyer  Special  Highway
Local  UT Shuttle  County

Lake Travis
PROBLEM STATEMENT

Public transportation investment has been identified as a necessary component of Austin’s future. Before expanding the current system, it is important to understand the external factors that may be influencing existing public transit use. Future development can be guided with the knowledge of transit-friendly urban characteristics. Areas with the most transit need can also be identified to guide future investment and improvement in the transit system. I hypothesize that the downtown and UT areas have the most transit usage given the high concentration of employment and large transit supply in the central core area. I also predict high population and employment densities will be a significant predictor of transit usage, while other factors such as low income and auto ownership will not be clearly observed in the maps. Some areas could also have high transit usage solely because of the existence of a park and ride or a transit center with many routes coming together. I hypothesize the areas with greatest transit need will be in East Austin and also the low density fringes of the city where expansion of the system may not be economically viable.

RESEARCH QUESTIONS

Answers to several questions are sought out in this work:

1. What is the service area of the bus system in Austin, TX?
2. What areas of the city have the most transit usage?
3. What are the characteristics (population density, employment density, income, auto ownership, land use) of the areas with highest transit usage?
4. What areas of the city have the most public transit need?

The latter two are the primary questions, while the first two provide background and support.

METHODOLOGY

The methodology is broken up into four main components. A more detailed description of the methodology can be found in the Appendix.

Acquire Data

Several data sources including spatial data (GIS shapefiles) and demographic/socioeconomic data are needed to conduct the study. The decision on what data would be used is based largely on the hypothesis (i.e. external factors impacting transit use) and its availability. One significant data source is the bus ridership data. Automatic passenger counting (APC) data is obtained from Capital Metro for January – June 2010. This data gives the number of boarding and alighting passengers at each stop for a large sample of bus runs during this time period. The data is aggregated to obtain the average boardings for each stop during weekdays and joined with a shapefile of bus stops; the shapefile is edited to also designate which stops are park and ride locations. A shapefile of transit routes is also obtained from Capital Metro. Information on which routes serve which stops, and how many trips or runs serve a stop during a weekday is obtain from Google’s General Transit Feed Specification (GTFS) files from 2010. All of this transit data from 2010 governs which other data sources are used.
For consistency with the transit data, socio-demographic data from 2010 is used. Working with 2010 provides some limitations because of the changes that have occurred in the past four years; Austin continues to grow and develop, and the bus system has undergone some service changes. However, given the temporal consistency of the data sources, the study still provides very valuable insights. Much of the variables needed (e.g. income, auto ownership) are available in the Census Summary File 3, but this data is not yet available for 2010 at the block group level. Therefore, traffic analysis zones (TAZ’s) from the CAMPO’s 2010 planning model are used as the level of analysis. This provides fine resolution (similar to the Census block group level) and TAZ’s are often used in transit planning models. The inputs to their model already have estimated attributes for each TAZ including population, employment, household income and autos per household. The TAZ file was converted to a shapefile from its TransCAD format.

In order to answer the final research question on transit need, a methodology from Jiao and Dillivan (2013) is used. Their estimate of transit demand requires additional demographic data: population age 16 and over, persons living in group quarters, population ages 12-15 and non-institutionalized population living in group quarters. Similar data is available from the 2010 Census at the block group level, but the number of vehicles available (also needed for their methodology) is at the TAZ level. The 2010 block group data is converted to TAZ data by using the Tabulate Intersection tool in ArcGIS to determine the fraction of each TAZ made up by each block group, and then dividing the block group population counts to TAZs according to these fractions. This assumes the population is uniformly distributed across block groups, which is a limiting assumption.

Additional feature data including county boundaries, water, streets, sidewalks, municipality boundaries and 2010 land use are collected from the Texas State Data Center and City of Austin. All shapefiles are projected, if needed, to the Central State Plan coordinate system (Datum: NAD 1983).

**Study Area Selection**

The first question of service area is be answered by creating a map of the area within walk access to a bus stop. The buffer and union tools are used to look at a ¼ mile region around the stops. This approach is commonly done in practice to estimate service area, but an alternative method is explored. The network analysis tools is for more realistic road network distances when estimating the service area. Next, three subareas are identified for further in-depth analysis.

- Buffer ¼ mile around each stop.
- Use Network Analyst tool to create ¼ mile service area around each stop using network distance.
- Use Tabulate Intersection tool with network distance service area polygons and TAZs; use resulting fractions to divide stop boardings to TAZs. Determine which TAZs have transit access.
- Conduct hot spot analysis to identify three study areas with highest and most significant ridership.
Socio-demographic Analysis

Once the study areas are selected, they are analyzed for demographic and socioeconomic trends.

- Create layouts for population density, employment density, household income, auto ownership and land use for the three study areas.
- Conduct linear regression for the TAZs with transit access with the number of boardings as the dependent variable, testing external and internal independent variables.

Public Transit Need Assessment

After characteristics of high transit usage areas are determined, areas with the most transit need are identified using a procedure similar to that used by Jiao and Dillivan (2013). The transit gap (supply – demand) for each TAZ is determined. Transit supply is calculated by the number of bus stops, routes and weekday trips accessible from each TAZ, each divided by area and standardized as a z-score. The four z-scores are added to obtain an overall z-score (i.e. equal weight placed on each factor). Demand is estimated by the total transit-dependent population:

Household drivers = (population age 15 and over) - (persons living in group quarters)
Transit-dependent household population = (household drivers) - (vehicles available)
Transit-dependent population = (transit-dependent household population) + (population ages 10-14) + (non-institutionalized population living in group quarters)

These equations are adapted from Jiao and Dillivan, with the ages changed slightly to match Census 2010 data age thresholds. This introduces some limitations, for example, estimating household drivers as population over 15 and not 16. The resulting transit-dependent population is also divided by area and standardized. The gap, transit supply – transit demand, is calculated for each TAZ to identify areas with greatest transit need.

- Calculate transit supply and demand measures, normalized by area, and calculate z-scores for each TAZ.
- Identify transit gaps as supply z-score minus demand z-score.

FINDINGS

The following maps and tables present the major findings of the study.
Map 3: Bus system service area.

The highlighted area is within a quarter mile from a bus stop.

By: Tyler Beduhn | November 16, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: CMTA (Stops), COA (Roads), TSDC (Counties, Water)
Table 1: Transit service summary table.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routes (Weekday)</td>
<td>93</td>
</tr>
<tr>
<td>Stops</td>
<td>3,071</td>
</tr>
<tr>
<td>Park and Rides</td>
<td>12</td>
</tr>
<tr>
<td>TAZs</td>
<td></td>
</tr>
<tr>
<td>Travis County</td>
<td>1,000</td>
</tr>
<tr>
<td>Williamson County</td>
<td>464</td>
</tr>
<tr>
<td>Transit Access</td>
<td>729</td>
</tr>
<tr>
<td>Service Area (1/4 mi.)</td>
<td></td>
</tr>
<tr>
<td>Buffer</td>
<td>114.5 sq. mi.</td>
</tr>
<tr>
<td>Network Distance</td>
<td>80.8 sq. mi.</td>
</tr>
<tr>
<td>Average Weekday Boardings</td>
<td>105,078</td>
</tr>
</tbody>
</table>
STOP LEVEL RIDERSHIP

By: Tyler Beduhn | November 16, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: CMTA (Stops, Boardings), COA (Roads), TSDC (Counties, Water)

Map 4: Average daily (weekday) boardings at stops.

Average weekday boardings are determined from Capital Metro Automatic Passenger Counting (APC) data from January - June 2010.
Map 5: Estimated TAZ ridership and hot spot analysis.

**TAZ LEVEL RIDERSHIP**

By: Tyler Beduhn | November 16, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: CAMPO (TAZ), CMTA (Stops, Boardings), COA (Roads), TSDC (Counties, Water)

**Average Weekday Boardings**

- 0
- 1 - 100
- 101 - 500
- 501 - 1,000
- 1,001 - 3,000
- > 3,000

Stop boardings are divided amongst TAZs proportional to the percent of the stop access area that each TAZ makes up.

**Hot Spot Analysis**

**Z-Score**

- No Hot Spots
- 1.65 - 1.96 Std. Dev.
- 1.96 - 2.58 Std. Dev.
- > 2.58 Std. Dev.
- Selected (Critical) TAZ
Map 6: Study area reference map.

STUDY AREAS
Reference Map
By: Tyler Beduhn | November 16, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: COA (Roads), TSDC (Counties, Water)

1 Study Area 1
*UT Campus*

3 Study Area 3
*North Central*

2 Study Area 2
*East Riverside*
STUDY AREAS

By: Tyler Beduhn | November 24, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: CAMPO (TAZ), CMTA (Stops, Routes), COA (Roads), TSDC (Water)

Bus Routes
- Express
- Feeder
- Flyer
- Special
- Local
- UT Shuttle

- Bus Stops
- Park and Ride
- Road
- Critical TAZ

Map 7: Study area descriptive map.
Map 8: Population density analysis map.

**POPULATION DENSITY**

By: Tyler Beduhn  |  November 24, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: CAMPO (TAZ, Population Density), CMTA (Stops), COA (Roads), TSDC (Water)

<table>
<thead>
<tr>
<th>Persons per Square Mile (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>≤ 1,000</td>
</tr>
<tr>
<td>1,001 - 5,000</td>
</tr>
<tr>
<td>5,001 - 10,000</td>
</tr>
<tr>
<td>10,001 - 25,000</td>
</tr>
<tr>
<td>25,001 - 60,000</td>
</tr>
</tbody>
</table>

- Bus Stops
- Park and Ride
- Road
- Critical TAZ
Map 9: Employment density analysis map.
HOUSEHOLD INCOME

By: Tyler Beduhn  | November 24, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: CAMPO (TAZ, Income), CMTA (Stops), COA (Roads), TSDC (Water)

Median Household Income (2010)

- ≤ $10,000
- $10,001 - $30,000
- $30,001 - $60,000
- $60,001 - $100,000
- > $100,000

Map 10: Median household income analysis map.
Map 11: Vehicle access analysis map.

PRIVATE VEHICLE ACCESS

By: Tyler Beduhn  |  November 24, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: CAMPO (TAZ, Vehicle Access), CMTA (Stops), COA (Roads), TSDC (Water)

Percent of Households with Zero Autos (2010)

- 0% - 0.5%  •  Bus Stops
- 0.6% - 1.5%  •  Park and Ride
- 1.6% - 2.5%  •  Road
- 2.6% - 5%  •  Critical TAZ
- 5.1% - 8%
LAND USE

By: Tyler Beduhn | November 24, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: CAMPO (TAZ), CMTA (Stops), COA (Roads, Land Use), TSDC (Water)

Land Use (2010)
- Single-Family Residential
- Multi-Family Residential
- Commercial
- Office
- Industrial
- Civic
- Open Space
- Transportation and Utilities
- Undeveloped

Map 12: Land use analysis map.
Map 13: TAZs classified by transit demand and supply.

TRANSPORT DEMAND AND SUPPLY

By: Tyler Beduhn | November 24, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: CAMPO (TAZ, Auto Access), CMTA (Stops, Routes), COA (Roads, Sidewalks), TSDC (Water), GTFS (Trips), Census (Demographics)

Demand

Supply

Demand is based on transit-dependent population of each TAZ.
Supply is based on the number of accessible stops, routes and trips and the length of sidewalks for each TAZ.
Map 14: TAZs classified by transit gap.

TRANSIT GAP

By: Tyler Beduhn  |  November 24, 2014
Projected Coordinate System: NAD 1983 State Plane Texas Central FIPS 4203 Feet
Sources: CAMPO (TAZ, Auto Access), CMTA (Stops, Routes), COA (Roads, Sidewalks), TSDC (Water), GTFS (Trips), Census (Demographics)

Transit gap is measured as the difference between transit supply z-score and transit demand z-score.

Existing service area is highlighted.
ANALYSIS

Map 3 shows the service area of the bus system, or the areas that are within ¼ mile access of a bus stop. A significant difference is observed between the area of the buffer and network distance approaches. It appears identifying the catchment area of a bus stop using a straight-line buffer overestimates the actually area that is accessible to the bus stop using the street network. In reality, transit users cannot cut across parcels, building and barriers to get to a bus stop. The network distance service area is carried through to the next step of distributing stop level ridership to TAZs.

The 3D visualization of stop level ridership shows several dominant areas of transit use, namely downtown, UT campus and East Riverside Drive (Map 4). There are also individual stops that dominate (e.g. Highland Mall, North Lamar Transit Center) which are major transfer points and thus would have a large number of boardings. Areas with the greatest and most significant transit use are identified in Map 5. The hypothesis of UT and East Riverside having the highest ridership is confirmed. These three study areas, UT Campus, East Riverside, and North Central (Highland Mall and North Lamar Transit Center), are further analyzed in the subsequent analysis maps.

High population density is observed in West Campus and part of East Riverside, while North Central has moderate to low density. UT Campus and the State office buildings to the south have a very high density of employment, while East Riverside and North Central have significantly lower densities. Very low median household incomes are seen with the student housing around campus and along East Riverside, and slightly higher incomes are observed in North Central. However, all of the 18 critical TAZs selected have median household incomes less than $40,000, much lower than the Austin average. There is a higher percentage of zero car households in the UT campus area, as expected, but a clear trend is not observed in the other areas. This may be limitations in the auto ownership data. It is based on CAMPO’s auto ownership submodel which predicts ownership for each TAZ based on variables such as income, household size and number of workers. Land use in the study areas appears to be a mix of multi-family residential, civic, commercial and single-family residential. Table 2 summaries the overall characteristics of these areas.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday Boardings</td>
<td>29,551 (28% of total system)</td>
</tr>
<tr>
<td>Population Density</td>
<td>5,892 per. / sq. mi.</td>
</tr>
<tr>
<td>Employment Density</td>
<td>6,709 emp. / sq. mi.</td>
</tr>
<tr>
<td>Household Income</td>
<td>$25,114</td>
</tr>
<tr>
<td>Percent Zero Car Households</td>
<td>2.3%</td>
</tr>
<tr>
<td>Dominant Land Uses</td>
<td>Multi-Family Residential, Commercial, Civic, Single-Family Residential</td>
</tr>
</tbody>
</table>
The analysis maps of the three study areas confirm parts of the initial hypothesis. Population density and/or employment density appear to anchor these high transit use areas. Lower incomes are also observed, but auto ownership does not have a clear relationship with ridership other than with student housing near campus. Linear regression is conducted on the 729 TAZs that have access to bus stops to quantify some of these relationships. TAZ weekday boardings is the dependent variable and several external and internal independent variables are tested. The results of the best two models are shown in the following tables. Population and employment densities are not found to be significant, but the absolute values are. For every additional person living in a TAZ, an increase of 0.40 daily boardings results, all other factors remaining the same. Similarly, for every $1,000 increase in median household income of a TAZ, daily boardings decrease by about 2, and for every additional car owned in a TAZ boardings decrease by 0.54 with all other factors remaining the same. The existence of park and ride was also not found to be significant. When adding an internal factor (i.e. number of daily bus trips accessible to the TAZ), the $R^2$ value increases and income becomes insignificant. Still, the independent variables only account for 29% of the variability in boardings so there are other factors at play. Transferring passengers are suspected to impact ridership counts of some TAZs, however it not possible to distinguish these passengers amongst total boardings, and it is difficult to identify popular transfer locations (i.e. add as a variable).

**Table 3: Linear regression results - external factors.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient (t-statistic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>90.22 (1.99)</td>
</tr>
<tr>
<td>Population</td>
<td>0.40 (4.42)</td>
</tr>
<tr>
<td>Employment</td>
<td>0.23 (10.44)</td>
</tr>
<tr>
<td>Median HH Income</td>
<td>-2.11 E -3 (-2.65)</td>
</tr>
<tr>
<td>Num. Vehicles</td>
<td>-0.54 (-3.94)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.17</td>
</tr>
</tbody>
</table>

**Table 4: Linear regression results - external and internal factors.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient (t-statistic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-246.61 (-6.55)</td>
</tr>
<tr>
<td>Population</td>
<td>0.44 (5.52)</td>
</tr>
<tr>
<td>Employment</td>
<td>0.21 (10.32)</td>
</tr>
<tr>
<td>Num. Vehicles</td>
<td>-0.54 (-4.43)</td>
</tr>
<tr>
<td>Weekday Accessible Bus Trips</td>
<td>0.50 (11.57)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Transit demand, supply and the resulting gap are shown in Maps 13 and 14. The areas with the highest demand are the UT campus, downtown and East Riverside while
the greatest supply is in downtown and parts of Central and East Austin. The greatest transit gap exists in the UT campus area according to this methodology. Other areas stand out such as North Austin, East Riverside and Onion Creek. Pflugerville and Round Rock, which do not have transit service, also have areas of high gap. The reason why UT has the highest gap when there appears to be an abundance of supply (see Map 7) is likely because of the limitations in the demand estimate. It is based on the characteristics of the population living in a TAZ and not on their travel needs. The main destination of these “transit-dependent” people (i.e. students) is campus, but these trips can be served by walking or biking. The results of the need assessment do not confirm the hypothesis, as there are many scattered TAZs within the existing service area, in addition to the fringes of Austin, that have a high gap.

CONCLUSION

Throughout this study, GIS is used to characterize public transit use and need in Austin, Texas. The service area, or area accessible to the fixed-route bus system, is identified, and a significant difference is observed between buffers around stops using both straight-line and network distances. This warrants future work to determine if network distances are more appropriate for establishing the catchment area of a stop (e.g. compare both approaches in regression to predict ridership). Stop level boardings are divided amongst TAZs according to the fraction of the stop catchment area made up by each TAZ. This is somewhat problematic when TAZs are very small; for example significant ridership was not observed in downtown using TAZ ridership estimates because stop boardings get widely distributed to many TAZs. However, significant ridership is observed in this area when looking at stop level ridership (Map 4). Overall, three critical areas of existing ridership are identified: UT Campus, East Riverside and North Central. Next, greater population and employment, lower incomes, lower car ownership and a mix of land uses (specifically including multi-family residential) are characteristic of these high transit use areas in Austin; this is shown through a series of analysis maps and linear regression. The results provide guidelines for future transit-friendly development. This includes higher densities, affordability and mixed land use.

The final part of the study identifies transit gaps, where supply is less than demand or potential transit users. There are a few limitations in the methodology used. Demographic data was estimated for TAZs from Census block groups, and the differences in geometry and the uniform population assumption yield errors. The UT area has the greatest gap, however the large demand estimate for this area does not consider that the major destination for much this population is campus. Other areas including North Austin, East Riverside, Onion Creek, Pflugerville and Round Rock exhibit a transit gap. The next step in this work would be to look within the areas with the highest gap, evaluate current service quality and determine if characteristics (i.e. density, income, etc.) are supportive of transit. This can guide improvements or investments, such as expanding service, rerouting or increasing frequency. Perhaps another approach for future work is a “suitability” analysis using the knowledge of factors conducive to transit use and overlaying the existing transit system to identify areas that are favorable to transit but are not currently served.
Data:

The transit network data was obtained from Capital Metro (Van Sutherland, GIS Coordinator). The APC data was also obtained from Capital Metro (Jennifer Govea, Service Analysis Manager) through the author’s graduate research work. Data on specific routes and trips serving stops was obtained from GTFS files (http://www.gtfs-data-exchange.com/agency/capital-metro/). The 2010 TAZ and socio-demographic data were obtained from CAMPO while other demographic data at the block group level was obtained from the 2010 Census Summary File 1. Streets, sidewalks, municipality boundaries, counties and land use were all obtained from the City of Austin (ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/). Block groups and surface water shapefiles were obtained from the Texas State Data Center (http://txsdc.utsa.edu/Data/Tiger/2010/CountyShapeFiles.aspx).

Detailed Methodology:

Acquire Data

1. Collect county boundary shapefile. Select Travis and Williamson Counties and export to a new shapefile, CountyOutlines.
2. Collect surface water shapefiles for both Travis and Williamson Counties. Project to State Plan Texas Central. Merge to one water shapefile.
3. Collect streets, sidewalks, Austin city limits, municipality boundaries and 2010 land use shapefiles. Clip to CountyOutlines.
4. Select major highways in streets shapefiles and export to a highway shapefile.
5. Build a network dataset from the streets shapefile (Network Analyst extension).
6. Collect bus routes and bus stop shapefiles, select weekday service routes and export to new route shapefile. Edit shapefile to add a field for service type for each route: local, express, flyer, feeder, UT shuttle, special. Obtain GTFS files for spring 2010. Process files using a Python script to get which routes (and directions) and trips serve each stop, and save as a spreadsheet. Obtain locations (stop IDs) of park and rides from Capital Metro and save as spreadsheet (list of all stops and binary value indicating if a park and ride is located at the stop). Join park and ride spreadsheet to stops shapefile. Join spreadsheet of average weekday boardings at each stop to the stops shapefile.
7. Collect TAZ TransCAD file and export to shapefile. Ensure the correct projection is used. Select by attributes TAZ’s in Travis and Williamson counties, and export to a new shapefile. Remove any unnecessary fields from the attribute table.
8. Collect 2010 block groups for Travis and Williamson Counties. Project to State Plane Texas Central and merge to create a new shapefile. Collect population by age and population in group quarters for block groups, and save as a spreadsheet. Join this spreadsheet to the block group shapefile by GEOID.
9. Create a **Reference Map** showing the county boundaries, major highways, rivers, and city limits.
10. Create a **Descriptive Map** showing bus routes symbolized by service type and park and ride locations.
Study Area Selection

1. Use the buffer tool to create a ¼ mile buffer around each stop, then dissolve to remove internal boundaries. Calculate area and export shapefile.

2. Use the Network Analyst tool to create a service area. Use bus stops as facilities and join facilities and stops so stop ID and boardings are associated with facilities. Use distance as impedance and 0.25 and the break. Generate polygons (detailed) and allow overlapping. Join facilities with stops to polygons so each polygon has an associated stop ID and boardings. Export polygons as new shapefile. Dissolve polygons, calculate area and export shapefile.

3. Create an **Analysis Map** comparing the service areas of the buffer and network approaches.

4. Use Tabulate Intersection tool with the network distance access area polygons as the zone data and the TAZ’s as the class data to obtain the fraction of the access area for each stop that is made up of each TAZ. In Excel, multiple the average weekday boardings for each stop by the fractions of each TAZ, and sum ridership for each TAZ. In another column, denote which TAZs have transit access (if TAZ is listed in Tabulate Intersection results). Join the results with the TAZ attribute table.

5. Use ArcScene to visualize stop level boardings in 3D. Extrude stops based on the number of boardings.

6. Conduct a hot spot analysis to identify TAZ clusters with significant transit ridership. Use “zone of indifference” as the conceptualization of spatial relationships with 1,320 feet as the distance threshold. Identify three study areas (UT/West Campus/North Campus, East Riverside and North Central – transit centers and Highland). Select the significant TAZs and export shapefile.

7. Create two **Analysis Maps**, one showing 3D image of stop ridership and the other with TAZ’s symbolized by total ridership and the results of the hot spot analysis.

8. Create a table summarizing transit service overall: number of routes, number of stops, number of park and rides, number of TAZ’s with transit service, total TAZ’s, area (sq. mi.) of service area, average weekday boardings

Socio-demographic Analysis

1. Create a **Reference Map** and **Descriptive Map** of the three study areas.

2. Create **Analysis Maps** of each factor with three side-by-side data frames of the study areas. Also symbolize bus stops, streets and park and rides (if any). Layouts are created for each:
   a. Population density
   b. Employment density
   c. Median household income
   d. Percent of households with zero cars available
   e. Land use

3. Conduct a linear regression analysis in SPSS for all TAZ’s that have transit service (i.e. within 0.25 mile network distance from a stop). Use TAZ ridership as the dependent variable and test population, employment, median household
income, number of zero car households, number of park and rides and accessible bus trips as the independent variables. Create a table of the results.

Transit Need Assessment

1. In Excel, prepare measurements of transit supply. Using the results of the Tabulate Area analysis in Study Area Selection, Step 4, the number of stops accessible from each TAZ is determined. Note that if a stop is accessible (i.e. 0.25 mile network distance) from any point in a TAZ, it is counted as transit supply for that TAZ. Determine the number of stops accessible by each TAZ, and divide by the TAZ area and calculate a z-score. Determine the number of unique routes accessible to each TAZ based on the routes serving accessible stops. Standardize the number of routes accessible (normalize by area and calculate z-score). Determine the number of unique bus trips throughout a weekday accessible to each TAZ, divide by area and calculate a z-score. Intersect sidewalks and TAZs to split the sidewalk lines at polygon boundaries. Calculate the resulting sidewalk lengths (miles). Dissolve sidewalks using TAZ as the dissolve field, summing sidewalk lengths. Add the four supply z-scores to get a measure of transit supply for each TAZ. Join the resulting spreadsheet to the main TAZ shapefile.

2. In Excel, distribute the block group population measures (population age 15 and over, population living in group quarters, population ages 10-14, non-institutionalized population living in group quarters) to TAZs. Use the Tabulate Area tool to determine the fraction of each block group made up by each TAZ, and apply these fractions to the block group population measures. Sum the resulting estimates for each TAZ. Join the resulting spreadsheet to the TAZ attribute table.

3. Add a field to the TAZ attribute table for transit demand. Calculate field:

\[
\text{Demand} = [\text{POP\_OVER15}] - [\text{GRP\_QTR}] - ([\text{HH\_1C}] + 2 \times [\text{HH\_2C}] + 3 \times [\text{HH\_3C}]) + [\text{POP\_10TO14}] + [\text{NONINST}]
\]

Add two more fields to the attribute table: normalized demand and demand z-score. Calculate field and normalize the demand with TAZ area. Look at the statistics of the normalized demand field and note the mean and standard deviation. Calculate the demand z-score field using the mean and standard deviation.

4. Add a field to the TAZ attribute table for transit gap. Calculate field as transit supply – transit demand.

5. Create two Analysis Maps, one showing transit demand and supply z-scores and the other showing transit gap z-scores. Classify demand, supply and gap into 5 categories using natural breaks (Lowest, Low, Moderate, High, Highest).
REFERENCES


Dill, J., M. Schlossberg, L. Ma, C. Meyer (2013). Predicting transit ridership at the stop level: The role of service and urban form. Presented at the 92nd Annual Meeting of the Transportation Research Board.


