Safety and Operations of Large-Area Rural/Urban Intermodal Systems

SOLARIS

A Tier 1 university transportation center led by the University of Nevada, Reno.

Final Report

August 2017

Economic Analysis of Public Transportation in Reno, Nevada

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Table of Contents

Executive Summary

Access to public transit is important and beneficial economically and socially in numerous ways. Using economic and demographic variables from U.S. Census data, we have examined who is being served by public transit in Reno, as well as examined the flow of workers to their jobs to identify possible locations for expansion. We focus on areas with high densities of workers and jobs, especially those that are low income. The first part of our research looks at access to public transit, which we define as individuals living or working within 400 meters of a bus stop. The second part of the research consists of an analysis on use of public transit. We have been conducting regression analyses on the factors that influence choice of transportation to work. After our data analyses, we have found locations that are possibly being underserved by public transit based on our specified criteria.

The focus was placed on areas of high density levels of workers and jobs, with an emphasis on low-income workers. From our analysis on public transit access, we have found that there are several areas that have strong potential for usage should the RTC expand its service to those areas.

There are four important findings from this research:

1) There are several areas that have strong potential for usage if the RTC were to expand its service to those areas.
2) Many non-served areas we identified had higher densities of individuals likely to take public transit than areas currently being served.
3) The regression analyses support the idea of lower income individuals being more likely to take public transit.

4) The regressions also show that race is an important factor in addition to income.

Many of the non-served areas we identified had higher densities of individuals likely to take public transit than some of the areas currently being served. Our regression analyses support the idea of lower income individuals being more likely to take public transit. Additionally, the regressions show us that not only is income an important factor, but race is influential as well. These results can be helpful in terms of locating good quality locations for public transit service, as well as identifying the current service locations that may not be as good. This research has shown that there are numerous areas with strong potential for public transit usage, as well as areas that are possibly being overserved.

Introduction

There have been numerous studies that quantify the potential benefits of public transit. A study of Jobs Access and Reverse Commute (JARC) programs by Thakuriah, Sriraj and Persky, found that for every dollar spent on public transit, there is a return of $1.90 to users, $1.50 to non-users, and between $3.10 and $3.50 to society is expected. A benefit/cost ratio (BCR), defined as monetary benefits divided by cost of transit, was calculated to be between 1.9 and 2.5. A study by Multisystems et al. (2000) estimated the BCR of certain public transit programs in Florida, Maryland, and Kentucky for public transportation to work. The BCR of these programs was estimated to be 2.87, 2.52 and 1.01 respectively. A study by Cronin, Hagerich and Hotaling in Florida, estimated that the return to investment to the State is $5.71 for every dollar invested on public transit trips to work. A study by HDR Decision Economics found that over 65% of public transit trips are for work and if public transportation was not available, 25% of public transit users claimed they would not be able to work, get medical care, or attend school.

The primary areas of focus for this research include: 1) Access to public transit and 2) Use of public transit, in an effort to better understand public transit access and usage. In this research, we are defining public transit as the bus system of the Regional Transportation Commission (RTC), and does not include other forms of transportation like train, subway or taxi. For the second primary focus of this research on public transit usage, we examine factors that influence the choice of transportation to work which include factors such as income, race, and gender.

Literature Review

According to Porter et al., studies have typically focused on three sections of economic impacts of investment in public transportation. The first is job creation, which occurs through capital and operation spending. The second is effects on local development patterns. The third main aspect of focus has been on the direct benefits to riders, including such things as time and cost savings. (Porter et al.) What has not been examined as much is the indirect impact that public transit can have. Porter et al. examine other potential indirect cost savings to other groups, not just to the riders of public transit. Other government programs may benefit as well from public transportation. (Porter et al.) The indirect benefits can occur due to increased access to jobs, health care, and education, which may reduce demand for other government services. (Porter et al.) There have been some findings on the indirect benefits of public transportation. The first finding is that transportation is a critical factor for employment. There has been a connection determined between public transit and job access, where employment increased for lower wage workers after the introduction of public transit. The second finding is that transit can improve access to educational opportunities, which also indirectly boosts employment. It has been found that more education and higher quality education leads to decreased unemployment and increased wages. The fourth finding is that improved access to preventative health care reduces costs for other health services like emergency room visits. (Porter et al.) The following figures show the factors contributing to modal choice.

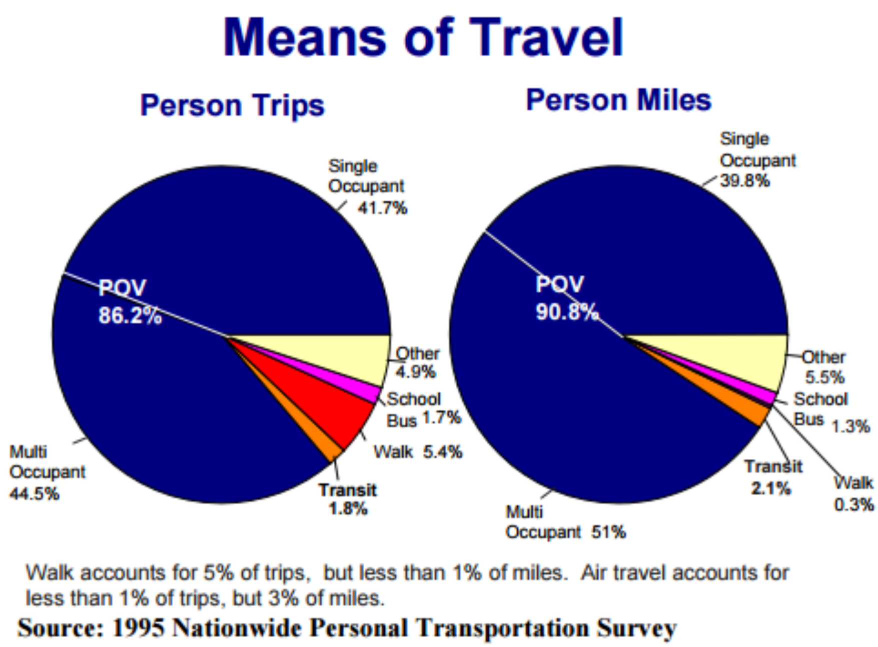


Figure 1

Income (x $1000) by Mode Split
Source: DelDOT Household Survey 1995-2001

	< 10k	10 - 14.9	15- 19.9	20 - 24.9	25 – 29.9	30 – 34.9	35 – 39.9	40 – 49,9	50 – 74.9	75 – 99.9	100 – 149.9	150 +
Driver	57.7	70.3	82.1	81.8	82.6	86.3	84.5	87.3	90.0	91.0	92.4	87.2
Passenger	16.0	12.3	14.1	13.3	13.0	9.3	11.6	10.1	7.7	7.0	5.4	10.9
Public Bus	6.2	8.1	1.2	1.6	1.9	0.9	2.5	0.8	0.4	0.9	0.5	1.5
Walked	13.7	6.2	2.2	2.7	1.3	1.5	0.9	1.0	0.6	0.7	0.6	
School Bus	1.3		0.2		0.6	0.8	0.4	0.5	0.9	0.2	0.4	
Bike	3.4	2.3		0.2	0.2	0.5				0.1	0.2	
Other	1.8	0.4	0.3	0.4	0.4	0.1	0.1	0.4	0.3	0.2	0.3	0.4

Figure 2

There have been numerous papers that investigate the importance of density on public transit and public transit ridership. In "Cost of a Ride: The Effects of Densities on Fixed-Guideway Transit Ridership and Capital Costs", Guerra and Cervero look at more than 50 transit investment projects built in the U.S. since 1970, the authors find a strong correlation between costs and ridership. As would be expected, capital costs and ridership are positively correlated. (Guerra and Cervero 2010) In addition, both ridership and capital costs typically rise with job and population densities. By clustering trip ends near stops, concentrated development tends to have many more transit trips per square mile than the less concentrated development. (Guerra and Cervero 2010) However, density typically increases construction costs as well. This is through increased costs for "right-of-way" acquisitions and building demolitions, more complicated route alignments, utility relocation expenses, and higher labor costs. (Guerra and Cervero 2010) The authors show that dense areas both benefit from and support transit.

There has been a long history of attempts to quantify the required levels of urban density to support transit. The most cited study, by Pushkarev and Zupan (1977), looked at eight modes of public transportation: taxicab, dial-a-bus, local bus, express bus, light rail, light guideway transit, rapid transit and commuter rail. To study the characteristics of a city that best explained variations in the cost-effectiveness of these modes, the authors focused on three specific factors: non-residential CBD (Central Business District) floor space, residential neighborhood densities, and distance to the CBD. (Pushkarev and Zupan 1977) Using regression models, these city characteristics were used to estimate travel demand and passenger operating costs, at various service frequencies. The authors found that cities with larger CBDs and higher residential densities along linear corridors could support higher levels of transit service. (Pushkarev and Zupan 1977)

Table 1. Transit-supportive density levels adapted from Pushkarev and Zupan (1977)

Mode	Service	Minimum residential units per net acre	Remarks
Local Bus	Minimum (20 bus/day)	4	10 million non-residential CBD s.f.
Local Bus	Intermediate (40/day)	7	
Local Bus	Frequent (120/day)	15	35 million non-residential CBD s.f.
Express Bus (foot)	Five buses in two hour peak period	15 (2 square mile area)	50+ million non-residential CBD s.f.
Express Bus (auto)	5-10 buses in two hour peak period	3 (20 square mile area)	10 to 15 miles from CBD (preferably 20+ million non-residential CBD s.f.)
Light Rail	5 minute peak-hour headways	9 (corridor of 25 to 100 square miles	20 to 50 million non-residential CBD s.f.
Heavy Rail Rapid Transit	5 minute peak-hour headways	12 (corridor of 100 to 50 square miles)	50+ million non-residential CBD s.f.
Commuter Rail	Twenty trains per day	1 to 2	Only to largest downtowns

In 2011, Cervero and Guerra published "Urban Densities and Transit: A Multi-Dimensional Perspective" where they the widely-accepted idea that a fairly dense urban development area is an "essential" feature of a successful public transit system. (Cervero and Guerra 2011) The difficult part is that beyond this broad statement, the specifics become much more difficult on how exactly and when exactly to increase urban densities. (Cervero and Guerra 2011) This paper examines the relationship between urban density and public transit from numerous different angles. This paper shows multiple angles in addressing the challenges of increasing urban densities and making transit investments to become cost-effective. While there indeed is empirical evidence to suggest rail investments in the U.S. have social benefits, much skepticism remains among the more vocal critics of American transit policy. (Cervero and Guerra 2011) All sides agree that increasing urban densities will place public transit on firmer financial footing. The analysis suggests that light-rail systems need approximately 30 people per acre near stations and heavy rail systems require higher densities than in order to be in the top 25% of cost-effective rail transit investments in the U.S. (Cervero and Guerra 2011) The ridership gains would be very significant, particularly when jobs are concentrated within 0.25 miles of a station and housing within 0.5 miles. (Cervero and Guerra 2011) More research and findings are required that show the impact of higher densities combined with other factors, like higher parking charges, and how these could be combined to create higher performing transit services. (Cervero and Guerra 2011)

In "Making the Most of Transit: Density, Employment Growth, and Ridership around New Stations", Kolko assesses how well California has achieved the integration of land use and transportation planning by looking at employment growth around new transit stations from 1996 to 2006. There are 3 key facts in the paper which show the importance of locating transit near jobs and encouraging job growth near transit. (Kolko 2011) The first is that transit ridership depends on proximity to transit, especially workplace proximity. The second is that employment density is more strongly associated with transit ridership than residential density is. The third is that in California, residential density is higher than the national average and rising, but employment density is lower than the national average and falling. (Kolko 2011) The author claims that employment patterns are more important for transit ridership than residential patterns, thus the paper focuses on employment growth rather than population growth. Looking across the 200-plus transit stations that opened in California from 1992 to 2006, the author finds that the new stations located in areas with high residential density and very high employment density. (Kolko 2011) However, opening new stations was not accompanied by an increase in average employment growth in the areas immediately surrounding these stations (relative to comparison areas). This includes when the stations opened and several years afterward. In addition, employment around new stations varied widely: Employment growth increased near 18 new stations and decreased near 20, relative to comparison areas, with the largest increases in areas that had higher residential and employment density prior to the station opening. (Kolko 2011) For the rest of the stations, the difference between employment growth around the station and in the comparison areas before and after the station opening was not statistically significant. (Kolko 2011) Employment growth increased most around stations located in higher-density areas. (Kolko 2011) There was no finding of any boost to employment growth associated with the opening of new transit stations, on average. (Kolko 2011) This finding shows the crucial importance of transit being located in high density areas, and why it is a key focus of our research.

Data and Methodology

1) Data for access to public transit

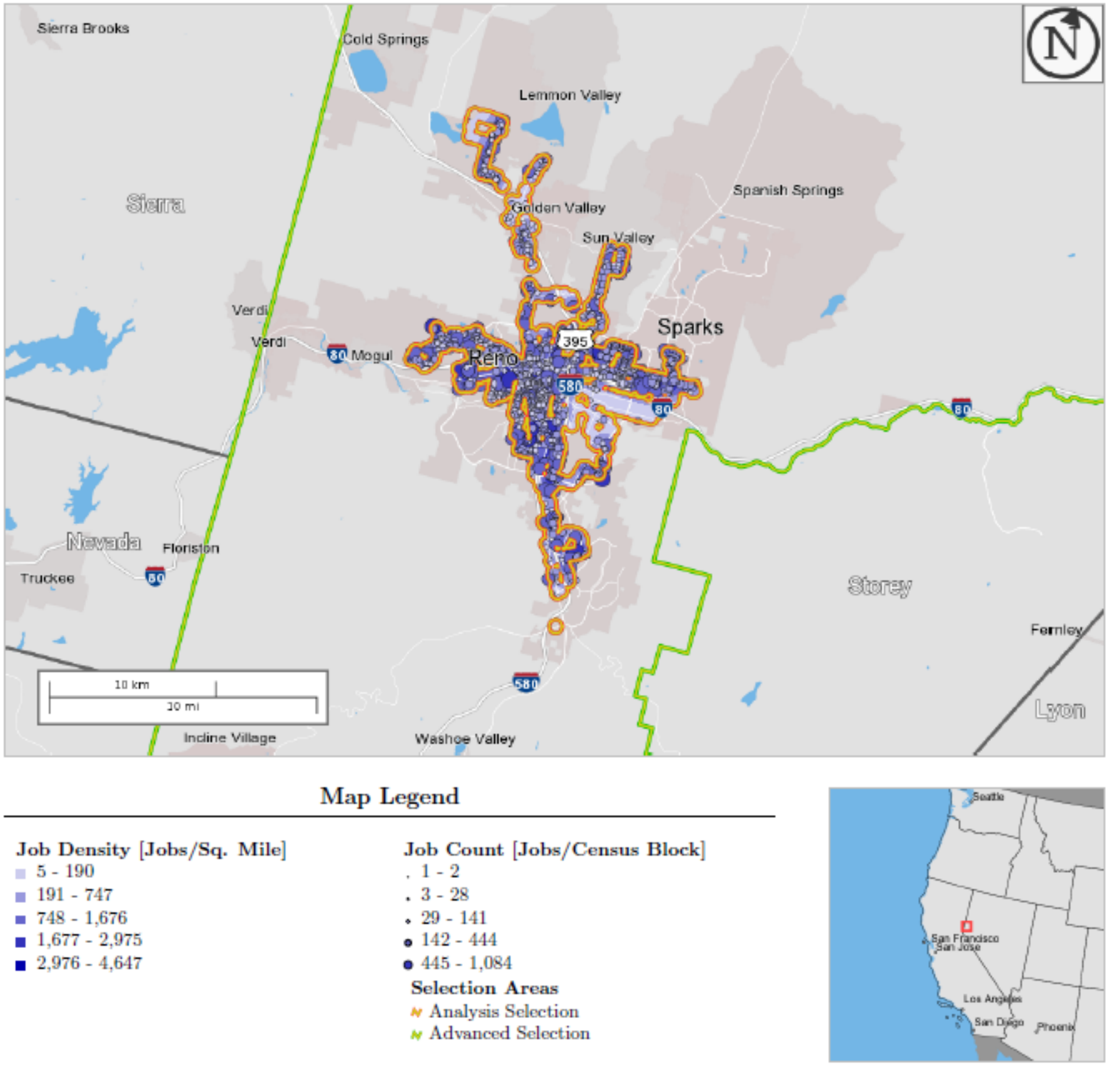
The data we are using for this research come from the United States Census Bureau. The main data source for the first part is the LEHD Origin-Destination Employment Statistics (LODES) from the Longitudinal Employer-Household Dynamics (LEHD). From the LODES, we have been using Origin-Destination, Workplace, and Residence data. The LODES data we are using from 2014, and these datasets provide information at the Census Block level. Using the LODES data as well as the United States Census Bureau's "OnTheMap" program, we have performed analyses on public transit access and demographic and economic variables. We have defined public transit access by whether someone is located within 400 meters of a bus stop. We have done this for both the individual's residence and the individual's workplace. An individual is defined as having access to public transit at their home, if they live within 400 meters of a bus stop and has access to public transit at their job if their workplace is located within 400 meters of a bus stop. Using a 400-meter radius around each bus stop in the Reno area, we have defined that area as the service area. Any location outside of 400 meters from any bus stop is considered outside of the service area. By using the LODES data with the "OnTheMap" program, we have conducted analyses and created maps and tables to represent the analysis of the service area as well as the non-service area. The categories included in these analyses include variables such as worker age, earnings, industry sector, race, education and gender.

2) Data for use of public transit

The data for the second part of the research Public Use Microdata Sample (PUMS) from the American Community Survey (ACS) for the year 2014. The PUMS contains a sample of actual survey responses of individuals from the ACS. Each observation in the dataset represents a single individual and their actual responses to the survey questions. The PUMS data are given at the state level, so the 2014 data we have used is for the entire state of Nevada. Using the PUMS data, we have conducted binomial logit regression analyses on mode of transportation to work. The dependent variable in these regressions is the mode of transportation to work. The explanatory variables included in these regressions represent income, race and gender. So far, we have found that income, race and gender are significant factors in mode of transportation choice and we will continue to explore this. Due to the limitations of this data set, we are not able to identify the exact individuals that are using public transit or not. Therefore, there is not a direct link between the access data and the usage data. However, we still can use the results from this data to help understand what factors contribute to the modal choice, either taking the bus or driving a car.

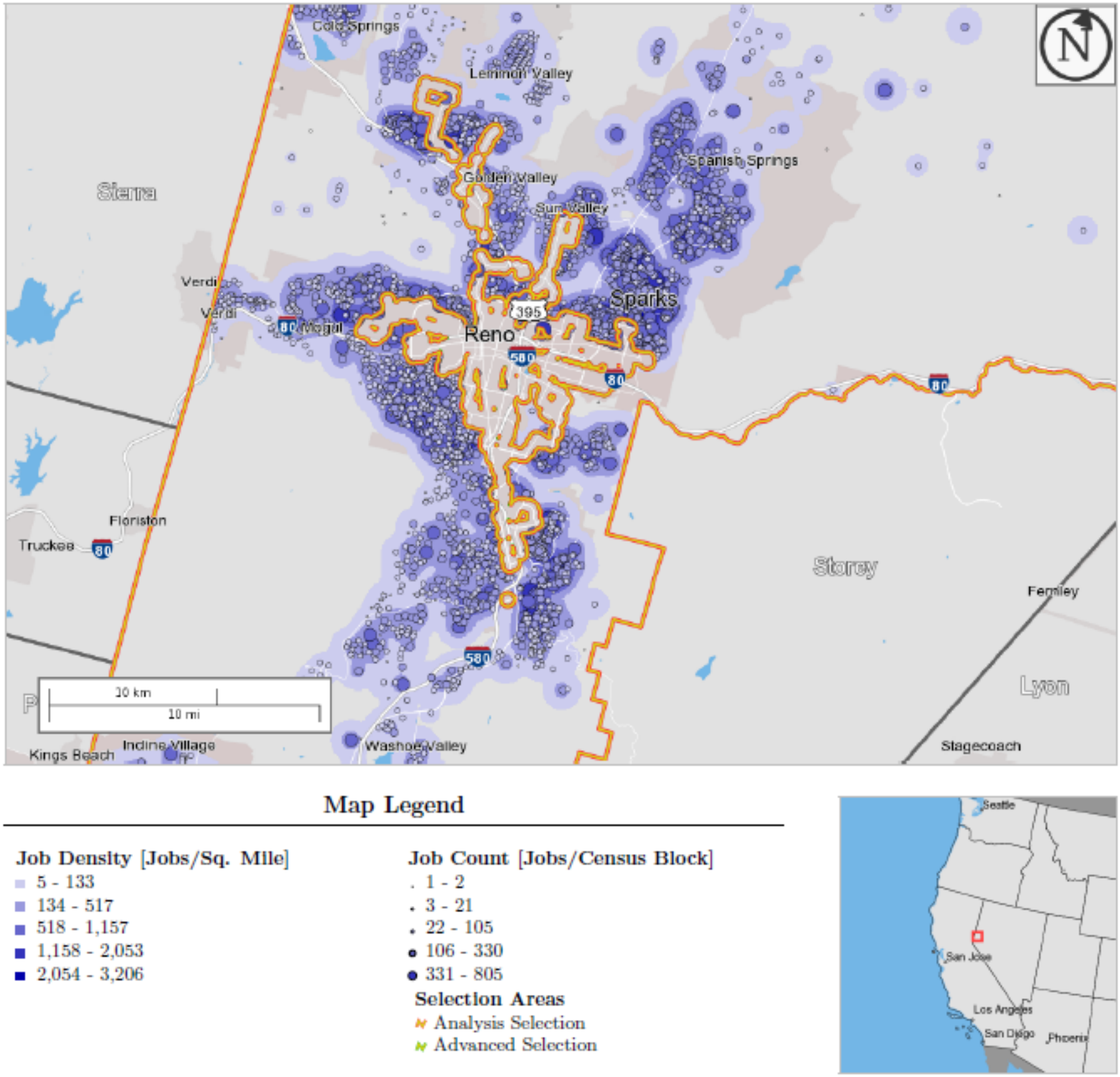
Results

Map 1: Residence within Service Area



Map 1 above is a visual display of the service area, which is shown by the orange borders, and the residences inside the service area. The dots on the map indicate workers living in that location, with larger dots representing higher counts of workers and darker shades of purple for increased density. It can be seen from this map that the population of residences in the service area is not equally distributed and there are certain areas with more worker residences and higher densities. As can be seen in Table 2, 41.6% of workers live inside of the service area.

Map 2: Residence Outside of Service Area



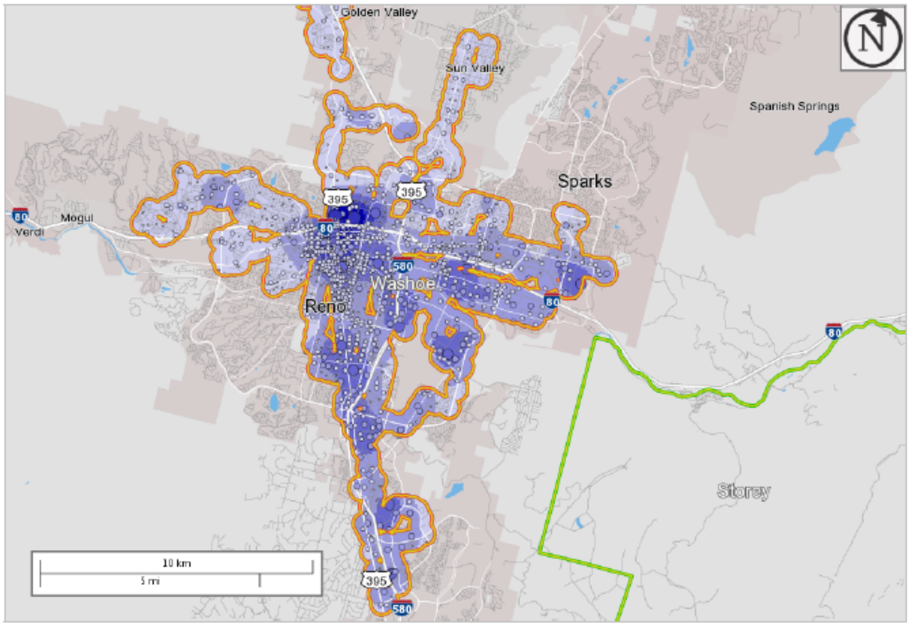
Map 2 shows the service area once again, this time showing the residences in Washoe County that are outside of the service area. As can be seen from this map, there is a substantial population in the surrounding area that does not have access to public transportation. The majority of workers live outside of the service area, 58.4% versus the 41.6% inside.

	Homes Inside				Homes Outside				Homes Total	
Total All Jobs										
	2014				2014					
	Count	Share Within	Share of Total		Count	Share	Share of Total		Count	Share of Total
Total All Jobs	79,067	100.0%	41.6%		111,122	100.0%	58.4%		190,189	100.0%
Jobs by Worker Age										
	2014				2014					
	Count	Share			Count	Share				
Age 29 or younger	20,837	26.4%	11.0%		22,822	20.5%	12.0%		43,659	23.0%
Age 30 to 54	41,494	52.5%	21.8%		61,762	55.6%	32.5%		103,256	54.3%
Age 55 or older	16,736	21.2%	8.8%		26,538	23.9%	14.0%		43,274	22.8%
Jobs by Earnings										
	2014				2014					
	Count	Share			Count	Share				
$1,250 per month or less	20,133	25.5%	10.6%		23,021	20.7%	12.1%		43,154	22.7%
$1,251 to $3,333 per month	37,078	46.9%	19.5%		38,062	34.3%	20.0%		75140	39.5%
More than $3,333 per month	21,856	27.6%	11.5%		50,039	45.0%	26.3%		71,895	37.8%
Jobs by NAICS Industry Sector										
	2014				2014					
	Count	Share			Count	Share				
Agriculture, Forestry, Fishing and Hunting	265	0.3%	0.1%		428	0.4%	0.2%		693	0.4%
Mining, Quarrying, and Oil and Gas Extraction	321	0.4%	0.2%		614	0.6%	0.3%		935	0.5%
Utilities	232	0.3%	0.1%		706	0.6%	0.4%		938	0.5%
Construction	4,132	5.2%	2.2%		6,273	5.6%	3.3%		10,405	5.5%
Manufacturing	5,051	6.4%	2.7%		6,911	6.2%	3.6%		11,962	6.3%
Wholesale Trade	3,390	4.3%	1.8%		5,068	4.6%	2.7%		8,458	4.4%
Retail Trade	9,464	12.0%	5.0%		12,024	10.8%	6.3%		21,488	11.3%
Transportation and Warehousing	5,506	7.0%	2.9%		6,762	6.1%	3.6%		12,268	6.5%
Information	816	1.0%	0.4%		1,305	1.2%	0.7%		2,121	1.1%
Finance and Insurance	2,031	2.6%	1.1%		3,276	2.9%	1.7%		5,307	2.8%
Real Estate and Rental and Leasing	1,393	1.8%	0.7%		1,921	1.7%	1.0%		3,314	1.7%
Professional, Scientific, and Technical Services	3,523	4.5%	1.9%		6,125	5.5%	3.2%		9,648	5.1%
Management of Companies and Enterprises	902	1.1%	0.5%		1,736	1.6%	0.9%		2,638	1.4%
Administration & Support, Waste Management and Remediation	6,326	8.0%	3.3%		6,833	6.1%	3.6%		13,159	6.9%
Educational Services	5,279	6.7%	2.8%		11,056	9.9%	5.8%		16,335	8.6%
Health Care and Social Assistance	8,363	10.6%	4.4%		12,616	11.4%	6.6%		20,979	11.0%
Arts, Entertainment, and Recreation	2,410	3.0%	1.3%		3,116	2.8%	1.6%		5,526	2.9%
Accommodation and Food Services	14,651	18.5%	7.7%		14,392	13.0%	7.6%		29,043	15.3%
Other Services (excluding Public Administration)	2,121	2.7%	1.1%		2,951	2.7%	1.6%		5,072	2.7%
Public Administration	2,891	3.7%	1.5%		7,009	6.3%	3.7%		9,900	5.2%
Jobs by Worker Race										
	2014				2014					
	Count	Share			Count	Share				
White Alone	46,394	58.7%	24.4%		82,486	74.2%	43.4%		128,880	67.8%
Hispanic or Latino	20,330	25.7%	10.7%		15,964	14.4%	8.4%		36,294	19.1%
Black or African American Alone	3,243	4.1%	1.7%		2,463	2.2%	1.3%		5,706	3.0%
American Indian or Alaska Native Alone	1,477	1.9%	0.8%		1,722	1.5%	0.9%		3,199	1.7%
Asian Alone	5,428	6.9%	2.9%		6,030	5.4%	3.2%		11,458	6.0%
Native Hawaiian or Other Pacific Islander Alone	386	0.5%	0.2%		373	0.3%	0.2%		759	0.4%
Two or More Race Groups	1,809	2.3%	1.0%		2,084	1.9%	1.1%		3,893	2.0%
Jobs by Worker Ethnicity										
	2014				2014					
	Count	Share			Count	Share				
Not Hispanic or Latino	58,737	74.3%	30.9%		95,158	85.6%	50.0%		153895	80.9%
Jobs by Worker Educational Attainment										
	2014				2014					
	Count	Share			Count	Share				
Less than high school	10,289	13.0%	5.4%		10,111	9.1%	5.3%		20,400	10.7%
High school or equivalent, no college	14,309	18.1%	7.5%		20,259	18.2%	10.7%		34,568	18.2%
Some college or Associate degree	18,598	23.5%	9.8%		29,545	26.6%	15.5%		48,143	25.3%
Bachelor's degree or advanced degree	15,034	19.0%	7.9%		28,385	25.5%	14.9%		43,419	22.8%
Educational attainment not available (workers aged 29 or younger)	20,837	26.4%	11.0%		22,822	20.5%	12.0%		43,659	23.0%
Jobs by Worker Sex										
	2014				2014					
	Count	Share			Count	Share				
Male	41,233	52.1%	21.7%		57,282	51.5%	30.1%		98,515	51.8%
Female	37,834	47.9%	19.9%		53,840	48.5%	28.3%		91,674	48.2%

Table 2: Analysis of Residence

Table 2 shows a breakdown of the workers by several demographic categories including age, earnings, industry, race, education, and sex. The "Homes Inside" column represents the workers living inside the service area, as seen in Map 1. The "Homes Outside" column represents the workers living outside of the service area, as seen in Map 2. There are 79,067 workers living inside the service area and 111,122 workers living outside. In Table 2, we can see that the breakdown of demographics is not the same for those living inside the service area as those living outside the service area. For instance, if we look at the income breakdown for those living inside versus outside, we can see that those living inside are relatively poorer. Only 27.6% of those living in the service area make more than $3,333 per month compared to 45% outside of the service area. We can also see from this table that there is a big discrepancy when it comes to race. 74.2% of people living outside the service area are white, compared to just 58.7% being white inside the service area. Inside the service area, there is a much larger proportion of minorities compared to outside the service area.

Map's 3 and 4 use the same logic as Map 1 and Map 2, but instead of showing residences, these maps show workplaces. Map 3 represents the workers by their workplace inside the service area. When comparing Map 3 to Map 1, we can see that the workplaces inside the service area are much more concentrated than the residences inside the service area. There is a high job count and density in the area around the 395 and I-80 intersection. Map 4 shows the workplaces outside of the service area. When comparing with Map 2, it can be easily seen that there are many more residences outside of the service area than workplaces. Table 3 shows an analysis of workers based on workplace inside and outside of the service area. In addition, Table 2 and Table 3 show that there are only 46,544 individuals who work outside of the service area, while there are 111,112 workers living outside of the service area. From Table 2 and Table 3, we can see that 76.1% of individuals in the dataset work inside of the service area, while only 41.6% live inside of the service area. Therefore, most workers have a bus stop near their workplace, but not near their residence.



Map 3: Workplace within Service Area

Map 4: Workplace Outside of Service Area

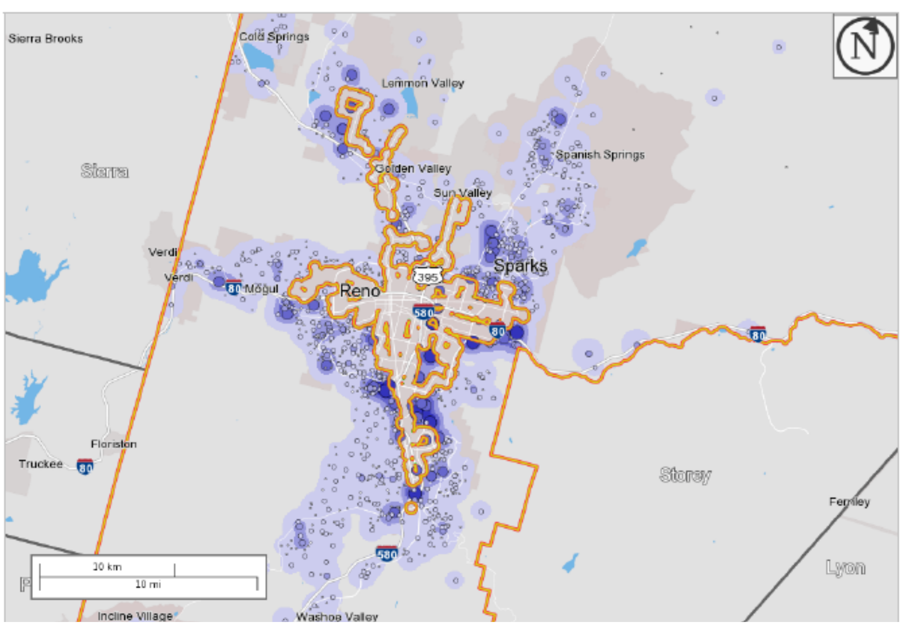


Table 3: Analysis of Workplace

	Work Inside			Work Outside			Work Total	
Total All Jobs								
	2014			2014				
	Count	Share	Share of Total	Count	Share	Share of Total	Count	Share of Total
Total All Jobs	148,895	100.0%	76.1%	46,844	100.0%	23.9%	195,739	100.0%
Jobs by Worker Age								
	2014			2014				
	Count	Share		Count	Share			
Age 29 or younger	34,037	22.9%	17.4%	11,384	24.3%	5.8%	45,421	23.2%
Age 30 to 54	80,564	54.1%	41.2%	24,893	53.1%	12.7%	105,457	53.9%
Age 55 or older	34,294	23.0%	17.5%	10,567	22.6%	5.4%	44,861	22.9%
Jobs by Earnings								
	2014			2014				
	Count	Share		Count	Share			
$1,250 per month or less	33,876	22.8%	17.3%	11,670	24.9%	6.0%	45,546	23.3%
$1,251 to $3,333 per month	58,140	39.0%	29.7%	20,085	42.9%	10.3%	78225	40.0%
More than $3,333 per month	56,879	38.2%	29.1%	15,089	32.2%	7.7%	71,968	36.8%
Jobs by NAICS Industry Sector								
	2014			2014				
	Count	Share		Count	Share			
Agriculture, Forestry, Fishing and Hunting	23	0.0%	0.0%	96	0.2%	0.0%	119	0.1%
Mining, Quarrying, and Oil and Gas Extraction	238	0.2%	0.1%	131	0.3%	0.1%	369	0.2%
Utilities	592	0.4%	0.3%	197	0.4%	0.1%	789	0.4%
Construction	6,804	4.6%	3.5%	4,079	8.7%	2.1%	10,883	5.6%
Manufacturing	8,111	5.4%	4.1%	3,473	7.4%	1.8%	11,584	5.9%
Wholesale Trade	6,588	4.4%	3.4%	2,731	5.8%	1.4%	9,319	4.8%
Retail Trade	16,725	11.2%	8.5%	5,449	11.6%	2.8%	22,174	11.3%
Transportation and Warehousing	8,325	5.6%	4.3%	4,527	9.7%	2.3%	12,852	6.6%
Information	1,835	1.2%	0.9%	393	0.8%	0.2%	2,228	1.1%
Finance and Insurance	4,495	3.0%	2.3%	1,245	2.7%	0.6%	5,740	2.9%
Real Estate and Rental and Leasing	2,411	1.6%	1.2%	1,096	2.3%	0.6%	3,507	1.8%
Professional, Scientific, and Technical Services	6,917	4.6%	3.5%	3,448	7.4%	1.8%	10,365	5.3%
Management of Companies and Enterprises	2,283	1.5%	1.2%	537	1.1%	0.3%	2,820	1.4%
Administration & Support, Waste Management and Remediation	11,125	7.5%	5.7%	3,705	7.9%	1.9%	14,830	7.6%
Educational Services	16,278	10.9%	8.3%	820	1.8%	0.4%	17,098	8.7%
Health Care and Social Assistance	17,556	11.8%	9.0%	4,240	9.1%	2.2%	21,796	11.1%
Arts, Entertainment, and Recreation	2,859	1.9%	1.5%	2,703	5.8%	1.4%	5,562	2.8%
Accommodation and Food Services	24,241	16.3%	12.4%	5,842	12.5%	3.0%	30,083	15.4%
Other Services (excluding Public Administration)	3,926	2.6%	2.0%	1,458	3.1%	0.7%	5,384	2.8%
Public Administration	7,563	5.1%	3.9%	674	1.4%	0.3%	8,237	4.2%
Jobs by Worker Race								
	2014			2014				
	Count	Share		Count	Share			
White Alone	101,193	68.0%	51.7%	31,091	66.4%	15.9%	132,284	67.6%
Hispanic or Latino	27,562	18.5%	14.1%	9,517	20.3%	4.9%	37,079	18.9%
Black or African American Alone	4,938	3.3%	2.5%	1,404	3.0%	0.7%	6,342	3.2%
American Indian or Alaska Native Alone	2,364	1.6%	1.2%	994	2.1%	0.5%	3,358	1.7%
Asian Alone	9,092	6.1%	4.6%	2,656	5.7%	1.4%	11,748	6.0%
Native Hawaiian or Other Pacific Islander Alone	641	0.4%	0.3%	171	0.4%	0.1%	812	0.4%
Two or More Race Groups	3,105	2.1%	1.6%	1,011	2.2%	0.5%	4,116	2.1%
Jobs by Worker Ethnicity								
	2014			2014				
	Count	Share		Count	Share			
Not Hispanic or Latino	121,333	81.5%	62.0%	37,327	79.7%	19.1%	158660	81.1%
Jobs by Worker Educational Attainment								
	2014			2014				
	Count	Share		Count	Share			
Less than high school	15,286	10.3%	7.8%	5,430	11.6%	2.8%	20,716	10.6%
High school or equivalent, no college	26,458	17.8%	13.5%	8,709	18.6%	4.4%	35,167	18.0%
Some college or Associate degree	37,808	25.4%	19.3%	11,631	24.8%	5.9%	49,439	25.3%
Bachelor's degree or advanced degree	35,306	23.7%	18.0%	9,690	20.7%	5.0%	44,996	23.0%
Educational attainment not available (workers aged 29 or younger)	34,037	22.9%	17.4%	11,384	24.3%	5.8%	45,421	23.2%
Jobs by Worker Sex								
	2014			2014				
	Count	Share		Count	Share			
Male	75,241	50.5%	38.4%	25,654	54.8%	13.1%	100,895	51.5%
Female	73,654	49.5%	37.6%	21,190	45.2%	10.8%	94,844	48.5%

Regressions

Using the PUMS data I have conducted a binomial logit regression on mode of transportation to work. The dependent variable in these regressions is the mode of transportation to work, and more specifically, whether an individual uses public transportation. For this, created the dummy variable, BUS. If bus=1, then that individual uses the bus to get to work. If bus=0, then that person drove their car to work. This regression includes only individuals who either took the bus or drove their car, and does not include individuals who used other forms of transportation. The explanatory variables included in this regression represent income, race and sex. The variable, INCOME, is the only continuous variable in this regression, and represents the individual's annual income for 2014 in dollar amount. For race, I created dummy variables, BLACK, HISPANIC, and ASIAN. To represent sex, I created a dummy variable called MALE.

The table below shows a summarization of income for those who took public transportation versus those who drove a car. The average income for individuals taking the bus is $27,821 and those driving a car made an average of $43,139. This is consistent with the hypothesis that individuals taking public transportation are likely to make less money than those who drive a car to work.

Income: Bus vs. Car

```
. sum income if bus==1
```

Variable	Obs	Mean	Std. Dev.	Min	Max
income	395	27821.12	29130.25	0	317653.9

```
. sum income if bus==0
```

Variable	Obs	Mean	Std. Dev.	Min	Max
income	10,459	43138.98	45178.99	0	317653.9

The following shows the results from Stata for the binomial logit regression with BUS as the dependent variable, and INCOME, BLACK, HISPANIC, ASIAN and MALE as the dependent variables. In this case, WHITE must be excluded and is therefore used as the reference for the other racial variables.

logit bus income black hispanic asian male

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .02824582
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
income	-4.02e-07	.00000	-7.31	0.000	-5.1e-07	-2.9e-07	42581.5
black*	.0836832	.01266	6.61	0.000	.058865	.108501	.064032
hispanic*	.0203358	.00448	4.54	0.000	.011562	.02911	.236871
asian*	.017645	.00743	2.38	0.018	.003087	.032203	.089737
male*	.0112328	.00288	3.90	0.000	.005583	.016883	.528377

(*) dy/dx is for discrete change of dummy variable from 0 to 1

We can see from this binomial logit regression that all the independent variables in the model are statistically significant. By looking at the marginal effects, we can get a sense of the meaning behind the coefficients. For income, the marginal effects are taken at the mean, and we can see that income is significantly negatively related with taking the bus. As income increases, the probability of an individual taking the bus decreases, holding all other factors constant. As for the racial variables, we can see that BLACK, HISPANIC, and ASIAN are all statistically significant and positive. This means that individuals who are Black, Hispanic, and Asian are more likely to take public transportation than those who are White. MALE is also statistically significant and positive, showing that males are more likely to take public transportation than females. The predicted probability of someone taking public transit in this model is 2.82%. The following four logit regressions now look at the impact of race and gender at different levels of income. These groups are split into low-income, mid-income, and high-income as with the previous data.

Low-Income

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .04905245
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
black*	.2141044	.04008	5.34	0.000	.135552	.292657	.067234
hispanic*	.0523438	.01361	3.85	0.000	.025662	.079025	.277021
asian*	.0658565	.02823	2.33	0.020	.01053	.121183	.079574
male*	.0098861	.00847	1.17	0.243	-.006719	.026492	.457021

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Mid-Income

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .03803115
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
black*	.1035485	.02176	4.76	0.000	.060898	.146199	.078488
hispanic*	.0189306	.00763	2.48	0.013	.00397	.033892	.316104
asian*	.0222767	.01366	1.63	0.103	-.0045	.049053	.105288
male*	.0120011	.00578	2.08	0.038	.000666	.023336	.488155

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Low + Mid-Income

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .04242625
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
black*	.1383079	.01987	6.96	0.000	.09937	.177246	.074437
hispanic*	.0292172	.00682	4.29	0.000	.015855	.04258	.302037
asian*	.0343316	.01285	2.67	0.008	.009153	.05951	.096033
male*	.01089	.00482	2.26	0.024	.001439	.020341	.476949

(*) dy/dx is for discrete change of dummy variable from 0 to 1

High-Income

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .01539689
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
black*	.0117343	.01104	1.06	0.288	-.009902	.033371	.048324
hispanic*	.0143909	.00672	2.14	0.032	.001213	.027569	.138497
asian*	-.0028002	.00674	-0.42	0.678	-.016006	.010406	.080231
male*	.0154187	.00365	4.22	0.000	.008264	.022574	.606012

(*) dy/dx is for discrete change of dummy variable from 0 to 1

We can see from these binomial logit regressions that the coefficients and significance are different at different income levels: low, mid and high. For the low-income group, the predicted probability for taking the bus for this group is 4.9%. We can see that the racial variables are statistically significant while the gender variable is not. This is interesting that for the low-income group, it appears that gender is not a significant factor in decision to take public transit. BLACK has the largest coefficient of .2141. For the mid-income group, BLACK and HISPANIC are significant at the 1% and 5% level respectively. However, ASIAN is no longer significant at the 10% and MALE becomes significant at the 5%. This is different than for the low-income group, with gender now becoming a significant factor. The coefficient on BLACK is .1035 compared with the .2141 for the low-income group. The predicted probability in this case has decreased from 4.91% to 3.80%. For the next regression, the low-income and mid-income groups are combined, meaning any worker making under $40,000 is included. In this case, all three racial variables are significant at the 1% level and the gender variable is statistically significant at the 5% level. The predicted probability for this combined group is 4.24%. If we look at the individuals making over $40,000 annually, the predicted probability for taking public transit drops all the way to 1.54%. Additionally, HISPANIC is the only significant racial variable, however, MALE is also significant. The following set of four regressions considers the effects of income for the different racial groups: Black, Hispanic, Asian, and White, as well as the gender variable once again.

Black

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .08184377
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
income	-2.92e-06	.00000	-6.62	0.000	-3.8e-06	-2.1e-06	35166
male*	.0285171	.01878	1.52	0.129	-.008287	.065322	.51223

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Black, low-income

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .20835603
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
income	-6.41e-06	.00000	-3.64	0.000	-9.9e-06	-3.0e-06	7287.15
male*	.0624666	.04087	1.53	0.126	-.017638	.142571	.51223

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Hispanic

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .04868512
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
income	-8.12e-07	.00000	-3.67	0.000	-1.2e-06	-3.8e-07	29935.1
male*	.0093586	.00823	1.14	0.256	-.006773	.025491	.554648

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Hispanic, low-income

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .07143929
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
income	-1.16e-06	.00000	-2.69	0.007	-2.0e-06	-3.2e-07	6695
male*	.0134082	.01197	1.12	0.263	-.010061	.036877	.554648

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Asian

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .02584194
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
income	-8.78e-07	.00000	-5.07	0.000	-1.2e-06	-5.4e-07	40002.3
male*	.0206419	.00978	2.11	0.035	.001474	.03981	.454825

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Asian, low-income

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .07773323
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
income	-2.50e-06	.00000	-2.37	0.018	-4.6e-06	-4.3e-07	6858.91
male*	.0581439	.02672	2.18	0.030	.005769	.110519	.454825

(*) dy/dx is for discrete change of dummy variable from 0 to 1

White

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .01905542
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
income	-1.16e-07	.00000	-2.51	0.012	-2.1e-07	-2.5e-08	49326.9
male*	.0083371	.00345	2.42	0.016	.001572	.015103	.531367

(*) dy/dx is for discrete change of dummy variable from 0 to 1

White, low-income

```
Marginal effects after logit
      y  = Pr(bus) (predict)
         =  .02478698
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
income	-1.50e-07	.00000	-1.99	0.046	-3.0e-07	-2.4e-09	5917.89
male*	.0107802	.0047	2.29	0.022	.001565	.019995	.531367

(*) dy/dx is for discrete change of dummy variable from 0 to 1

This set of binomial logit regressions show some interesting results as well. The coefficients and significance are different at different income levels: low, mid and high. The regressions also show that the predicted probability for taking public transit varies among different races at different income levels. In the first regression, we see that income is strongly significant, however gender is not for black individuals. The predicted probability evaluated at the mean income level for all blacks of $35,166 is 8.18%. However, when evaluating the probability of taking public transit at the mean income level for blacks in the low-income group, the probability jumps up to 20.84%. The predicted probability for Hispanic is 4.87% at the mean income and 7.14% at the mean for low-income Hispanics. The probability for Asians is 2.58% at the mean level, however it jumps to 7.77% for low-income Asians. So, it appears that Asians are less likely than Hispanics to take public transit generally, however, low-income Asians may be just as likely if not more likely to take the bus than low-income Hispanics. The predicted probability for whites is only 1.91% at the average income of $49,326.90, and evaluated at the low-income average of $5917.89, the probability of taking public transit only increases to 2.48%. These results show that when evaluated at similar levels of income, the probability of taking public transit varies greatly among different races.

Map 5: Identifying Non-Served Areas by Residence

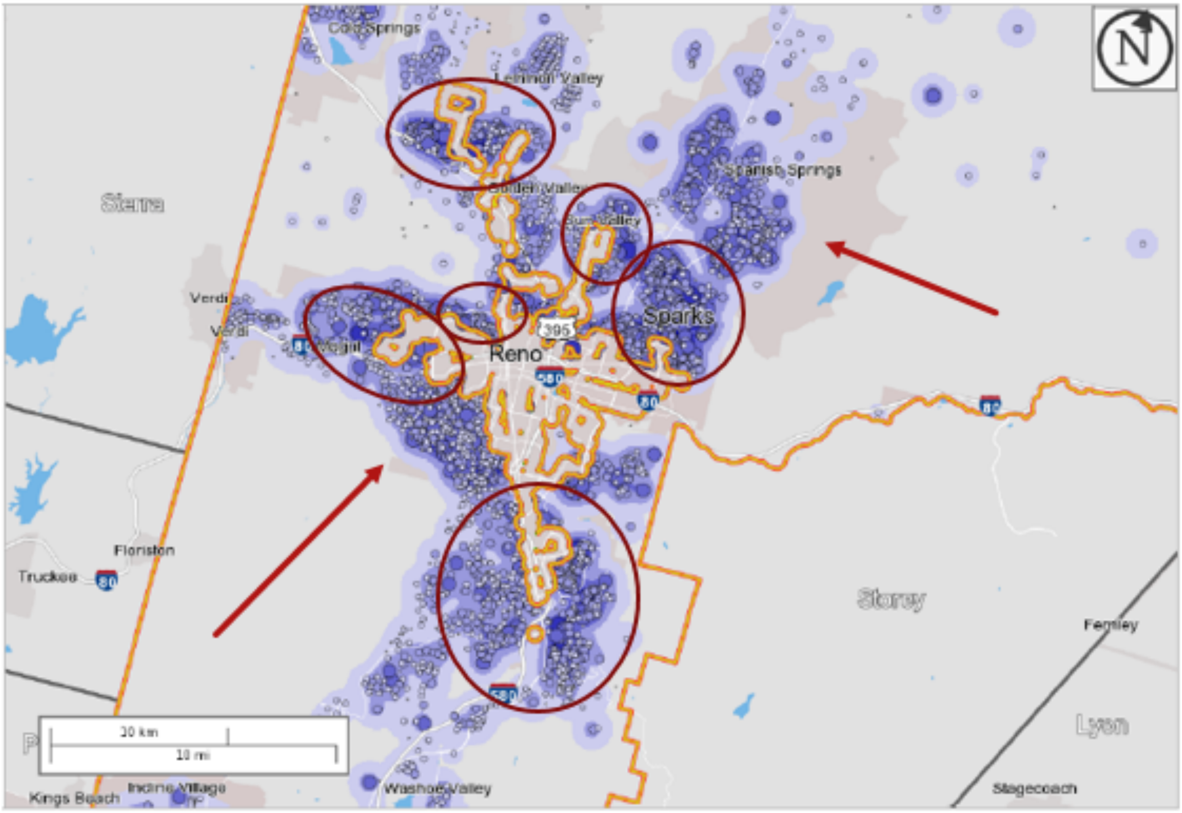


Table 4: Workers (Residence)

Area	Sun Valley		West Univ.		Sparks		Stead		Northwest		South Reno	
Service	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Size (Sq. Mi.)	1.014	1.751	1.061	1.771	3.626	3.728	3.354	2.704	5.368	2.251	7.031	11.85
# of Census Blocks	41	82	103	146	269	241	177	96	254	143	310	443
Total Count	2848	3277	2391	5101	9784	9663	6732	2652	6791	5595	6142	5427
Low-Inc	645	814	627	1330	2069	2279	1430	612	1468	1276	1202	1074
Mid-Inc	1462	1692	889	2125	4122	4467	3044	1351	2196	2071	1832	2089
Density (Workers/sq. mi.)	2808.68	1871.50	2253.53	2880.29	2698.29	2592.01	2007.16	980.77	1265.09	2485.56	873.56	458.13
Low-Inc	636.09	464.88	590.95	750.99	570.60	611.32	426.36	226.33	273.47	566.86	170.96	90.66
Low + Mid-Inc Density	2077.91	1431.18	1428.84	1950.88	1707.39	1809.55	1333.93	725.96	682.56	1486.89	431.52	267.01

Map 6: Non-Served Areas by Workplace

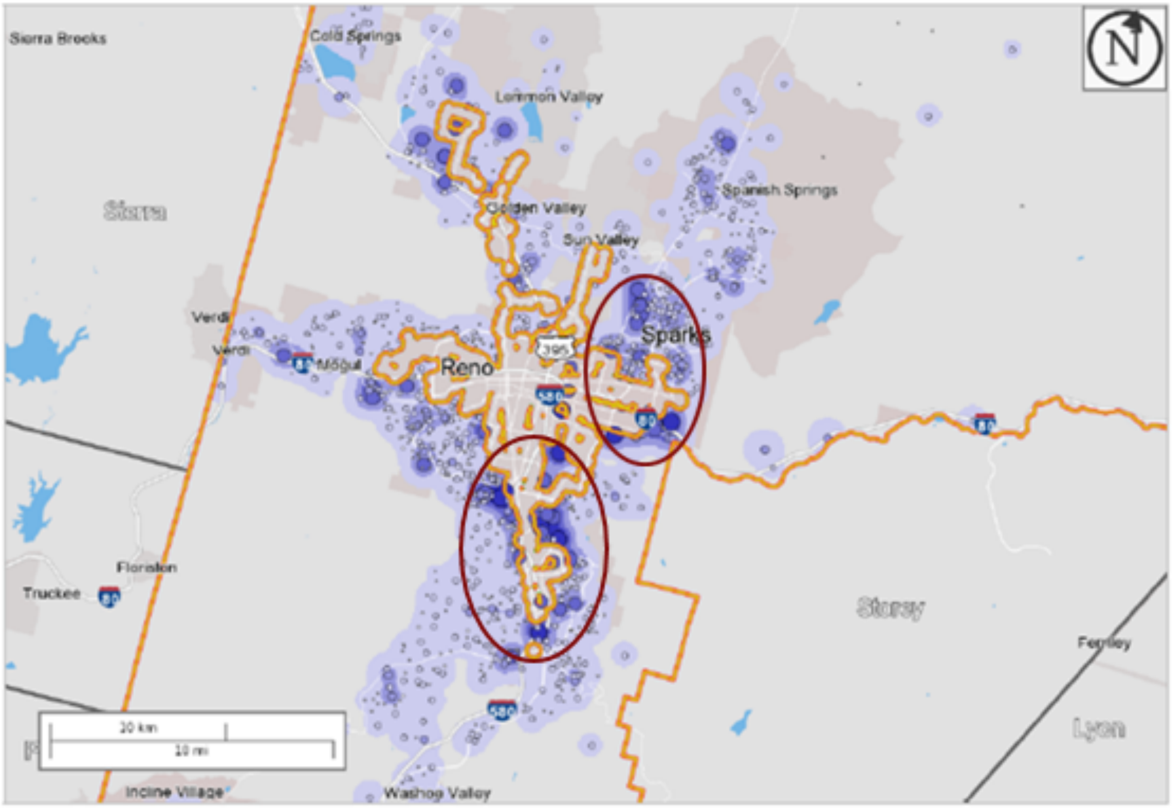


Table 5: Jobs (Workplace)

Area	Sun Valley		West Univ.		Sparks		Stead		Northwest		South Reno	
Service	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Size (Sq. Mi.)	1.014	1.751	1.061	1.771	3.626	3.728	3.354	2.704	5.368	2.251	7.031	11.846
# of Census Blocks	41	82	103	146	269	241	177	96	254	143	310	443
Total Count	86	434	111	1341	1576	11022	808	919	1497	2469	12534	21617
Low-Inc	43	164	34	470	519	2900	205	111	387	909	2582	4929
Mid-Inc	39	212	52	624	685	5056	289	533	719	1116	5657	7573
Density (Jobs/sq. mi.)	84.81	247.86	104.62	757.20	434.64	2956.55	240.91	339.87	278.87	1096.85	1782.68	1824.84
Low-Inc Density	42.41	93.66	32.05	265.39	143.13	777.90	61.12	41.05	72.09	403.82	367.23	416.09
Low + Mid-Inc Density	80.87	214.73	81.06	617.73	332.05	2134.12	147.29	238.17	206.04	899.60	1171.81	1055.38

Table 6: Combined Workers and Jobs

Area	Sun Valley		West Univ.		Sparks		Stead		Northwest		South Reno	
Service	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Size (Sq. Mi.)	1.014	1.751	1.061	1.771	3.626	3.728	3.354	2.704	5.368	2.251	7.031	11.846
# of Census Blocks	41	82	103	146	269	241	177	96	254	143	310	443
Total Count	2934	3711	2502	6442	11360	20685	7540	3571	8288	8064	18676	27044
Low-Inc	688	978	661	1800	2588	5179	1635	723	1855	2185	3784	6003
Mid-Inc	1501	1904	941	2749	4807	9523	3333	1884	2915	3187	7489	9662
Density (Combo/sq. mi.)	2893.49	2119.36	2358.15	3637.49	3132.93	5548.55	2248.06	1320.64	1543.96	3582.41	2656.24	2282.96
Low-Inc Density	678.50	558.54	623.00	1016.37	713.73	1389.22	487.48	267.38	345.57	970.68	538.19	506.75
Low + Mid-Inc Density	2158.78	1645.92	1509.90	2568.61	2039.44	3943.67	1481.22	964.13	888.60	2386.49	1603.33	1322.39

These maps and tables show areas that are good candidates for public transit service, as well as a comparison between current served areas and non-served areas. Maps 5 shows the non-served areas that I have identified as having relatively high densities of workers, which are circled in the map. The regression results showed that lower income workers are more likely to take public transit, so not only are we comparing the total densities in the served and non-served areas, but also the density of low and middle income workers. The arrows point to two locations that seem to have high densities by looking at the map, however these areas are both high-income areas. Therefore, these areas would not be good candidates for public transit expansion, as shown in the regression results with high-income workers being very unlikely to take public transit. Map 6 shows two circled areas that have high densities of non-served jobs based on workplace. As we saw in the previous maps and tables, workplace is much better served than residence, and therefore there are not as many non-served areas identified in this map. Sparks is identified in both maps, so that means the only new area identified in Map 6 compared to Map 5 is South Reno.

Tables 4, 5 and 6 consist of statistics for the six areas that are identified in Maps 5 and 6. The first row list the names of the six different areas: Sun Valley, West University, Sparks, Stead, Northwest, and South Reno. These are areas that both have significant numbers of both served and non-served locations within that area. The second row says “No” for the area that is not being served, and “Yes” for the area that is being served. The third row consist of the size of the specific area in square miles. The next row shows the number of census blocks in that area. The total count row represents the total number of workers in that area. The “Low-Inc” row represents individuals who make under $15,000 per year in their jobs. The “Mid-inc” row shows workers who make between $15,000 and $40,000 in annual income. The “Density” row shows the population density in that area, which is calculated by taking the total number of workers divided by the size of the area, giving the density in the form of workers per square mile for Table 4. This is done for Table 5 as well, but instead of workers it is the density of jobs per square mile. For Table 6, the density is the number of jobs plus the number of workers to get a total density amount in that area with both workers and jobs. The last two rows show the population density for low income workers and low plus middle income workers in the respective areas. Once again, we are defining “low-income” in this case as individuals who make under $15,000 per year in their jobs and we are defining “middle income” as workers who make between $15,000 and $40,000 in annual income. Therefore, the “Low + Mid-Inc Density” includes all workers or jobs where the annual income is under $40,000.

Table 7 shows a ranking of the served and non-served areas in terms of density of workers plus jobs combined as in Table 6. There are three separate rankings: first for total density, second by low-income and density, and third by low plus mid-income density. It is clear that there are many non-served areas that have higher densities than areas currently being served.

Table 7: Ranking of Areas by Density

Rank	Area	Service	Density (Combo/sq. mi.)
1	Sparks	Served	5548.55
2	West Univ.	Served	3637.49
3	Northwest	Served	3582.41
4	Sparks	**Non-Served**	3132.93
5	Sun Valley	**Non-Served**	2893.49
6	South Reno	**Non-Served**	2656.24
7	West Univ.	**Non-Served**	2358.15
8	South Reno	Served	2282.96
9	Stead	**Non-Served**	2248.06
10	Sun Valley	Served	2119.36
11	Northwest	**Non-Served**	1543.96
12	Stead	Served	1320.64
Rank	Area	Service	Low-Inc Density
1	Sparks	Served	1389.22
2	West Univ.	Served	1016.37
3	Northwest	Served	970.68
4	Sparks	**Non-Served**	713.73
5	Sun Valley	**Non-Served**	678.50
6	West Univ.	**Non-Served**	623.00
7	Sun Valley	Served	558.54
8	South Reno	**Non-Served**	538.19
9	South Reno	Served	506.75
10	Stead	**Non-Served**	487.48
11	Northwest	**Non-Served**	345.57
12	Stead	Served	267.38
Rank	Area	Service	Low + Mid-Inc Density
1	Sparks	Served	3943.67
2	West Univ.	Served	2568.61
3	Northwest	Served	2386.49
4	Sun Valley	**Non-Served**	2158.78
5	Sparks	**Non-Served**	2039.44
6	Sun Valley	Served	1645.92
7	South Reno	**Non-Served**	1603.33
8	West Univ.	**Non-Served**	1509.90
9	Stead	**Non-Served**	1481.22
10	South Reno	Served	1322.39
11	Stead	Served	964.13
12	Northwest	**Non-Served**	888.60

Conclusions

In an effort to better understand access and usage of public transportation in Reno, Nevada, we analyzed economic and demographic data from the U.S. Census Bureau. We examined those currently with access to public transit, as well as where workers live and work in order to identify potential locations for public transit expansion in the Reno area. The focus was placed on areas of high density levels of workers and jobs, with an emphasis on low-income workers. From our analysis on public transit access, we have found that there are several areas that have strong potential for usage should the RTC expand its service to those areas.

This analysis shows us four important conclusions:

1) There are several areas that have strong potential for usage if the RTC were to expand its service to those areas.
2) Many non-served areas we identified had higher densities of individuals likely to take public transit than areas currently being served.
3) The regression analyses support the idea of lower income individuals being more likely to take public transit.
4) The regressions also show that race is an important factor in addition to income.

Many of the non-served areas we identified had higher densities of individuals likely to take public transit than some of the areas currently being served. Our regression analyses support the idea of lower income individuals being more likely to take public transit. Additionally, the regressions show us that not only is income an important factor, but race is influential as well. The predicted probabilities for taking public transit vary across the different racial groups studied. There are some policy implications from this research regarding public transit planning and service. These results can be helpful in terms of locating good quality locations for public transit service, as well as identifying the current service locations that may not be as good. This research has shown that there are numerous areas with strong potential for public transit usage, as well as areas that are possibly being overserved. This means that even without expansion, the RTC has the ability to improve its service and ridership by shifting its routes to include these high potential areas and would therefore increase efficiency and ridership on the buses.

Going forward, there are many possibilities for more research. This research used a basic definition for access as distance to bus stops. However, there are other factors that can determine how well an area is being served. For instance, going forward, RTC data on frequency and timing of the buses in the service area can be examined. This data is currently available from the RTC, which includes information on the scheduling of the buses, including times of arrival at bus stops, frequency, and ridership. This data can be helpful in figuring out if there are areas that are currently being over or underserved. This is important because we don't want to only look at public transit expansion, but also shifting current resources that may be better allocated. There may be certain areas that are being overserved by public transit, and other areas that would benefit from increased bus frequency.

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