SUSTAINABLE PUBLIC TRANSIT INVESTMENTS: INCREASING NON-MOTORIZED ACCESS AND MULTIPLE TRIP TYPE USAGE

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SUSTAINABLE PUBLIC TRANSIT INVESTMENTS: INCREASING NON-MOTORIZED ACCESS AND MULTIPLE TRIP TYPE USAGE

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For transit riders everywhere.

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LIST OF ABBREVIATIONS

BRT – Bus Rapid Transit

CAA – Clean Air Act

CBD – Central Business District

DOT – Department of Transportation

EPA – Environmental Protection Agency

FTA- Federal Transit Administration

GIS – Geographic Information Systems

HOV – High Occupancy Vehicle

HUD- Department of Housing and Urban Development

LR- Light Rail

MPO – Metropolitan Planning Organization

MSA – Metropolitan Statistical Area

NTD- National Transit Database

PM – Particulate Matter

RTD – Regional Transit District (Denver)

RTP- Regional Transportation Plan

SRT- Sacramento Regional Transit

TIP- Transportation Improvement Program

TMA/TMO – Transportation Management Association or Organization

TTI- Texas Transportation Institute

VMT- Vehicles Miles Traveled

SUMMARY

Public transit is a key method for increasing sustainability in the transportation sector; transit can decrease emissions harmful to the environment and increase accessibility. Given the limited resources available for public transit, it makes sense to meet multiple sustainability goals simultaneously. Transit that is accessible by non-motorized means and serves multiple trip types can potentially reduce vehicle usage and increase mobility for everyone. This research assesses whether transit systems with high non-motorized access rates and non-work trip usage are meeting social and environmental goals and what factors impact non-work and non-motorized access rates.

Eight criteria were used to choose 17 metropolitan regions that represent a range of transit conditions in the US. Non-parametric correlations were calculated between non-work usage and non-motorized access and a dataset of 41 variables that measure regional characteristics, transit efficiency, land use, rider demographics, and transit operations and design. In-depth case studies, including site visits and interviews, were done for Denver, CO; Minneapolis/St. Paul, MN; and Sacramento, CA.

The correlations and case studies both confirm that transit system with high non-work usage and non-motorized access are not meeting social or environmental sustainability goals. These systems primarily serve low-income riders, are less well funded, and provide limited service. Only systems with higher per capita funding levels meet social goals and higher funding is correlated to higher income riders. However, having higher income riders does not imply that social goals are met. Regional policies regarding operations and design of transit can increase usage for non-work trips and non-motorized access and are necessary to ensure both social and environmental goals are met.

CHAPTER 1
INTRODUCTION

1.1 Background

Transportation policy in the United States is arguably at a crossroads with several significant challenges facing federal, state, and local decision-makers. The transportation system faces considerable levels of congestion, rising energy prices, and infrastructure that is coming to the end of useful life. The existing funding mechanisms for transportation can no longer keep up with demand and the increasing costs of transportation projects. More recently, transportation has been identified as a major contributor to greenhouse gas and, therefore, a likely source of mitigation strategies. These collective challenges in transportation present an opportunity to re-examine transportation policy and funding mechanisms from a boarder societal perspective.

The concept of sustainability is increasingly the lens through which researchers and policy-makers are examining various urban policies, including those relating to transportation. Sustainable development is generally defined as, “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland 1987). In practice, three major components- environmental, economic, and social- are included in the definition of sustainability. In transportation, these three components relate to the environmental impacts associated with the construction and operation of a facility or system, the economic benefits associated with the accessibility provided by transportation, and the social benefits of connectivity transportation provides between people and their community (Jeon, Amekudzi, and Guensler 2008).

Public transit is often seen as part of transportation's sustainability strategy, usually for environmental reasons. Transit service can reduce emissions of criteria pollutants and greenhouse gases by reducing vehicles miles traveled (VMT) and the number of cold starts. However, public transit systems also contribute to social and economic sustainability by relieving congestion, stimulating economic development, and improving accessibility and mobility for the transit dependent. Table 1.1 shows the sustainability goals for the three aspects of sustainability. Both goals for internal transit operations and for the community are presented.

Table 1.1 Internal and External Sustainability Goals for Public Transit

Aspects of Sustainability	Social	Economic	Environmental
Internal Goals	Equitable funding and service	Funding source that is tied to behavior trying to change and is stable	Limit emissions generated from transit system
External Goals	Increase accessibility and mobility for everyone	Add value to the local economy, reduce dependence on foreign energy sources, reduce congestion	Reduce emissions of greenhouse gases and air pollutants

Given the limited funding available for new public transit infrastructure, it makes sense to prioritize projects that meet multiple sustainability goals simultaneously. This research explores two overlaps between sustainability goals for public transit.

1.2 Motivation

Observations on transit service in Atlanta, Georgia motivated this study. With the stated goal of reducing congestion, the Georgia Regional Transportation Authority (GRTA) created an express bus system to bring suburban commuters to jobs in downtown and midtown Atlanta. While this system expanded, the local transit service operated by the Metropolitan Atlanta Rapid Transit Authority (MARTA) was cut back.

The expansion of express service aimed at suburban commuters raised social equity issues, as well as questions about the overall effectiveness of reducing emissions, a major environmental sustainability goal.

As seen in Table 1.2, the income difference between MARTA and express bus riders is stark. The express service provides very limited mobility benefits to low-income riders. It only operates during peak hours on weekdays and serves only high employment districts. Also the service originates in park and ride lots, many of which have no local bus service and limited pedestrian access.

Table 1.2 Income of Express Bus Riders Compared to MARTA Riders

MARTA (Own scale)		MARTA (common scale)	Express Bus (common scale)	Express Bus (Own scale)	
Under $10,000	17.9%	63%	8%	1.7%	Under $15,000
$10,000-$19,999	24.6%			5.9%	$15,000-$29,999
$20,000-$29,999	20.4%				
$30,000-$39,999	14.9%	30%	44%	13.3%	$30,000-$44,999
$40,000-$49,999	7.2%			14.3%	$45,000-$59,999
$50,000-$74,999	7.8%			16.2%	$60,000-$74,999
Over $75,000	7.2%	7%	49%	32.7%	$75,000-$119,999
				15.9%	Over $120,000

Source: (MARTA 2008; Georgia State University Public and Performance Management Group 2008)

The transit dependent, which includes low-income workers, people with disabilities, youth, and the elderly, require transit service that is accessible by foot, wheelchair, or bicycle. In addition, they need transit service that serves all types of destinations including work, school, shopping, medical appointments, and recreation. These trips occur during all hours of the day; even work trips for many low-income transit riders are not in the peak hours (Giuliano 2005).

Express bus riders are choice riders; the vast majority own one or more vehicles (Georgia State University Public and Performance Management Group 2008). Converting these drivers to transit riders is an important element of a transportation strategy to reduce emissions. However, transit designed to serve only the work trip requires riders to use a vehicle for all other trip types. Work trips are under 30 percent of VMT and 20 percent of person trips in the United States and non-work trips continue to increase in market share (McGuckin and Nanda 2005). In addition, a vehicle is necessary to access the express bus stop. This type of transit service reduces VMT, but not emissions from cold starts. Table 1.3 contrasts levels of non-work trip usage and non-motorized access between MARTA and express bus riders.

Table 1.3 Trip Type and Access Mode on MARTA and Express Bus

	Non-Work Trips	Non-Motorized Access
MARTA	46.4%	76.2%
Express Bus	4.3%	4.2%

Source: (Georgia State University Public and Performance Management Group 2008; MARTA 2008)

Express bus service allows transit to serve areas that do not have the land use density or pedestrian infrastructure to sustain any other type of transit service. However, express bus service alone, not as a part of a functioning local transit system, provides only limited mobility benefits and emission reductions.

Transit serving multiple trip types and accessed by non-motorized means meets multiple sustainability goals. Figure 1.1 illustrates this point. The figure takes social, economic, and environmental sustainability goals from Table 1.1 and looks at how to implement them. For goals from all three aspects of sustainability the end result is the same.

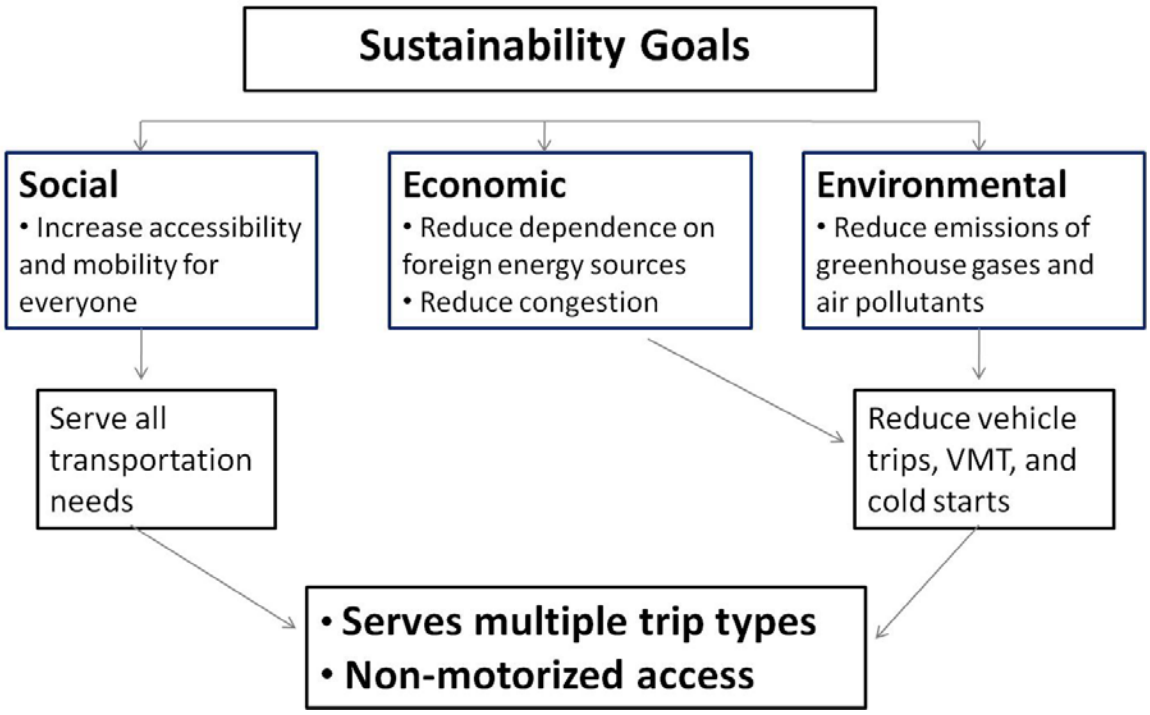


Figure 1.1 Sustainability Goal Overlaps

1.3 Research Objectives and Approach

This research has two objectives. First, this research will assess whether transit with high non-work trip usage and non-motorized access in fact meets minimum social and environmental sustainability goals. Second, this research will identify operation and design characteristics of public transit systems that increase non-motorized access and transit use for multiple trip types. This information will be used to develop policy recommendations for transit investment strategies that promote sustainability goals.

This study uses a mixed methods research design. A mixed methods design allows use of all available quantitative and qualitative data. Both case studies and statistical correlations are used to make comparisons and draw conclusions. A

representative sample of 17 metropolitan areas across the United States is used as the dataset.

The analysis is primarily at the region and transit system level. Where data exist, differences between transit modes (heavy rail, light rail, local bus, express bus, commuter rail) are noted. However, the focus is in the design and operation of the entire transit system, regardless of the number of transit modes and operators in a region. Other work has been done that examines built environment characteristics that increase non-motorized access at the station level (Cervero 2001; Ryan 2009).

This research design primarily looks at overlaps in the environmental and social aspects of sustainability. It does not directly address the economic aspects. Both the economic sustainability of transit systems themselves and transit's contribution to overall economic sustainability are important topics, but outside the scope of this effort.

There are a number of ways that public transit contributes to social sustainability; however, for the purpose of this research transit's social contribution is considered primarily to be mobility and accessibility regardless of car ownership. This will be measured by the percent of a region that is accessible by transit and peak headway of local bus service.

Likewise there are multiple environmental benefits of public transit. This analysis focuses on emission reductions from choice riders using transit instead of driving personal vehicles. Modeling trip reductions and emission levels are beyond the technical scale of this study. Instead the more general measures of transit trips per capita and the median income of transit riders will be assessed to determine if transit is replacing vehicle trips. Choice riders are defined by income rather than car ownership, since some choice riders take the choice all the way to not owning a car, despite having the financial means to do so.

1.4 Dissertation Organization

Following this introductory chapter, Chapter 2 examines how the existing literature frames social and environmental goals for public transit as trade-offs instead of focusing on the overlaps. Chapter 3 details the methodology and data sources used. Background data on the state of public transit in the 17 regions is presented in Chapter 4. Chapter 5 contains the statistical results of correlations between non-work and non-motorized access levels and an assortment of dependent variables. The results of in-depth case studies of three of the regions are presented in Chapter 6. Chapter 7 provides a synthesis of the results and draws conclusions. Chapter 8 provides policy recommendations based on these results and outlines future research needs.

CHAPTER 2
LITERATURE REVIEW

It is clear from a review of recent transportation research and conference topics that sustainability has become a key topic. Researchers are attempting to develop a sustainability conceptual framework and operationalize the framework. Recent papers have suggested indicators and methods of measurement (Johnston 2008; Mitropoulos, Prevedouros, and Nathanail 2010; Jeon and Amekudzi 2010; Jeon, Amekudzi, and Guensler 2008). For example, Johnston uses theories of personal and national well-being to outline an approach that measures genuine wealth and equity between income classes (Johnston 2008).

However, often environmental and economic goals are put at odds with social equity goals. A critique of the focus on environmental aspects of sustainability to the detriment of social aspects in transportation has started to emerge (Martens 2006; Lucas et al. 2007; Feitelson 2002; Boschmann and Mei-Po 2008). In part, this is an analysis of the limitations of the existing methods used to measure benefits. Marten examines the built-in bias in two of the main transportation decision-making tools, transportation modeling and cost-benefit analysis, against people who travel less. He argues for substituting accessibility gains for travel time savings in the measurement of benefits (Martens 2006). Lucas et al. agree that the technical capacity to assess social impacts falls behind the assessment of economic and environmental impacts (Lucas et al. 2007).

One of the challenges for assessing social equity is the numerous definitions and measures of transportation equity found in the literature. In general, equity can be examined at the individual, group, or geographic levels. At each level, equity can be measured by market, opportunity, or outcomes standards (Taylor 2004). The 1964 Civil

Rights Act and Executive Order 12898 on Environmental Justice provide the legal foundation for the equity protections found in transportation. In practice, many transportation decisions are made from the perspective of providing equity by geographic region (Taylor 2004; Taylor and Samples 2002). This study considers the question of equality in terms of opportunity for low-income groups.

The same tension between social and environmental sustainability goals has long existing in the public transit literature in the form of the debates over type of service, funding, and population served. The issue of service type is often simplified to a bus versus rail debate. Many of the studies that have examined this issue have focused on the difference in operating and capital costs between modes, capacity and speed, impact on property values, and densities necessary to generate ridership (Zhang 2009; Brown 2009; Henry 2006). One of the most visible examples of a social equity issue relating to service type took place in Los Angeles over the building of new rail service at the expense of existing bus service (Grengs 2002).

Funding-related research has examined both the source of funds and their use for operating or capital subsidies. Examinations of capital and operating subsidies have addressed the impact of different funding sources on economic inefficiency, job creation, and political influence (Schweitzer and Taylor 2007; Taylor and Samples 2002; Taylor 2004; Pickrell 1992). Using a regional input-output model, Taylor argues that transit operating expenditures generate more economic benefits than capital investments (2004).

Research on funding sources has examined the regressive nature of various taxes and the equity of pricing (Chernick and Reschovsky 1997; Derrick and Scott 1998; Poterba 2000; Schweitzer and Taylor 2007; Wachs 2003). Taylor and Schweitzer conclude that the increasingly popular method of using local sales taxes to fund

transportation projects fails both equity and environmental goals, if the funds are primarily used to fund highway projects (Schweitzer and Taylor 2007).

The issue of who is receiving service often boils down to transit dependent versus choice riders. This research examines the flow of resources between central cities and suburbs, between whites and people of color, and between high and low income communities (Garrett and Taylor 1999; Giuliano 2005). Garrett and Taylor in a 1999 paper address the growing emphasis on commuter and rail services for more affluent suburban riders, in part due to environmental concerns, at the expense of local bus service in the inner-city. They conclude this shift is inequitable and economically inefficient. Over a decade later, this shift is still under discussion.

Although the variables might change, in essence, these are all arguments over how to prioritize (and how to measure) social, environmental, and economic goals for public transit. As noted, these discussions are often framed as dichotomies (e.g. bus versus rail, dependent versus choice riders), thus implying a trade-off among sustainability goals. For example, aligning policies to charge the true costs of transportation (to decrease environmental externalities) could be counter to goals of increasing transportation mobility and accessibility for low-income populations (Lucas 2006). This issue is raised in discussions on the equity of pricing (Cain and Jones 2007; Ungemah 2007).

While much of the research to date has focused on determining tradeoffs between goals, overlaps do exist. For example, recent articles have examined the dual benefits of walking to public health and the environment (Morency, Trepanier, and Demers 2009). The concept of sustainability presents a framework that emphasizes interactions between previously separate environmental, social, and economic goals. The opportunity and challenge presented by a sustainability analysis is determining the calculus of measuring the interactions between different performance measures. One

solution is identifying measures that meet multiple goals simultaneously. Non-motorized access to transit and transit usage for multiple trip types are two potential measures that can meet multiple goals.

The literature on non-motorized access to transit primarily focuses on the distance people are willing to walk to transit; the general rule of thumb has been one fourth to a half mile, but some studies have shown it to be longer (Alshalalfah and Shalaby 2007; Crowley, Shalaby, and Zarei 2009; El-Geneidy 2010). A Transit Cooperative Research Program literature review on access to public transit notes that access mode choice is dependent on both characteristics of the traveler and external design and policy factors (Coffel et al. 2009). The characteristics of travelers include gender, fear of crime, and socio-demographic variables, like car ownership and income (Kim, Ulfarsson, and Hennessy 2007)

A large body of research has examined how land use and the built environment impact travel behavior and non-motorized trips, including transit access (Frank et al. 2005; Ryan 2009). Key variables identified include land use mix, and population and employment density. Cervero examined pedestrian access to rail at the aggregate level in San Francisco Bay Area and the disaggregate level in Montgomery County, Maryland. He found compact mixed use land use significantly increases walk access at the aggregate level and sidewalk and street dimensions significantly increase walk access at the disaggregate level (Cervero 2001). Cervero's research focused on station area characteristics; little research has examined transit system level variables.

The research on the use of transit for non-work trips mostly comes from mode choice modeling (Frank et al. 2005). Clearly socio-economic characteristics, like income and car ownership, have been found to be significant to higher non-work trip rates. A study of Toronto found the ownership of unlimited transit passes to be the most important variable predicting number of daily transit trips. Transit pass ownership levels

were linked to demographic characteristics and access to transit and autos (Badoe and Yendeti 2007). The lack of understanding of non-work travel and the need for good data sources has been identified. (Niles 1999).

In addition to land use and socio-economic characteristics, transit operations and funding/pricing potentially impact non-work trips and non-motorized access. There is less research in these areas as they relate to sustainability impacts. Transit economics research examines fare elasticity and the impact of transit pricing on ridership over all (Litman 2004). The impact of fare programs has not been examined in great detail.

Clearly, network design could impact access and trip type usage. A number of researchers have examined characteristics of different network designs and performance indicators (Musso and Vuchic 1988). Derrible and Kennedy, using graph theory, found that network design plays a significant role in predicting boardings per capita on subway systems around the world. The coverage, directness, and connectivity of the system are all positively correlated to boardings (Derrible and Kennedy 2009). The Center for Transit Oriented Development released a study that stressed the importance of linking major destinations with transit service in order to increase ridership (Center for Transit-Oriented Development 2009).

The traditional Central Business District (CBD) hub with spokes design is focused on serving work trips. Thompson and Matoff conclude that decentralized transfer-based networks compare well to radial single seat CBD networks for effective, efficiency, and equity measures (Thompson 2003). Recent work by Brown and Thompson is attempting to break the bus/rail dichotomy and analyze the role both play in an integrated transit system. They conclude that rail as a backbone with a multi-destination service strategy leads to the best performance (Brown 2009, 2009). These studies primarily examine the impact on overall transit ridership.

While the emphasis on sustainability in transportation is a relatively new subject in the literature, the questions of how to achieve environmental, economic, and social goals with public transit has been discussed for decades. The goal of this research is to use the sustainability framework to bridge some of the divide between social and environmental goals for transit. The variables that have been found to be significant in the existing literature will be used to assess non-work trips and non-motorized access.

CHAPTER 3
METHODOLOGY AND DATA SOURCES

This research uses a representative sample of 17 metropolitan regions in the United States to examine trends in public transit usage. A mix of qualitative and quantitative factors is used to assess the regions and draw conclusions. The research was conducted in three phases. The first phase identified the study regions, provided background information on each transit system, and assessed general transit trends across the country. The second phase estimated correlations among a set of variables and the level of non-motorized access and non-work trips. The third phase consisted of an in-depth case study of three of the regions. This chapter explains the methodology and data sources used.

3.1 Determining the Study Regions

This study focuses on urban public transit systems; public transit in small cities and rural areas are not considered. Only metropolitan areas with year 2000 population over 500,000 were considered. There are multiple definitions and demarcations of metropolitan regions in the US. In this study, the Metropolitan Planning Organization (MPO) is used as the boundary for metropolitan regions and, whenever possible, is used as the unit for all regional calculations. When regional data is not available at the MPO level, the same type of regional boundary is used for all regions in order to maintain consistency.

In order to focus on regions that are investing in transit, the universe of potential regions was restricted to areas that have received non-formula federal funds for transit projects since the year 2000. A list of regions fitting these criteria was generated from the Federal Transit Administration (FTA) New Start budget allocations from between

2000 and 2008 and the transit earmarks in the federal transportation bill SAFETEA-LU. All of the transit related earmarks were totaled by region and regions with over $1 million in earmarks were considered. The low threshold of $1 million was chosen to ensure that regions with bus only service would be included.

Eight factors were used to pick a sample of 17 metropolitan areas. The eight factors are shown in Table 3.1. From the list of possible regions, 17 were chosen to ensure there were at least three cities in each category for all eight criteria. Table 3.2 shows the cities in each category. In addition, geographic dispersion was considered. A map of the regions is shown in Figure 3.1. Where multiple regions fit the criteria, data availability was considered to finalize the list.

The eight criteria ensure that the sample includes regions across the spectrum of transit conditions. The regions are spread out geographically and include a range in population size and racial make-up. The age and existence of rail service measures the level of existing transit and provides for a variety in type of rail service. The federal funding type ensures varying levels of investment; not only cities with a successful New Starts application are included. Congestion levels, air quality concerns, and economic growth are included as factors that impact regional transit decision-making.

Table 3.1 Criteria Used to Determine Sample

Criteria	Categories
Geographic	West, East, Midwest
Economic Conditions (Job growth between 1996-2006)	Over 20%, 10-20%, Under 10%
Federal Funding Status	New Starts Project since 2000, Over $1 million in SAFETEA-LU earmarks
Clean Air Act Status for Particulate Matter (PM) and Ozone	Nonattainment for at least one Ozone and one PM standard, Nonattainment for only one, Attainment
Congestion Levels	In top 25 of Texas Transportation Institute (TTI) congestion index, Not in top 25 of TTI index
Age of Rail Service	Pre 1960's, 1960-1980's, 1990-2000's, No rail or only monorail service
2000 Population of MPO	Over 3 million, 1-3 million, ½-1 million
Racial Composition of Central City	Majority White, Majority People of Color

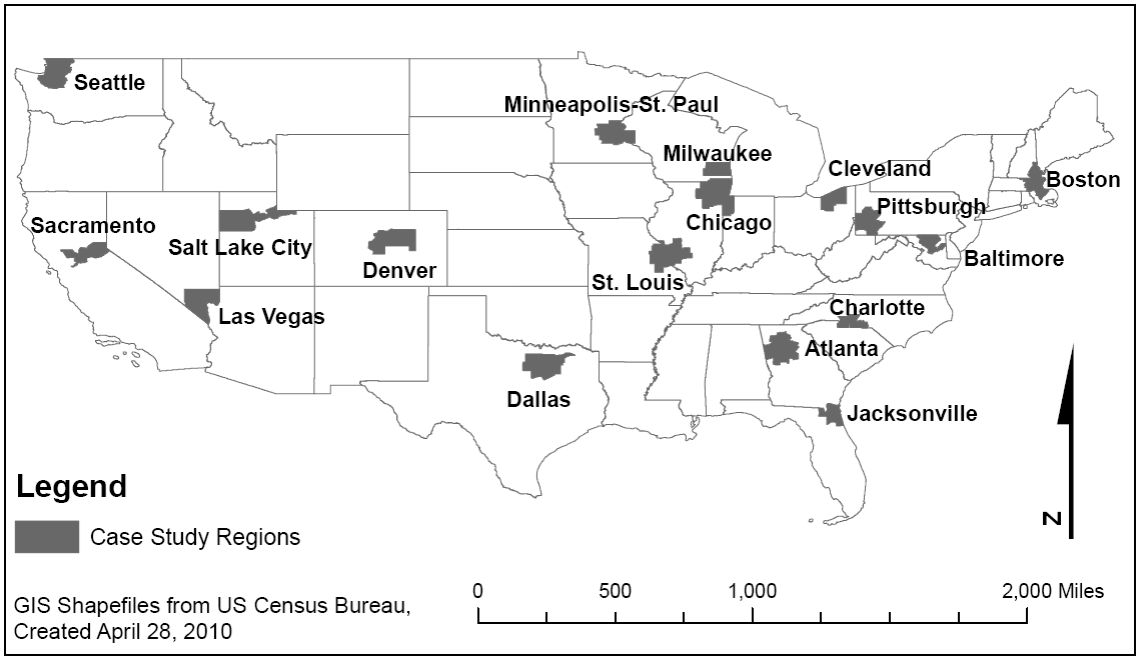


Figure 3.1 The Study Regions

Table 3.2 Cities in Each Category of Each Criteria

Economic Condition (Job Growth 1996-2006)	*Over 20%*	*10-20%*	*Under 10%*	
	Atlanta, Charlotte, Dallas, Jacksonville, Las Vegas, Sacramento	Baltimore, Boston, Chicago, Denver, Seattle, Salt Lake City, Twin Cities	Cleveland, Milwaukee, Pittsburgh, St. Louis	
Federal Funding Status	*New Starts*	*Earmarks only*		
	Seattle, Baltimore, Pittsburgh, Chicago, St. Louis, Cleveland, Twin Cities, Denver, Salt Lake City, Atlanta, Charlotte, Dallas	Sacramento, Boston, Milwaukee, Las Vegas, Jacksonville		
Population of Metro Area (MSA in 2000)	*Over 3 Million*	*1-3 Million*	*500,000-1 million*	
	Atlanta, Dallas, Chicago, Boston, Seattle	Sacramento, Denver, Baltimore, Twin Cities, Las Vegas, St. Louis, Milwaukee, Pittsburgh, Cleveland	Charlotte, Jacksonville, Salt Lake City	
Clean Air Act Attainment Status for Particulate Matter (PM) and Ozone	*Nonattainment for at least one Ozone and one PM Standard*	*Nonattainment for only PM or only Ozone*	*Attainment*	
	Sacramento, Baltimore, Pittsburgh, Chicago, Cleveland, St. Louis, Atlanta, Las Vegas	Boston, Denver, Milwaukee, Salt Lake City, Charlotte, Dallas	Seattle, Twin Cities, Jacksonville	
Congestion Levels as Defined by the Texas Transportation Institute (TTI)	*In the top 25 regions for congestion*	*Not in the top 25 regions*		
	Atlanta, Boston, Baltimore, Charlotte, Chicago, Denver, Seattle, Dallas, Twin Cities	Cleveland, Jacksonville, Las Vegas, Milwaukee, Pittsburgh, Sacramento, Salt Lake City, St. Louis		
Racial Composition of Central City	*Majority White*	*Majority People of Color*		
	Boston, Charlotte, Dallas, Denver, Jacksonville, Las Vegas, Pittsburgh, Salt Lake City, Seattle, Twin Cities	Atlanta, Baltimore, Chicago, Cleveland, Milwaukee, Sacramento, St. Louis		
Age of the Rail System	*pre-1960's*	*1960-1980s*	*1990-2000s*	*No rail*
	Boston, Chicago, Cleveland	Atlanta, Baltimore, Pittsburgh, Sacramento	Charlotte, Dallas, Denver, Salt Lake City, Seattle, St. Louis, Twin Cities	Jacksonville, Las Vegas, Milwaukee

3.2 Background Information

Once the study regions were selected, background information was gathered on the transit in each region. Existing transit service, future transit plans, and transit funding sources were examined. This information was used to assess general trends in transit service.

The level of transit service between 1996 and 2007 was measured by peak vehicles in service for each mode. In order to examine trends, the change in service over time was categorized into three groups: an increase followed by a decrease, increasing service, and decreasing service. Data from the National Transit Database (NTD) was used. Future transit plans for each region were obtained from New Starts applications, the Regional Transportation Plans (RTP), and planning documents from transit agencies. Sources of transit funding were determined from the NTD and transit agency budgets.

3.3 Non-Work and Non-Motorized Access Correlations

Due to the small sample size and lack of normality, non-parametric correlations were calculated for non-work usage and non-motorized access levels and a range of land use, transit operations, and demographic variables. Both Kendall's Tau and Spearman's Rho were used as a double-check mechanism; they use slightly different methods of calculating a correlation using the ranks, instead of the numeric value, of each variable in the dataset. Since correlations compare two continuous variables, the non-parametric Whitney-Mann test was used for the categorical variables. This test determines if the mean rank of the samples for each category are significantly different.

The percentage of non-work trip usage and non-motorized access were obtained from on-board surveys performed by transit agencies or the MPO. The surveys were conducted between 2005 and 2009. The number of transit agencies in each MPO

ranges from one to twelve. In most cases the survey data was obtained for the main transit agencies serving the central city. Table 3.3 shows the transit agencies in each region and where survey data was obtained.

Sixteen of the regions collected data on trip purpose, but only 13 of the cities collected data on access mode. A trip was defined as a work trip if either the origin or destination was work related. In cases where access and egress of a transit trip was recorded, only the transit access was considered. Non-motorized access was defined as walk, bike, and 'other' access types. In cases where transfer from another transit mode was listed, where possible, the percent of non-motorized access to that mode was calculated. In most cases, the agencies provided a written summary of the survey results; however, in five cases the raw data was provided. In these cases, the values were calculated using the sample weighting provided by the agency.

The non-work and non-motorized access levels were compared to a set of variables. Land use and demographic variables found to be significant in other studies of public transit usage were used. In addition, new variables were formulated to measure transit system design. Most of the variables were calculated for the MPO region. Some variables are only for the transit agencies where survey data was available and others for main transit agencies. The level of analysis was primarily determined by data availability and the type of variable. Table 3.4 shows the 29 continuous variables and at what geographic level they were calculated. Table 3.5 lists the 11 categorical variables examined.

The data for the variables came from a variety of sources: the on-board surveys, the NTD, transit agency and MPO websites, and the US Census Bureau. When possible, data from the same year as the on-board survey for that region was used. If not possible, the most recent data was used. In a few cases where significant transit

service cuts had taken place since the on-board survey, only pre-service cut data was used. A full list of all data sources is in Appendix A.

A number of the land use variables were calculated using Geographic Information System (GIS) software. The GIS files for transit routes, stops, and stations were obtained from the transit agencies and MPOs. In a few cases where GIS files were not obtainable, they were created using Google Earth and the agencies' online route maps. Access to transit was defined as within a half mile buffer of a bus stop, local bus route, or rail station. Calculations for population and jobs within the half mile transit buffer used area weighting of year 2000 population and jobs data. The population data was calculated at the census block group level; unfortunately, the job data is only available at the census tract level.

The transit operations variables were calculated from analysis of the transit routes and NTD data. Local service is defined as bus service that runs throughout the day; service with limited stops is defined as local if it is not peak-hour only. A route is defined as serving the CBD if it stops within a half mile buffer of the downtown transit station in the central city of each region. The number of hubs in a system was calculated by a visual analysis of the transit map and GIS analysis of routes with overlapping stops and half mile buffers.

Some variables required aggregation up to the regional level since the data was collected at the level of transit agency or transit mode. The variables were aggregated using the percent of annual unlinked trips on that mode or agency as a percent of the region total in the year of the on-board survey. The full dataset is in Appendix B.

Table 3.3 Transit Agencies and Survey Data

Region	Transit Agencies *(Main Agencies in Italics)*	Survey Data From	Year of Survey	Trip Purpose	Access Mode
Atlanta	*MARTA,* GRTA, Cobb County, Gwinnett County, Clayton County	MARTA, GRTA	2008	X	X
Baltimore	Annapolis County, Carroll Transit, Harford County, Howard County, *Maryland Transit Administration (MTA)*	MTA	2005	X	
Boston	*Massachusetts Bay Transportation Authority (MBTA),* Boston Cape-Ann Transportation Authority	MBTA	2009	X	X
Charlotte	*Charlotte Area Transit System (CATS)*	All Agencies	2007	X	X
Chicago	*Pace Suburban Bus, Metra, Chicago Transit Authority (CTA)*	All Agencies	2005-2007	X	X
Cleveland	Brunswick Transit Alternative, Laketran, Lorain County Transit, *Greater Cleveland Regional Transit Authority*	All Agencies	2007	X	X
Dallas	*Dallas Area Rapid Transit (DART),* Denton County, Fort Worth Transportation Authority	DART	2007	X	X
Denver	*Regional Transportation District (RTD)*	All Agencies	2008	X	X
Jacksonville	*Jacksonville Transportation Authority (JTA),* St. Johns County	JTA	2006	X	
Las Vegas	*Regional Transportation Commission of Southern Nevada (RTC),* Las Vegas Monorail Company	RTC	2006	X	X
Milwaukee	Kenosha Transit, *Milwaukee County Transit System (MCTS),* Ozaukee County, Racine Transit, Washington County, Waukesha Metro	MCTS	2009	X	
Pittsburgh	Beaver County, Fayette Area Coordinated Transportation, Mid Mon Valley Transit Authority, *Port Authority of Allegheny County,* GG and C Bus Company, Westmoreland County	All Agencies	2007	X	X
Sacramento	City of Elk Grove, Placer County, Roseville Transit, *Sacramento Regional Transit District,* Unitrans, Yolo County, Yuba-Sutter Transit	All Agencies	2006	X	X
Saint Louis	*Bi-State Development Agency (Metro),* Madison County	Metro	2008		X
Salt Lake City	*Utah Transit Authority*	All Agencies	2006	X	
Seattle	Everett Transit, *King County*, Kitsap Transit, Pierce County, Seattle Center Monorail, Snohomish County Transit, Sound Transit, Tacoma Ferry, Washington State Ferries	King County, Pierce County	2007	X	X
Twin Cities	*Metro Transit*	All Agencies	2008	X	X

Table 3.4 Continuous Variables for Correlations

Continuous Variable	Description	Level of Analysis	Data Source
Non-Work Trips	Percent of trips for non-work	Surveyed Agencies	On-Board Survey
Non-Motorized Access	Percent of access to transit by non-motorized means	Surveyed Agencies	On-Board Survey
Unlinked Trips per Capita	2006 Unlinked transit trips per capita of the region	Regional	NTD
VMT per Capita	2007 Vehicles Miles Traveled per capita of the region	Regional	Federal Highway Administration
Land Area Cover	Percent of land area in MPO within ½ mile of transit	Regional	2000 Census, GIS analysis
Population Cover	Percent of population in MPO living within ½ mile of transit	Regional	2000 Census, GIS analysis
Job Cover	Percent of jobs in MPO within ½ mile of transit	Regional	2000 Census, GIS analysis
Accessible Population Density	Population of transit accessible area in people per sq mile	Regional	2000 Census, GIS analysis
Accessible Job Density	Job density of transit accessible area in jobs per square mile	Regional	2000 Census, GIS analysis
Daily Parking	2008 median daily parking price in CBD	Regional	2008 Colliers Parking Survey
Monthly Parking	2008 median monthly parking price in CBD	Regional	2008 Colliers Parking Survey
Peak Bus Headway	Average headway of local bus service in morning peak	Main Agencies	Agency bus schedules
Operators	Number of transit operators in MPO	Regional	NTD
Modes	Number of transit modes in MPO	Regional	Agency websites
Percent Local Routes	Percent of bus routes in the region that are local service	Regional and Main Transit Agencies only	Agency bus schedules
Percent bus routes in CBD	Percent of bus routes in the region that serve the CBD	Regional and Main Transit Agencies only	GIS analysis of transit routes
Hubs	Number of distinct locations with transfers to over 10% of all transit routes within a ½ mile	Regional and Main Transit Agencies	GIS analysis of transit routes
Percent Trips by Bus	Percent of 2007 unlinked transit trips on bus	Regional	NTD
Percent White	Percent of transit riders who report white or Caucasian ethnicity from on-board surveys	Surveyed Agencies	On-Board Survey
Median Income	Median of household income self-reported by transit riders from on-board surveys	Surveyed Agencies	On-Board Survey
Percent of Region's Income	Median income of transit riders as a percentage of region's household median income from same year as survey	Surveyed Agencies	On-Board Survey, HUD

Table 3.4 (continued)

Unlimited Passes	Percent of trips paid for with unlimited ride passes from on-board surveys	Surveyed Agencies	On-Board Surveys
Rail with Parking	Percent of rail stations that have parking	Regional	Agency websites
Bus at Rail Stations	Percent of rail stations with local bus transfers	Regional	Agency websites
Park and Ride with Local Bus	Percent of park and ride lots for commuter bus that are also served by local bus	Regional	Agency websites
Cost per Passenger Trip	Operating expense per unlinked passenger trip for surveyed transit agencies for year of survey	Main Agencies	NTD
Passenger per Vehicle Hour	Unlinked passenger trips per vehicle revenue hour for surveyed transit agencies in survey year	Main Agencies	NTD
Average Length of Trip	Annual unlinked passenger trips divided by annual passenger miles for year of survey	Main Agencies	NTD
Annual Transit Budget per Capita	Annual Transit Operating and Capital budgets in the year of the survey divided by 2000 MPO population	Regional	NTD

Table 3.5 Categorical Variables for Correlations

Categorical Variables	Categories	Data Source
Geographic Location	East, West, Midwest	Map of the US
Jobs growth (1996-2006)	Over 20%, 10-20%, Under 10%	Bureau of Economic Analysis
State Funding	Yes, No/Minimal	MPO and Transit Agency Budget Reports
Federal Transit Funding 2000-2008	New Start Funding, Earmarks only	SAFETEA-LU, FTA New Starts Annual Reports
Population of Metro Area	Over 3 million, 1-3 million, 500,000-1 million	US Census Bureau
Clean Air Act Status	Nonattainment for at least one Ozone and one PM standard, Nonattainment for only one standard, Attainment	EPA The Green Book Nonattainment Areas for Criteria Pollutants
Congestion Level	In the top 25 regions for congestion, not in the top 25 regions for congestion	Texas Transportation Institute 2007 Urban Mobility Report
Racial Make-Up of Central City	Majority White, Majority People of Color	US Census Bureau
Bus Service Changes 1996-2007	Increasing, Decreasing	NTD
Transfer Fees at Main Agencies	Free, No transfers, Small fee	Transit Agency Websites
Fare Structure at Main Agencies	Flat, No Flat (Time of Day or Zones)	Transit Agency Websites

3.4 In-depth Case Studies

The last phase of research used in-depth case studies of three of the metropolitan regions to identify qualitative factors that can influence transit usage for non-work trips and non-motorized access to transit. The regions were chosen based on data availability, similar transit infrastructure, and different non-motorized access and non-work usage rates. Considering the current emphasis on light rail investments, the decision was made to focus on cities in varying stages of building light rail networks. Using these three criteria, the list of 17 regions was narrowed to Denver, Colorado; Sacramento, California; and the Twin Cities region in Minnesota. All three are state capital regions with a similar population and a light rail and bus transit network.

The three regions were compared using the variables from the previous phase along with additional variables focusing on the light rail infrastructure and regional policies. The new light rail variables included land use and pedestrian access around stations, operating characteristics, destinations served, and parking levels. Policy variables included decision-making determining the light rail corridors, parking policies, MPO transit-related goals, and route planning for schools.

The surrounding land use type and access level to light rail stations were determined using Google Earth satellite images. Land use was categorized in five general types and a visual assessment was used to place each half mile station area into a type. A description of each type is listed in Table 3.6. Each station was assessed to determine if pedestrians had access to both, one, or no sides of the station due to freight lines, freeways, or sound walls.

Table 3.6 Land Use Types Around Light Rail Stations

Land Use Type	Description
Downtown	Mixed use with buildings at the curb
Transitional	Commercial uses with parking lots surrounded by residential
Residential	Urban or suburban residential
Suburban	Office parks, park and ride lots, malls
Destination	Single use (e.g. stadium, airport)

A site visit was made to each region to collect and verify data. A visual inspection of each light rail line was made to assess surrounding land use and operating characteristics. Interviews were conducted with staff members at the main transit agency and MPO in each region. The interviews provided insight into policy goals, the politics behind the light rail corridor selection process, and verification of survey data. The details of the site visit interviews are in Appendix C.

3.5 Data Sources and Limitations

Data was collected from a range of sources; unfortunately these sources vary in reliability. Some of the sources are easily available, updated regularly, and standardized for all cities. These sources include the US Census, the National Transit Database, and New Starts funding requests. Regional Transportation Plans and Transportation Improvement Programs (TIPs) are available and updated for each region, but they are not standardized in content or clarity. Transit agency planning documents and on-board surveys can be hard to access, are not always up-to-date, and not standardized. Replacement measures were found for variables that could not be standardized.

A large amount of the necessary sources were publicly available on the internet. Websites for the transit agencies and MPO for each region contain many of the relevant documents and system information. In addition, data was downloaded from the US Census Bureau, State Departments of Transportation, and the FTA. Staff members at

the transit agencies and MPO for each region were contacted by email or phone to obtain data not found online.

Data availability was not as much a problem as was expected. Almost all of the agencies contacted were willing to assist in providing the data requested; one region had to be dropped from the study due to unresponsiveness by the transit agency. The requested data was not available for all transit agencies; some of the calculations were done without all 17 of the regions due to missing data.

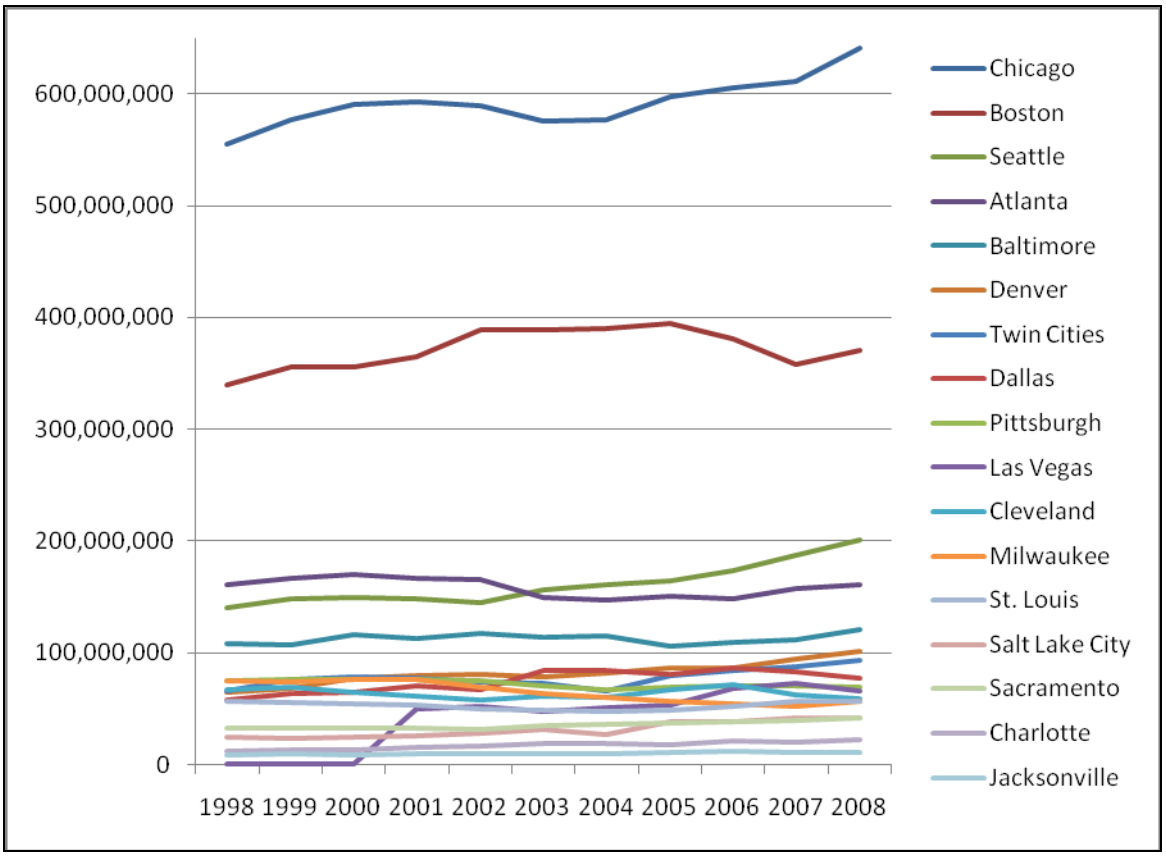
Validity is also threatened if the data available is dated or collection dates vary significantly. For regions, like St. Louis, Missouri, where services levels changed significantly during this research project, extra effort was taken to ensure the system variables were from the same year as the survey data. Almost all of the data is from 2005 to 2009. The exception is the 2000 census, which was the only source for geographic-specific population and employment data. Since land use variables are aggregated to the level of the entire transit system, localized changes in population and employment should not significantly influence the general measure.

In general, the data used for this research was the best data available and reflected local agency and research efforts to compile a high quality and credible database.

CHAPTER 4
BACKGROUND ON TRANSIT SERVICE

4.1 Service Levels over the Past Decade

Transit service and ridership levels vary over time; this chapter presents the changes between 1996 and 2008, and the new service in each study region. Since the ridership data ends in 2008, the impacts of the late 2008 economic crash are not reflected in this data. The ridership levels in each region between 1998 and 2008 are shown in Figure 4.1



Source: (Federal Transit Administration 2008)

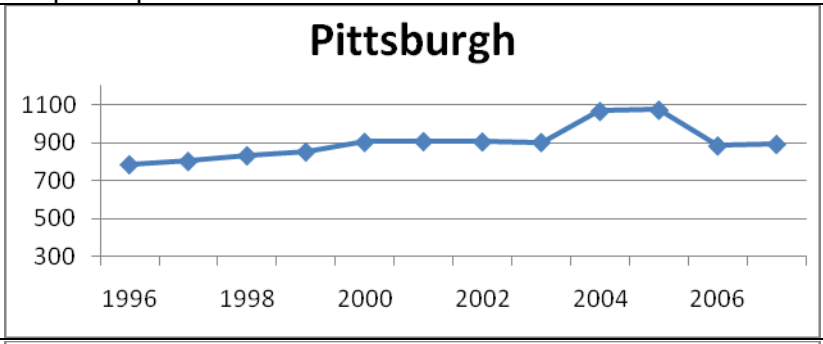
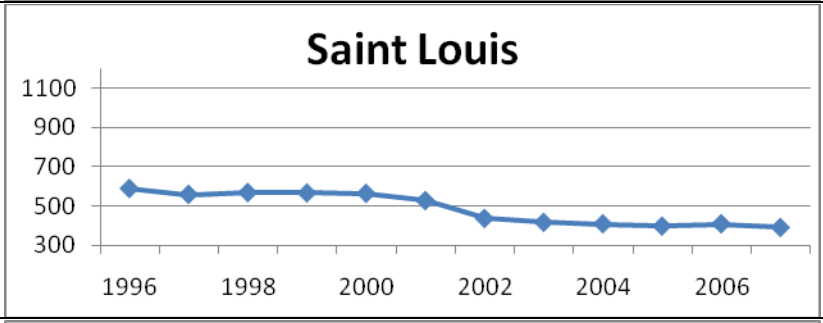
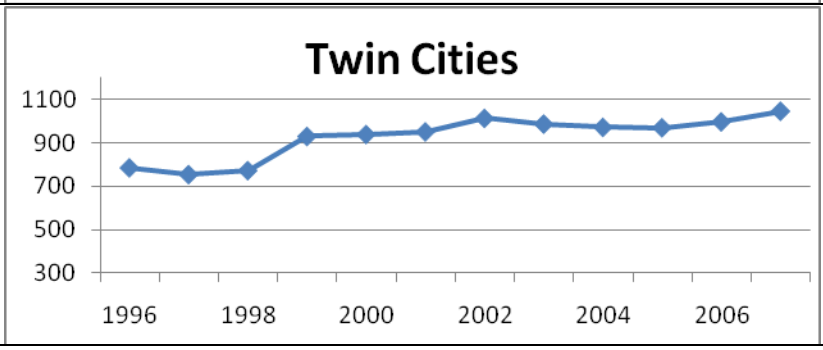
Figure 4.1 Unlinked Transit Trips Per Year Between 1998 and 2008 by Region

As seen in Figure 4.1, the trips per year in the study regions vary from 600 million in Chicago and close to 400 million in Boston to a clustering of the majority of regions under 100 million. Atlanta, Seattle, and Baltimore are in the middle region between 100 and 200 million. Seattle surpassed Atlanta in ridership in the middle of the decade with steady increases, while Atlanta's ridership decreased mid-decade. Las Vegas stands out as having made the most significant gains during this decade; it started with no transit service and ended the decade with 66 million trips per year.

Ridership levels are closely related to the amount of transit service provided. Peak hour vehicles in service is used as an indicator of the amount of service provided. Changes in bus service levels over the decade took three basic forms. The first form has service increasing until a peak, in most cases in 2003 or 2004, and then service decreases, but not below the original level. The second form has some initial years of increase, but by 2001 the service is decreasing and by 2007 is below the initial bus service level. The third form has service increasing with only minor decreases and ends at higher levels. Sample graphs of the three forms are in Figure 4.2.

The most consistent indicator for increasing bus service is job growth; all of the cities with increasing bus service had job growth over 10 percent during the study period. All of the cities with decreasing bus service have received federal New Starts or Small Starts funding for rail or Bus Rapid Transit (BRT) projects. Five out of the six cities with increasing bus service are also building rail projects.

In contrast to bus service, the only region where rail service decreased was Cleveland. In Atlanta and Baltimore the rail service takes the same form as their bus service, an initial increase followed by a decrease. In the remaining regions with rail service, the service increased over the 11 years.

Form	Sample Graph	Regions
Increased, Decreasing		Atlanta, Dallas, Pittsburgh, Seattle, Baltimore, Las Vegas
Decreasing		Boston, Cleveland, Saint Louis, Salt Lake City
Increasing		Charlotte, Chicago, Denver, Jacksonville, Milwaukee Sacramento, Twin Cities

Source: (Federal Transit Administration 2008)

Figure 4.2 Bus Peak Hour Vehicles in Service Changes Between 1996-2007

Some of the increase in service was caused by the introduction of new service. Table 4.1 shows the new service by transit mode and type of project by region. Express bus service is the most common new service due to lower capital costs and less planning time. Cities with older rail systems, like Chicago and Boston, primarily did improvements to their existing heavy and commuter rail infrastructure. Light rail is the most popular new rail type with three cities starting service and seven cities expanding their existing system.

Table 4.1 New Transit Projects 2000-2008 by Type

Transit Technology	Project Type	Cities
Light Rail	New System	Charlotte, Seattle, Twin Cities
	Extension and Improvements	Baltimore, Dallas, Denver, Pittsburgh, Sacramento, Salt Lake City, St. Louis
Commuter Rail	New System	Salt Lake City, Seattle, Twin Cities
	Extension	Chicago
	Improvements	Boston, Chicago
Heavy Rail	Extension	Atlanta, Chicago
	Improvements	Chicago
BRT	New System	Cleveland, Las Vegas, Salt Lake City
Express Bus/P&R lots	New Service	Atlanta, Baltimore, Charlotte, Cleveland, Dallas, Denver, Jacksonville, Milwaukee, Pittsburgh, Sacramento, Salt Lake City, Seattle, St. Louis, Twin Cities
Monorail/Streetcar	New Service	Las Vegas, Seattle

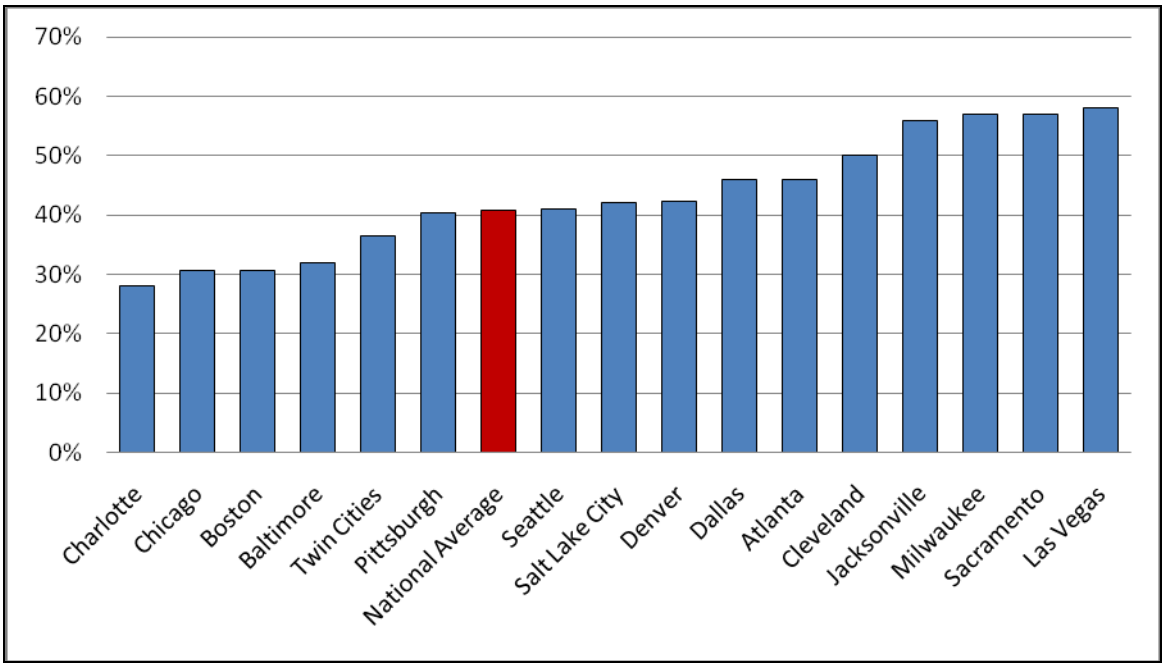
Source: Transit Agency and MPO websites and planning documents, FTA New Starts Budgets

In addition to the new service, all of the regions have future expansion plans. Dallas, Denver, Salt Lake City, and Seattle have full funding grant agreements to continue their light rail projects. A number of the study regions received stimulus funding for transit expansion projects. Chicago received funds for two BRT projects. Atlanta, St. Louis, Dallas/Ft. Worth, and Charlotte received funds for streetcar projects. Baltimore, Salt Lake City, Denver, and Seattle received funds for intermodal centers.

4.2 Non-Work Trips

Transit usage for non-work trips is the first of the two variables examined in this study. Within the sample, non-work trip usage ranges from 28 percent in Charlotte, North Carolina to 58 percent in Las Vegas, Nevada. The national average from a 2007 American Public Transit Association study is 41 percent (American Public Transportation Association 2007). The non-work usage for all of the regions is shown in Figure 4.3.

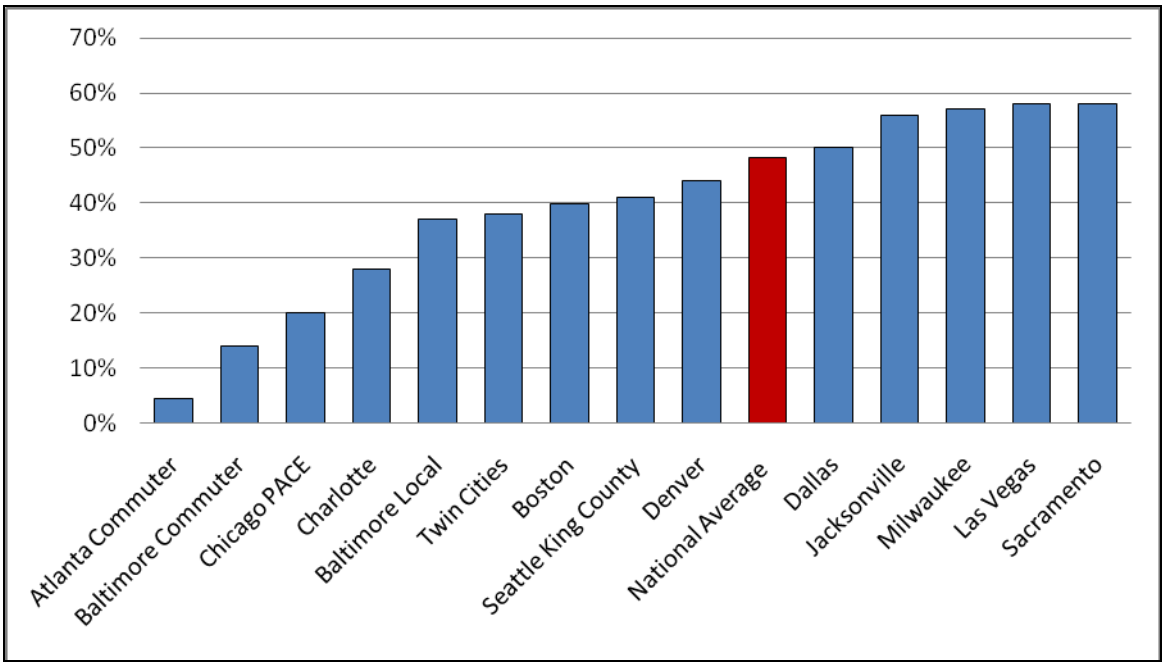
Some of the transit systems reported data by mode. Figures 4.4 and 4.5 show the non-work trips by bus and non-work trips by rail, respectively. Where the data is available, it is separated by bus or rail type. For example, since a different agency operates the commuter bus in Atlanta it is included separately; however, the local bus is not included since MARTA combines its bus and heavy rail data. Only Atlanta and Baltimore report their commuter bus separately. For the rest of the cities, the bus data includes commuter and local bus together.



Source: On-board survey data

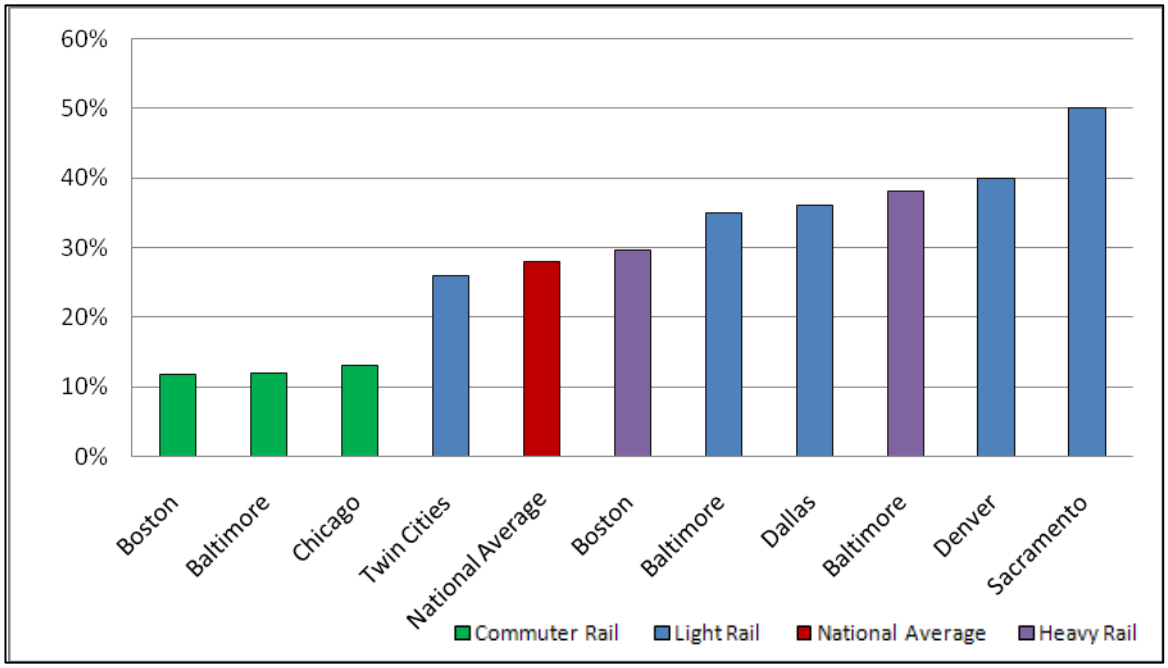
Figure 4.3 Non-Work Trips on Transit Overall

Figures 4.4 and 4.5 indicate "commuter" rail and "commuter" bus have the highest work usage. More interesting is the large range in light rail systems, between 26 percent in the Twin Cities to 50 percent in Sacramento. Both Sacramento and the Twin Cities appear to be outliers from the five point range between light rail in Baltimore, Dallas, and Denver. The large ranges demonstrate that there are differences between systems worth examining.



Source: On-board survey data

Figure 4.4 Non-Work Trips by Bus



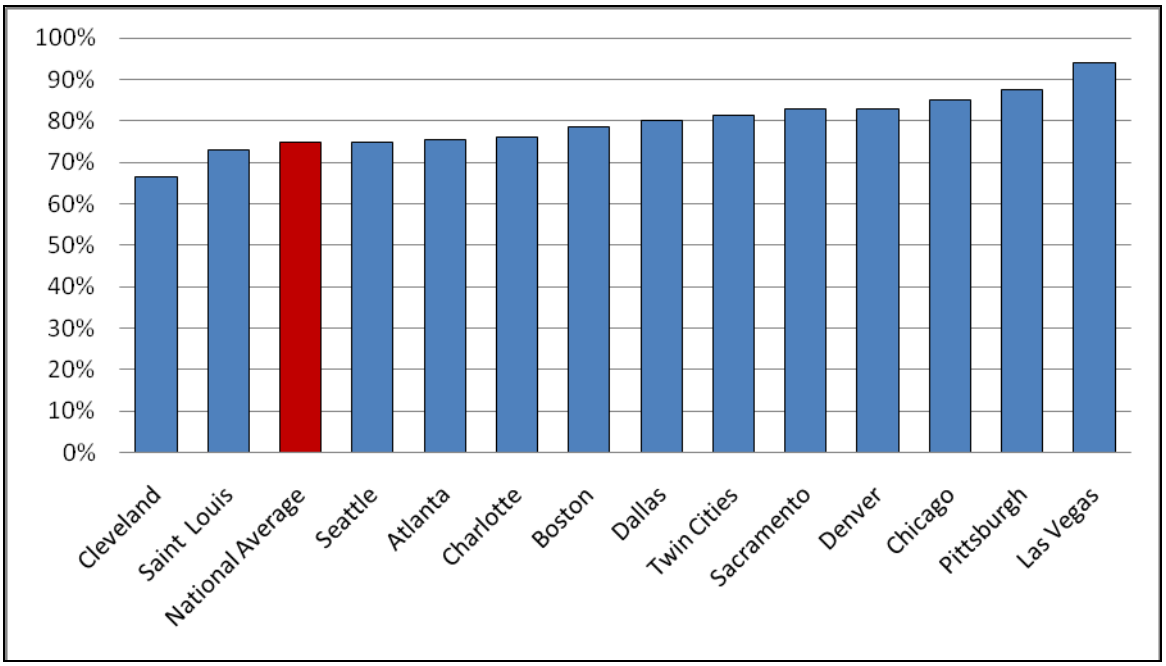
Source: On-board survey data

Figure 4.5 Non-Work Trips by Rail

4.3 Non-Motorized Access

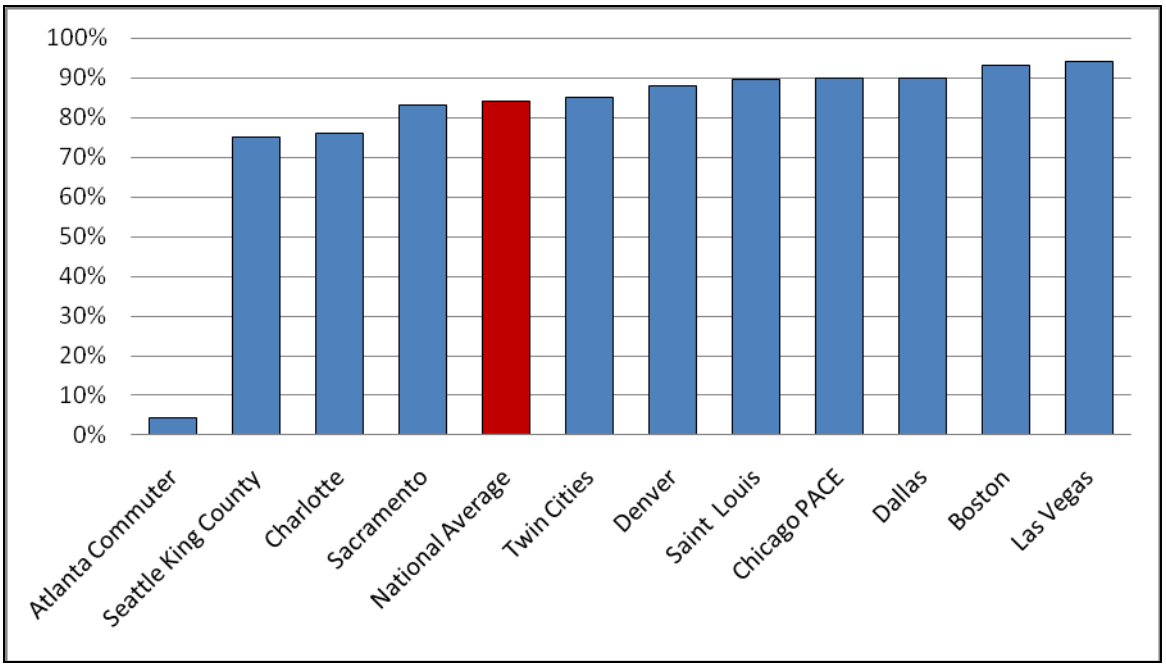
The non-motorized access rate runs from 67 percent in Cleveland, Ohio to 94 percent in Las Vegas, Nevada. The national average from the 2007 study is 75 percent (American Public Transportation Association 2007). Clearly, Las Vegas has a unique economy that contributes to high rates of both non-motorized access and non-work trips. The non-motorized access for all transit in each region is shown in Figure 4.6.

As with the non-work trips some agencies report data by transit mode. Figures 4.7 and 4.8 show the non-motorized access to bus and rail, respectively. Access to bus has less variation, except in the case of Atlanta where commuter bus is considered alone. In contrast to Atlanta, Pace, which provides bus service to suburban Chicago, has very high non-motorized access. Along with commuter bus, commuter rail has the lowest non-motorized access. As would be expected, the one heavy rail system has the highest non-motorized access. Light rail again provides a large range from 45 percent in Saint Louis to 70 percent in Sacramento.



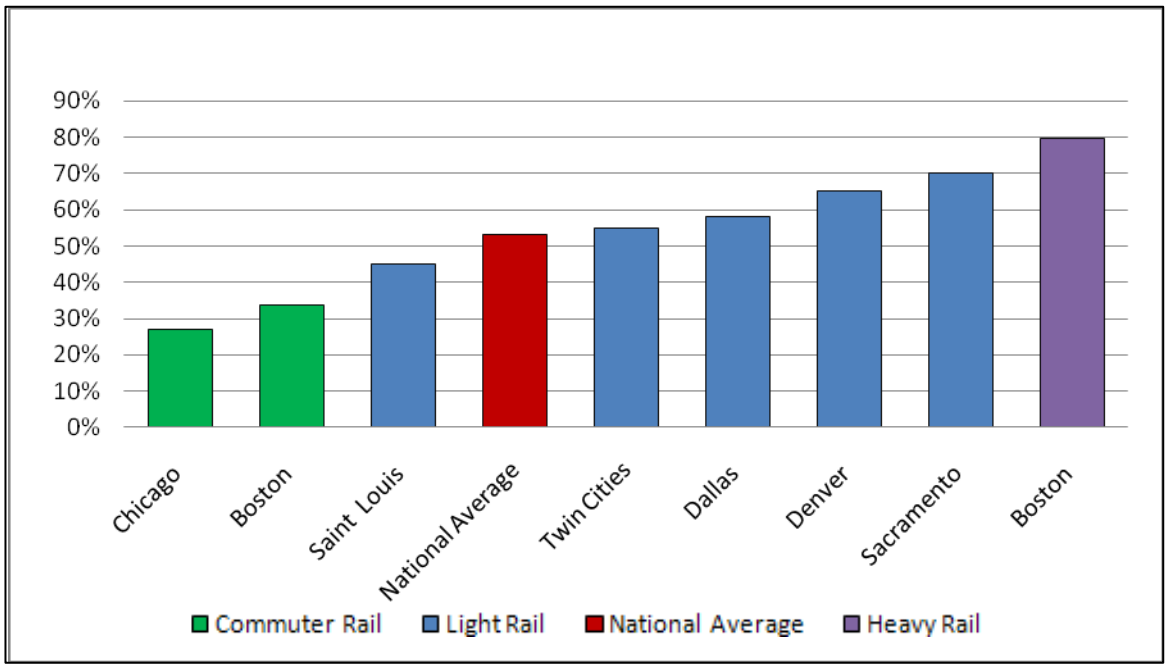
Source: On-board survey data

Figure 4.6 Non-Motorized Access to Transit Overall



Source: On-board survey data

Figure 4.7 Non-Motorized Access to Bus



Source: On-board survey data

Figure 4.8 Non-Motorized Access to Rail

CHAPTER 5
CORRELATIONS

Chapter 4 illustrated the range of non-work trip usage and non-motorized access across the sample regions. This chapter examines correlations between these two variables and a set of explanatory variables. Two sets of variables- continuous and categorical- are found in this study. Kendall's Tau and Spearman's Rho, both non-parametric correlation coefficients, are calculated for the continuous variables. Mann-Whitney tests are used to calculate significant differences for categorical variables.

The continuous variables fall into four categories. The first five variables measure transportation usage in the region and the second three measure transit efficiency. The next five are land use variables; they measure how much of the region has transit access and density levels. Three variables measure the demographics of transit riders. The remaining 14 variables measure aspects of the operations and design of the transit network. The categorical variables fall into two categories: variables that describe characteristics of the region and transit operations.

5.1 Non-Work Trips

The correlations and significance levels for non-work trip usage and the explanatory variables are presented in Table 5.1. The categorical test results are shown in Table 5.2. A number of variables have significant correlations to non-work trip usage at the 95 percent and 90 percent confidence levels.

Within the transportation usage category, two variables are significant. Transit spending per capita is negative indicating that as the spending per capita on transit increases the percent of non-work trips decreases. Daily parking is also negative and significant for one test at the 90 percent level. This validates the commonly accepted

knowledge that higher parking prices in the CBD is correlated to higher transit usage for work trips. The average length of transit trips is also negative. This means that there are more non-work trips in regions with on average shorter transit trips. The only land use variable that is significant is land area cover. Again the result is negative indicating that regions with higher non-work trip usage have a smaller percent of their land area accessible by transit. The percent of population and jobs accessible by transit and job and population density are not significant.

In the rider demographics category, the level of white riders is not significant, but both versions of the income variable are significant. Both variables are negative indicating that non-work usage is higher in regions with lower income riders.

Three of the transit operations and design variables are significant. The peak bus headway is positive, which means that there is higher non-work trip usage on systems with more time between buses. The number of modes is negative and significant at 90 percent for one test. This indicates that there is some correlation between a region having fewer modes, bus only, and higher non-work trip usage. Finally, the higher the percent of park and ride lots with local bus service (as opposed to only express bus service) the higher the non-work trip usage.

Table 5.1 Non-Work Usage Correlations

Type	(N=16) Variable	Kendall's Tau	Sig.	Spearman's Rho	Sig.
Independent	Non-Motorized Access	0.03	0.891	0.049	0.88
Transportation Usage	Unlinked Transit Trips per Capita	-0.293	0.115	-0.393	0.132
	Transit Spending per Capita	-0.594	0.001**	-0.767	0.001**
	VMT per Capita	0.042	0.822	-0.031	0.91
	Daily Parking Rate	-0.301	0.123	-0.452	0.091*
	Monthly Parking Rate	-0.269	0.149	-0.418	0.107
Transit Efficiency	Cost per Passenger Trip	0.008	0.964	-0.018	0.948
	Passenger per Vehicle Hour	-0.025	0.892	-0.026	0.922
	Average Length of Trip	-0.31	0.095*	-0.444	0.085*
Land Use	Land Area Cover	-0.559	0.003**	-0.698	0.003**
	Population Cover	0.034	0.857	0.028	0.918
	Job Cover	-0.094	0.619	-0.114	0.673
	Accessible Population Density	0.059	0.752	0.038	0.888
	Accessible Job Density	-0.126	0.499	-0.159	0.557
Rider Demographics	Percent White	-0.033	0.869	0.033	0.911
	Median Income	-0.433	0.026**	-0.59	0.021**
	Percent of Region's Median Income	-0.325	0.092*	-0.449	0.093*
Operations and Design	Peak Bus Headway	0.454	0.015**	0.571	0.021**
	Operators	0.213	0.271	0.299	0.261
	Modes	-0.335	0.097*	-0.418	0.107
	Percent Local Routes (Region)	0.185	0.321	0.286	0.282
	Percent Local Routes (Main)	0.177	0.343	0.254	0.343
	Percent Bus Routes in CBD (Region)	0.025	0.892	-0.034	0.901
	Percent Bus Routes in CBD (Main)	-0.068	0.718	-0.096	0.724
	Hubs (Region)	0.164	0.421	0.2	0.457
	Hubs (Main)	0.241	0.223	0.323	0.222
	Percent Trips by Bus	0.143	0.443	0.197	0.465
	Unlimited Passes	0.026	0.903	0.07	0.82
	Rail with Parking	-0.144	0.475	-0.222	0.445
	Bus at Rail Stations	0.079	0.7	0.022	0.94
	Park and Ride with Local Bus	0.528	0.01**	0.667	0.009**

****Significant at 95 percent confidence level**

***Significant at 90 percent confidence level**

Table 5.2 Non-Work Categorical Variable Mann-Whitney Test

	Two Category Variables					
Type	Variable	Category / Rank Mean		Ua	Z	P
Regional Factors	State Funding	No	Yes	29.5	0	0.5
		8.6	8.5			
	Race of Central City	POC	White	23.5	0.65	0.2578
		9.6	7.9			
	Presence of Rail	No	Yes	18.5	0.96	0.1685
		10.3	7.7			
	Top 25 TTI Congested	No	Yes	7	2.54	0.0055**
		12	5.8			
Operations	Fare Structure	Flat	Not Flat	10.5	2.17	0.015**
		10.8	5.5			
	Bus Service 1996-2006	Decreasing	Increasing	29	*Sample Size Too Small*	
		7.3	8.9			
	Three Category Variables					
	Variable	Category / Rank Mean			H	P
Regional Factors	Economic Conditions	Under 10%	10-20%	Over 20%	5.18	0.075*
		10.8	5.4	10.9		
	Metro Population	500,000-1 million	1-3 million	Over 3 million	1.91	0.3848
		7.3	10.1	6.6		
	CAA Status	Attainment	Only 1	2 or more	0.38	0.826
		8.3	7.7	9.3		
	Region of Country	East	Middle	West	1.94	.379
		7.1	8	10.9		
Operations	Transfer Policy	Free	Small Fee	No Transfer	2.22	0.32960
		8.6	5.9	10.9		

**Significant at 95 percent confidence level

*Significant at 90 percent confidence level

Two regional factors are significant in the categorical variables test. There is a significant difference between the non-work trip usage in regions that are in the top 25 of the TTI congestion index and regions that are not in the top 25. The non-work trip usage is significantly higher in regions not in the top 25. The non-work usage is higher in regions with the lowest or highest job growth compared to regions with intermediate job growth. Finally, non-work usage is higher in regions with flat transit fares compared to regions with distance or time of day variations.

The significant variables should be considered alone; it turns out that many are correlated to each other. The significant correlations between variables that are significantly correlated to non-work trips are shown in Table 5.3. Each pair of significant variables is only listed once.

All of the significant variables, except daily parking rates, are correlated to transit spending per capita. More than half are correlated to the median income of transit riders. The importance of these two factors will be examined in more detail at the end of this chapter.

Some of the correlations make perfect sense. Land area covered is positively correlated to average trip length; the smaller the transit accessible area the shorter the transit trips. Since correlations do not show causation, in other cases the connection is less clear. It can be debated whether the low-income ridership causes less accessible land, fewer modes (bus only), and higher local bus access to park and ride lots or if these design factors influence ridership. However, taken together these correlations paint a picture of the high non-work usage regions.

Table 5.3 Correlations Between Significant Variables

First Significant Variable	Second Significant Variable	Kendall's Tau	Sig.	Spearman's Rho	Sig.
Transit Spending per Capita	Average Length of Trips	0.309	0.084*	0.38	0.133
	Land Area Cover	0.483	0.007**	0.647	0.005**
	Median Income	0.494	0.008**	0.639	0.008**
	Percent of Region's Income	0.3	0.105	0.45	0.08*
	Peak Bus Headway	-0.364	0.043**	-0.455	0.067*
	Modes	0.34	0.081*	0.446	0.072*
	Park and Ride with Local Bus	-0.522	0.007**	-0.695	0.004**
Median Income	Land Area Cover	0.321	0.086*	0.5	0.049**
	Modes	0.416	0.039**	0.552	0.027**
	Percent of Region's Income	0.778	0.00**	0.909	0.00**
	Park and Ride with Local Bus	-0.402	0.048**	-0.573	0.032**
Land Area Cover	Average Length of Trip	0.394	0.029**	0.516	0.034**
	Park and Ride with Local Bus	-0.363	0.065*	-0.417	0.122
Modes	Percent of Region's Income	0.423	0.035**	0.559	0.024**
	Park and Ride with Local Bus	-0.354	0.097*	-0.427	0.113

**Significant at 95 percent confidence level

*Significant at 90 percent confidence level

High non-work trip usage occurs in regions with primarily infrequent bus only service (which tend to have flat fare pricing), a high low income ridership, and limited congestion and transit accessibility. In other words, high levels of non-work trips are made by transit dependent riders on buses in regions where transit is not widespread, frequent, or well funded.

5.2 Non-Motorized Access

The same correlation tests were run for the non-motorized rates in each region. Unfortunately the smaller sample size for non-motorized access may have limited the findings. In addition, there is less variation in non-motorized access across the regions compared to non-work trip usage. The results of the non-parametric correlations are shown in Table 5.4. The categorical variable test results are shown in Table 5.5.

Of all the variables, only median income and percent of regions median income are significant and negative at the 90 percent level for one test each. Again this indicates that non-motorized access is higher in regions with lower-income riders.

These results are from an analysis of transit systems in totality, not broken down by transit mode. The data that are available by mode confirms what one would expect; in general non-work usage and non-motorized access are higher on local bus than rail. Commuter rail service has the lowest rates for both variables. However, for light rail systems there is a variation of 25 percentage points for non-motorized access and 24 percentage points for non-work usage across the sample. The next chapter takes a qualitative approach to explaining that variation. But first, a closer examination is made of the income of transit riders, transit spending per capita, and transit trips per capita.

Table 5.4 Non-Motorized Access Correlations

Type	(N=13) Variable	Kendall's Tau	Sig.	Spearman's Rho	Sig.
Transportation Usage	Unlinked Transit Trips per Capita	0.154	0.464	0.214	0.482
	Total Transit Budget per Capita	-0.103	0.635	-0.11	0.721
	VMT per Capita	-0.282	0.18	-0.352	0.239
	Daily Parking Rate	0.076	0.731	0.091	0.778
	Monthly Parking Rate	0.039	0.855	0.047	0.879
Transit Efficiency	Cost per Passenger Trip	-0.026	0.903	-0.099	0.748
	Passenger per Vehicle Hour	-0.051	0.807	-0.082	0.789
	Average Length of Trip	0.051	0.807	0.038	0.901
Land Use	Land Area Cover	-0.116	0.582	-0.223	0.464
	Population Cover	0.333	0.113	0.456	0.117
	Job Cover	0.182	0.391	0.27	0.372
	Accessible Population Density	0.103	0.625	0.225	0.459
	Accessible Job Density	0.051	0.807	0.088	0.775
Rider Demographics	Percent White	0.107	0.63	0.179	0.579
	Median Income	-0.348	0.099*	-0.459	0.114
	Percent of Region's Median Income	-0.333	0.113	-0.495	0.086*
Operations and Design	Peak Bus Headway	0.092	0.667	0.144	0.64
	Operators	-0.04	0.852	-0.045	0.885
	Modes	-0.103	0.648	-0.163	0.595
	Percent Local Routes (Region)	-0.142	0.501	-0.253	0.404
	Percent Local Routes (Main)	-0.245	0.246	-0.344	0.25
	Percent Bus Routes in CBD (Region)	0.026	0.903	0.066	0.831
	Percent Bus Routes in CBD (Main)	0.039	0.855	0.052	0.865
	Hubs (Region)	0.195	0.407	0.235	0.439
	Hubs (Main)	-0.221	0.329	-0.271	0.371
	Percent Trips by Bus	0.128	0.542	0.22	0.471
	Unlimited Passes	0.091	0.697	0.127	0.709
	Rail with Parking	-0.015	0.945	-0.032	0.923
	Bus at Rail Stations	-0.313	0.166	-0.402	0.195
	Park and Ride with Local Bus	0.33	0.16	0.392	0.233

**Significant at 95 percent confidence level

*Significant at 90 percent confidence level

Table 5.5 Non-Motorized Access Categorical Variable Mann-Whitney Test

	Two Category Variables					
	Variable	Category / Rank Mean		Ua	z	P
Regional Factors	State Funding	No	Yes	20	0.07	0.4721
		7	7			
	Race of Central City	POC	White	28	-1.1	0.1357
		5.4	8			
	Presence of Rail	No	Yes	15	*Sample Size Too Small*	
		7	7			
	Top 25 TTI Congested	No	Yes	18	0.22	0.4129
		7.4	6.8			
	Metro Population	1-3 million	Over 3 million	13	0.65	0.2578
		7.1	5.6			
Operations	Bus Service 1996-2006	Decreasing	Increasing	*Sample Size Too Small*		
		5.3	7.8			
	Fare Structure	Flat	Not Flat	26	-0.64	0.2611
		6.2	7.7			
	Three Category Variables					
	Variable	Category / Rank Mean			H	P
Regional Factors	Economic Conditions	Under 10%	10-20%	Over 20%	1.03	0.5975
		5	7.6	7.6		
	CCA Status	Attainment	Only 1	2 or more	0.38	*Sample Size Too Small*
		5.5	7	7.4		
	Region of Country	East	Middle	West	1.45	0.4843
		5.6	7	8.8		
Operations	Transfer Policy	Free	Small Fee	No Transfer	2.5	*Sample Size Too Small*
		5.3	7.8	10		

5.3 Transit Spending Per Capita

Not only is transit spending per capita correlated to the other significant variables for non-work trips, but it is a good indicator of how much a region prioritizes transit. For a better understanding of this variable, correlation analysis with all of the other explanatory variables was conducted. The results are shown in Table 5.6.

As one would expect transit spending per capita is positively correlated to transit trips per capita. It is not, however, significantly correlated to a reduction in VMT per capita. In addition, it is not significantly correlated to either measure of transit efficiency: cost per passenger trip or passengers per vehicle hour. It does lead to increased peak local bus headway, but those local buses are less likely to serve park and ride lots.

High transit spending per capita is correlated at the 90 percent confidence level to longer transit trips. Similarly the more the spending the more land area of the region that is accessible. But that is the only land use variable that is significant. Higher spending does not correlate to higher population or job access by transit.

The racial composition of transit riders is not significant, but both income variables are. Regions that spend more per capita on transit have transit riders with a higher median income. Which comes first, the higher income riders or the higher transit spending is not given by a correlation. It is possible they have synergetic effects.

Table 5.6 Total Transit Spending Per Capita Correlations

Type	(N=17) Variable	Kendall's Tau	Sig.	Spearman's Rho	Sig.
Transportation Usage	Unlinked Transit Trips per Capita	0.544	0.002**	0.696	0.002**
	VMT per Capita	-0.103	0.564	-0.176	0.498
	Daily Parking Rate	0.245	0.19	0.33	0.211
	Monthly Parking Rate	0.17	0.343	0.254	0.326
Transit Efficiency	Cost per Passenger Trip	-0.088	0.621	-0.169	0.516
	Passenger per Vehicle Hour	0.029	0.869	0.037	0.889
	Average Length of Trip	0.309	0.084*	0.38	0.133
Land Use	Land Area Cover	0.483	0.007**	0.647	0.005**
	Population Cover	0.178	0.322	0.286	0.266
	Job Cover	0.239	0.186	0.372	0.141
	Accessible Population Density	0.015	0.934	0.029	0.911
	Accessible Job Density	0.118	0.51	0.14	0.593
Rider Demographics	Percent White	0.134	0.488	0.236	0.397
	Median Income	0.494	0.008**	0.639	0.008**
	Percent of Region's Median Income	0.3	0.105	0.45	0.08*
Operations and Design	Peak Bus Headway	-0.364	0.043**	-0.455	0.067*
	Operators	-0.195	0.295	-0.283	0.271
	Modes	0.34	0.081*	0.446	0.072*
	Percent Local Routes (Region)	-0.111	0.536	-0.155	0.554
	Percent Local Routes (Main)	0.015	0.934	0	1
	Percent Bus Routes in CBD (Region)	-0.074	0.68	-0.113	0.666
	Percent Bus Routes in CBD (Main)	-0.126	0.483	-0.188	0.47
	Hubs (Region)	-0.101	0.608	-0.153	0.558
	Hubs (Main)	-0.146	0.442	-0.171	0.513
	Percent Trips by Bus	-0.296	0.099*	-0.4	0.112
	Unlimited Passes	-0.221	0.273	-0.26	0.37
	Rail with Parking	0.317	0.102	0.438	0.102
	Bus at Rail Stations	-0.118	0.548	-0.108	0.701
	Park and Ride with Local Bus	-0.522	0.007**	-0.695	0.004**

**Significant at 95 percent confidence level

*Significant at 90 percent confidence level

5.4 Income Impacts

Since the median income of transit riders is correlated to both independent variables, correlations were calculated between median income and all of the remaining variables. The results are shown in Table 5.7. The only additional significant variables are monthly parking rates and unlinked transit trips per capita. Both are positive, which indicates that the median income of transit riders is higher in regions with higher monthly parking rates in the CBD and with higher transit usage. It is worth noting that while the accessible land area is significantly higher with higher income riders, the headway of local bus service is not significant.

In order to get a better idea of how income impacts non-work trips and non-motorized access, an examination by income group was done for cities with available data. Using the raw data from five cities, cross-tabs of income group by access mode and trip purpose were calculated. Each city used different income brackets for its survey so the x-axis for each figure is a compilation of all of the income brackets.

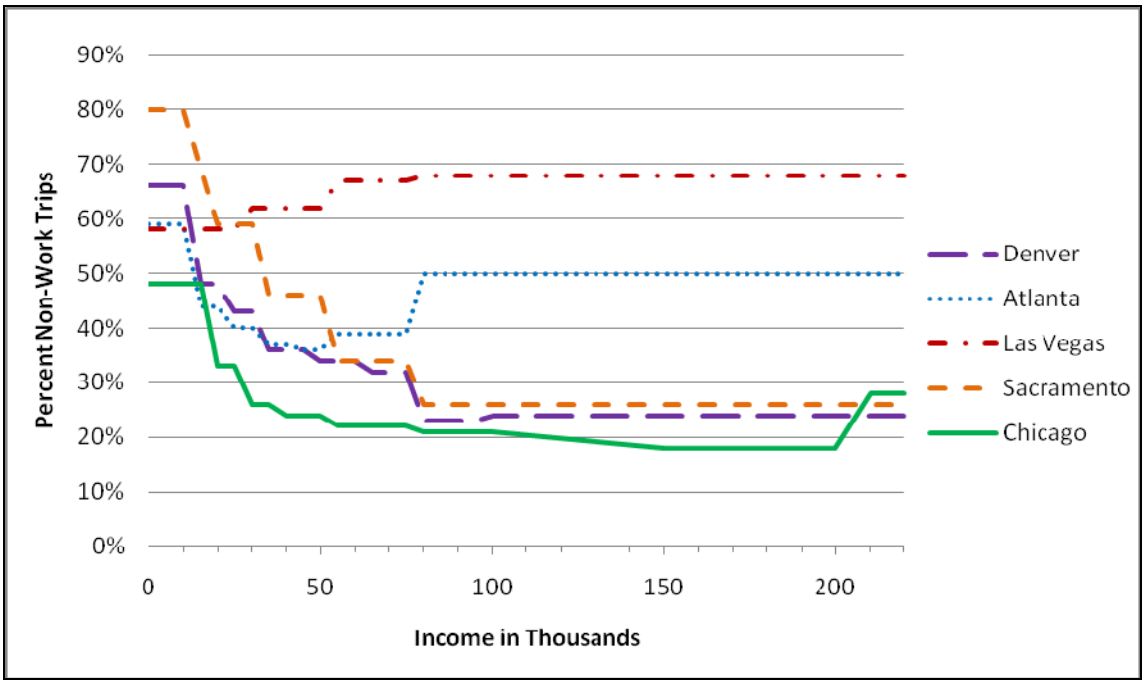
Non-work usage, shown in Figure 5.1, is the highest for the lowest income, drops for middle income riders and rises slightly for the highest income. Non-motorized access, shown in Figure 5.2, decreases as income increases. The exception in both cases is Las Vegas, where non-work and non-motorized access increase with income, likely due to high tourist ridership. Atlanta also stands out for having higher non-work usage by high income riders, but very low non-motorized access by high income riders. The Chicago data is only from the Chicago Transit Authority and so the higher non-motorized access is expected due to the higher density within the city.

Table 5.7 Median Income of Transit Riders Correlations

Type	(N=16) Variable	Kendall's Tau	Sig.	Spearman's Rho	Sig.
Transportation Usage	Unlinked Transit Trips per Capita	0.31	0.095*	0.437	0.09*
	VMT per Capita	-0.042	0.822	-0.047	0.863
	Transit Spending per Capita	0.494	0.008**	0.639	0.008**
	Daily Parking Rate	0.184	0.344	0.269	0.332
	Monthly Parking Rate	0.37	0.047**	0.459	0.073*
Transit Efficiency	Cost per Passenger Trip	-0.042	0.822	-0.018	0.948
	Passenger per Vehicle Hour	0.042	0.822	0.031	0.91
	Average Length of Trip	0.176	0.344	0.277	0.3
Land Use	Land Area Cover	0.321	0.086*	0.5	0.049**
	Population Cover	0.134	0.47	0.177	0.513
	Job Cover	0.23	0.222	0.356	0.175
	Accessible Population Density	-0.042	0.822	-0.153	0.571
	Accessible Job Density	-0.042	0.822	-0.146	0.59
Riders	Percent White	0.133	0.511	0.29	0.314
Operations and Design	Peak Bus Headway	-0.153	0.416	-0.177	0.512
	Operators	-0.132	0.493	-0.211	0.432
	Modes	0.416	0.039**	0.552	0.027**
	Percent Local Routes (Region)	-0.034	0.857	-0.024	0.931
	Percent Local Routes (Main)	0.034	0.857	0.027	0.922
	Percent Bus Routes in CBD (Region)	0.034	0.857	0.069	0.799
	Percent Bus Routes in CBD (Main)	0.025	0.892	0.053	0.845
	Hubs (Region)	-0.075	0.714	-0.073	0.789
	Hubs (Main)	0.139	0.482	0.184	0.494
	Percent Trips by Bus	-0.16	0.391	-0.206	0.443
	Unlimited Passes	-0.103	0.625	-0.11	0.721
	Rail with Parking	-0.056	0.784	-0.095	0.747
	Bus at Rail Stations	-0.173	0.404	-0.238	0.412
	Park and Ride with Local Bus	-0.402	0.048**	-0.573	0.032**

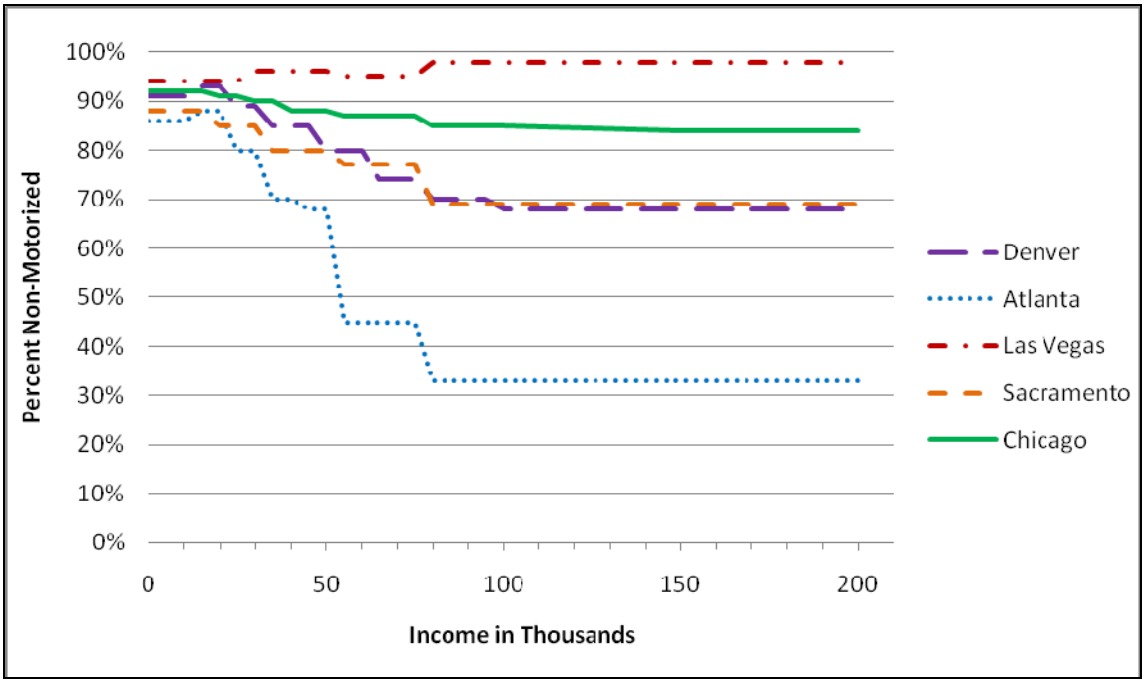
**Significant at 95 percent confidence level

*Significant at 90 percent confidence level



Source: On-board survey data

Figure 5.1 Non-Work Usage by Income Group

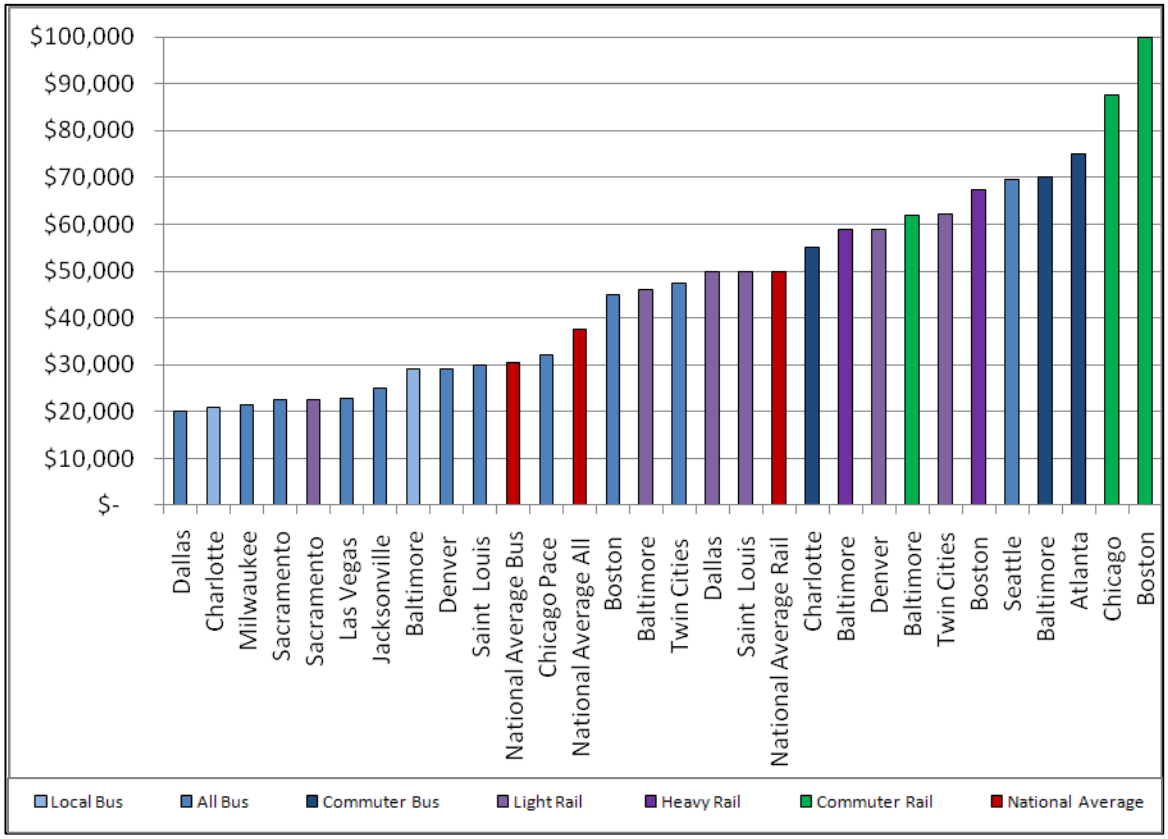


Source: On-board survey data

Figure 5.2 Non-Motorized Access by Income Group

There are income differences between transit modes as well. The generally accepted knowledge that rail riders have higher income than bus riders holds true in this sample. However, it is worth distinguishing between types of rail and bus. Figure 5.3 shows the median income by transit type for each region where data is available by mode. In some regions the local and commuter bus data is combined and in some regions local bus is separate from commuter bus.

Commuter bus and commuter rail have the highest median incomes. Light and heavy rail occupy the center of the income levels. Bus, local and mixed, is clustered at the lowest income levels. The two notable exceptions are light rail in Sacramento, which is near the bottom, and bus in Seattle, which is near the top.



Source: On-board survey data

Figure 5.3 Transit Mode By Income

5.5 Transit Trips Per Capita

Since transit trips per capita is one of the indicators of meeting environmental goals, a separate correlation analysis was done for this variable. The results are in Table 5.8. More transit trips per capita occur in regions with high transit spending per capita, lower VMT per capita, higher population density in the transit accessible area, and where a larger percentage of the population is accessible by transit. They have more frequent peak local bus service, are more likely to have multiple modes of transit, have a smaller percent of their trips on bus, fewer transit routes in the CDB, and more rail stations with parking. The median income of riders is barely significant at the 90 percent level on both tests.

Table 5.8 Per Capita Transit Trips Correlations

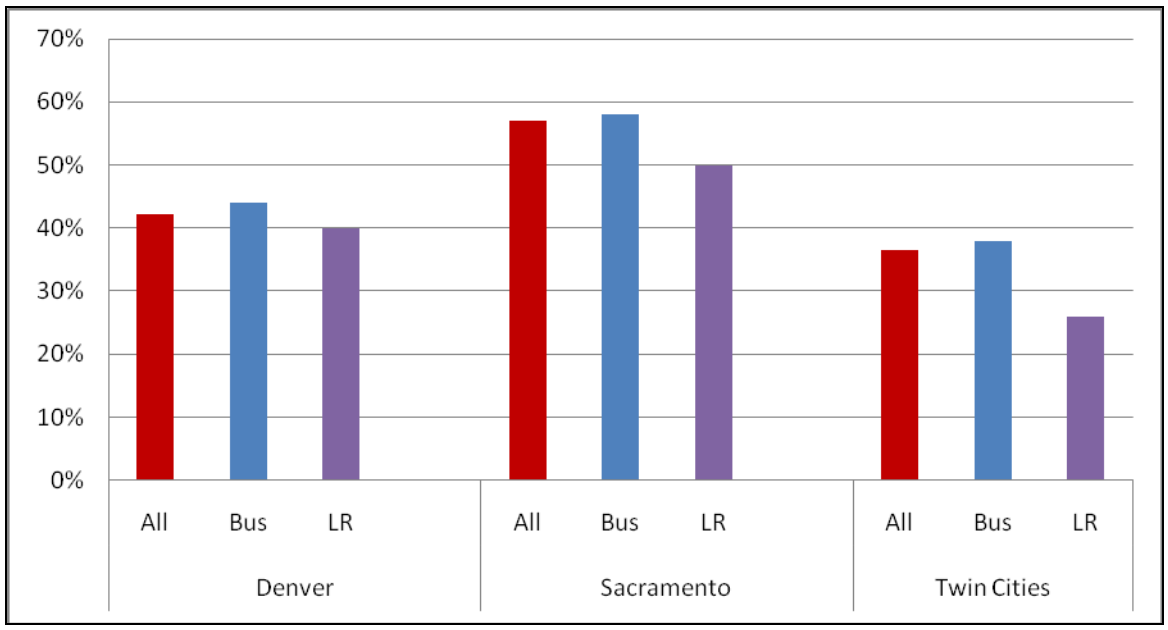
Type	(N=17) Variable	Kendall's Tau	Sig.	Spearman's Rho	Sig.
Transportation Usage	Transit Spending Per Capita	0.54	0.002**	0.70	0.002**
	VMT per Capita	-0.471	0.008**	-0.64	0.006**
	Daily Parking Rate	0.228	0.222	0.342	0.195
	Monthly Parking Rate	0.273	0.127	0.38	0.132
Transit Efficiency	Cost per Passenger Trip	-0.40	0.026**	-0.51	0.036**
	Passenger per Vehicle Hour	0.25	0.161	0.336	0.188
	Average Length of Trip	0.147	0.41	0.228	0.379
Land Use	Land Area Cover	0.23	0.2	0.34	0.182
	Population Cover	0.30	0.099*	0.44	0.081*
	Job Cover	0.25	0.16	0.38	0.13
	Accessible Population Density	0.35	0.048**	0.45	0.069*
	Accessible Job Density	0.28	0.12	0.36	0.16
Rider Demographics	Percent White	0.096	0.62	0.136	0.629
	Median Income	0.31	0.095*	0.44	0.09*
	Percent of Region's Median Income	0.18	0.32	0.28	0.30
Operations and Design	Peak Bus Headway	-0.35	0.052*	-0.48	0.05**
	Operators	-0.008	0.967	-0.015	0.955
	Modes	0.43	0.029**	0.51	0.036**
	Percent Local Routes (Region)	0.022	0.902	0.04	0.877
	Percent Local Routes (Main)	0.044	0.804	0.09	0.732
	Percent Routes in CBD (Region)	-0.37	0.039**	-0.47	0.06*
	Percent Routes in CBD (Main)	-0.29	0.11	-0.39	0.12
	Hubs (Region)	-0.028	0.889	-0.058	0.825
	Hubs (Main)	0.032	0.864	0.006	0.981
	Percent Trips by Bus	-0.30	0.099*	-0.39	0.12
	Unlimited Passes	-0.133	0.511	-0.163	0.578
	Rail with Parking	0.38	0.053*	0.47	0.077*
	Bus at Rail Stations	-0.217	0.271	-0.314	0.255
	Park and Ride with Local Bus	-0.193	0.321	-0.286	0.301

**Significant at 95 percent confidence level

*Significant at 90 percent confidence level

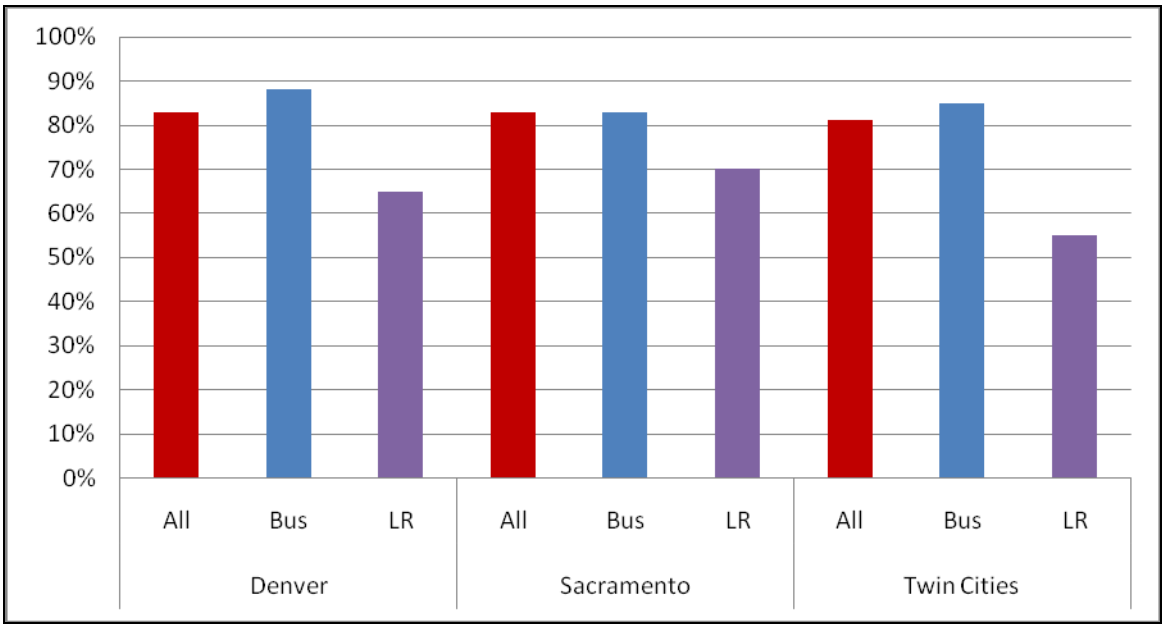
CHAPTER 6
CASE STUDIES

Since statistical correlations cannot give the full picture of the factors impacting non-work usage and non-motorized access, a closer analysis was done for three regions. Denver, Colorado, Minneapolis/St. Paul (Twin Cities), Minnesota, and Sacramento, California were chosen due to similar regional characteristics, but different non-work and non-motorized access levels. The non-work trip usage by transit mode is shown in Figure 6.1 and non-motorized access by transit mode in Figure 6.2. The non-motorized access overall and by bus is similar, but the non-motorized access to light rail has a 15 percentage point range.



Source: (Sacramento Regional Transit District 2006; Regional Transportation District 2008; Periscope 2008)

Figure 6.1 Non-Work Trips by Mode



Source: (Sacramento Regional Transit District 2006; Regional Transportation District 2008; Periscope 2008)

Figure 6.2 Non-Motorized Access by Mode

6.1 Regional Comparison

The Denver, Twin Cities, and Sacramento regions share a few key characteristics. They have a similar population; in 2007 the MPO population estimates were 2.7 million in Denver, 2.8 million in Twin Cities, and 2.1 million in Sacramento. All three are their state's capital. All three regions have a light rail and bus transit system and extensive bicycle infrastructure. Each region has a per capita VMT in the range of 9500-10,000 miles per year and a non-motorized mode share for all trips between seven and nine percent.

The similar population figures do not translate into similar job numbers. In 2000, the Twin Cities MPO region had 1.5 million jobs compared to 1.3 million in Denver and only 830,000 in Sacramento. Within the total transit accessible area of the MPO, Denver has the lowest population and job density. Sacramento has the highest population

density with 3614 people per square mile compared to Denver's 2624. The Twin Cities had the highest job density with 2015 jobs per square mile compared to Denver's 1393.

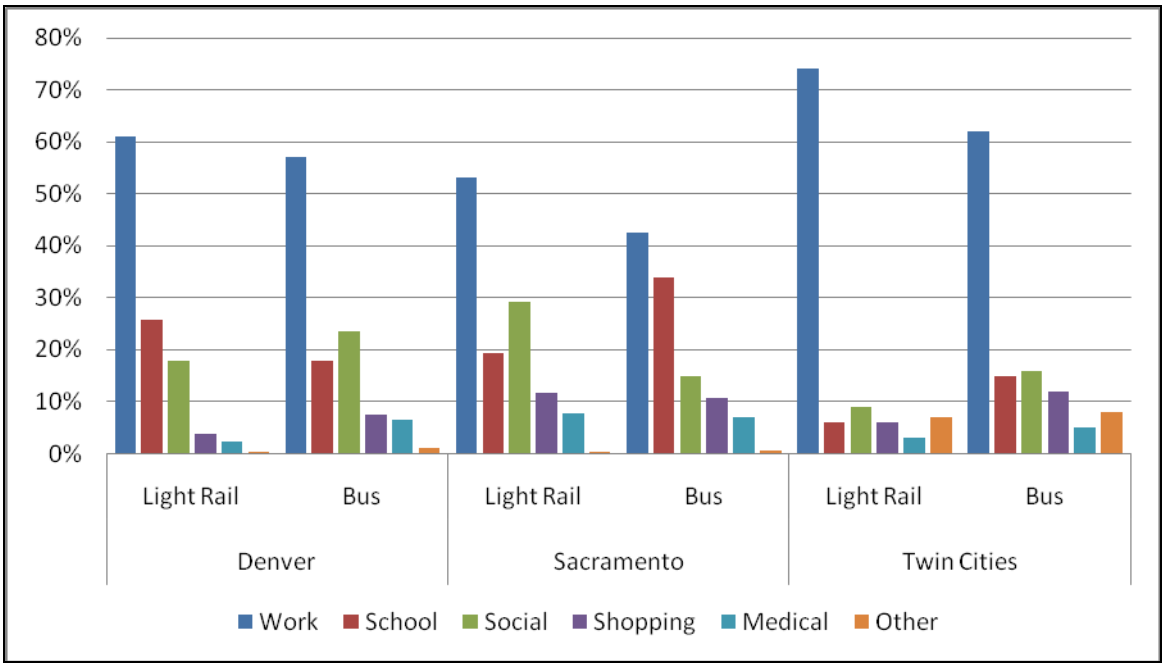
Despite its low density, a larger percent of the population and jobs in Denver are accessible by transit. Close to 90 percent of Denver's population and 88 percent of the jobs are within a half mile of transit service. In Sacramento, only 70 percent of the jobs and population is accessible to transit. In the Twin Cities 74 percent of the population and 82 percent of the jobs are within a half mile of transit.

One of the key differences between the regions is the age and extent of their light rail system. Sacramento opened its first light rail line in 1987 and has 37 miles and 47 stations. Denver opened its first light rail line in 1994 and has 35 miles with 37 stations. The Twin Cities started service on its first line in 2004; it has 12 miles with 17 stations. (The Twin Cities have a commuter rail line that opened in November 2009; no ridership data was available for this study.) Despite having the largest light rail network, Sacramento has the lowest annual transit usage per capita. In 2008, the Sacramento region had 18 fixed route trips per capita compared to 36 in Denver and 32 in the Twin Cities.

Weather is another major difference among the regions. Denver has an average temperature of 30˚ (F) in January and 74˚ in July. It gets on average 60 inches of snowfall and on average 89 days with precipitation. The Twin Cities has a January average of 12˚ and 74˚ in July. It gets 50 inches of snowfall and an average of 116 days with precipitation. Sacramento has an average January temperature of 45˚ and 76˚ in July. It gets no average snowfall and an average of 58 days with precipitation. It is worth pointing out that none of the on-board surveys were conducted in the winter.

6.2 Trip Purpose and Major Destinations

In order to explain the levels of non-work trips, it is useful to know the trip purpose. Figure 6.3 compares the three systems across six categories of trip purpose. The percentage of work trips in the Twin Cities is higher on both bus and light rail than in Sacramento and Denver; in fact, work trips by bus in the Twin Cities are higher than work trips on light rail in the other cities. The lower work trips are replaced by higher school and social trips in Denver and Sacramento.



Source: (Sacramento Regional Transit District 2006; Periscope 2008; Regional Transportation District 2008)

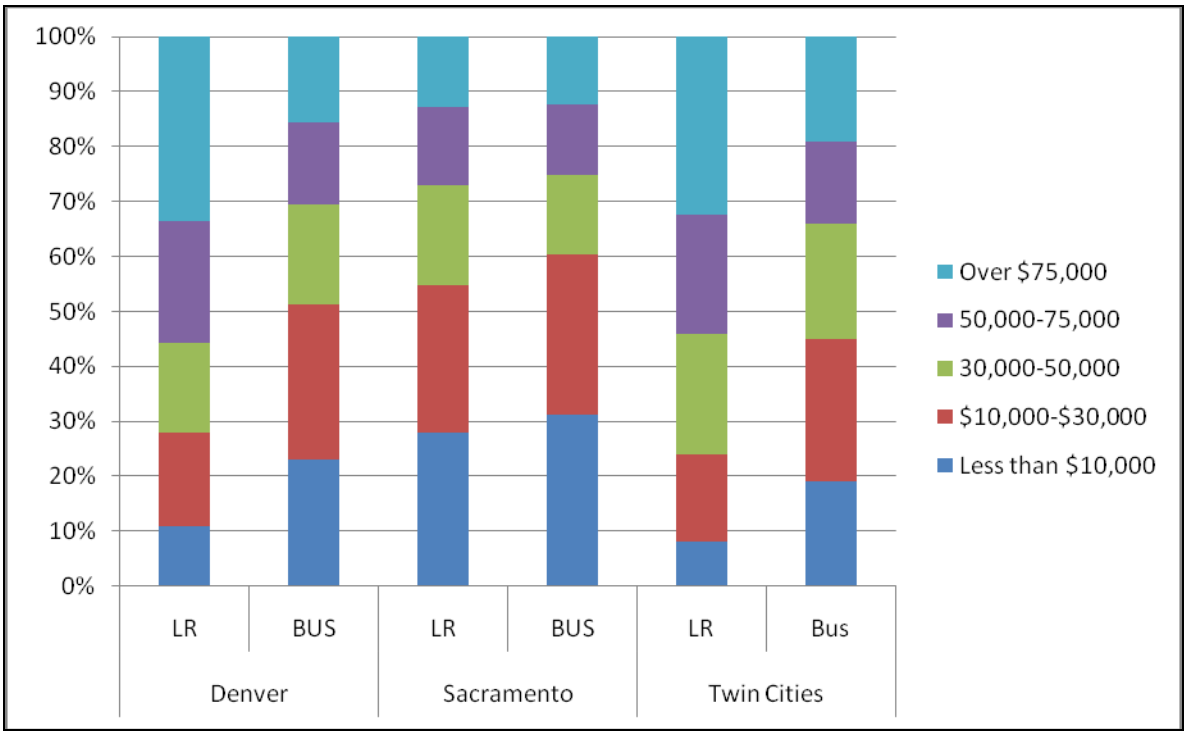
Figure 6.3 Trip Purpose by Mode in each Region

The light rail lines in Denver and Sacramento each serve two large colleges/universities. The Hiawatha line in the Twin Cities serves the far western edge of the University of Minnesota. While all three cities have buses that serve K-12 schools, Sacramento and Denver have bus routes exclusively designed for middle and high schools. All three regions have bus service designed for large universities. In the Twin Cities, the University of Minnesota has its own campus shuttle system, whose trips are not included in the results of the region's on-board survey. In Denver, the Regional Transit District (RTD) operates the bus service around the University of Colorado, Boulder. In Sacramento, the bus service for the University of California, Davis is provided by Unitrans; the trips on Unitrans are included in the on-board survey data.

Sacramento's light rail also serves the convention center and the state capitol. The Denver lines serve the convention center and two major sports arenas. The Twin Cities' line serves the airport, the Mall of America, and two major sports arenas. Denver and Sacramento have bus service to their major airports.

6.3 Demographics of Riders

As demonstrated by the correlations in Chapter 5, low-income transit riders are more likely to take non-work trips and access transit by non-motorized means. Figure 6.4 shows the transit ridership by a common income bracket for bus and light rail in each region.



Source: (Sacramento Regional Transit District 2006; Regional Transportation District 2008; Periscope 2008)

Figure 6.4 Income of Riders by Region and Transit Mode

In both Denver and the Twin Cities the assumption that light rail attracts higher income riders holds true. By contrast the highest light rail ridership in Sacramento is the lowest income bracket, under $10,000. The median income of bus riders and light rail riders in Sacramento are both under $30,000. The median bus rider makes 30 percent of the region's median income and the median light rail rider makes 36 percent of region's median income. In Denver and the Twin Cities, the median income of light rail riders is much higher. In Denver, the median income of bus riders is 40 percent of the region's median income compared to 74 percent for light rail riders. In the Twin Cities, the median income of bus riders is 59 percent of the region's median income and light rail riders have a median income of 77 percent of the regional value.

6.4 Pass and Fares

How transit agencies price and market their transit passes and how riders pay for their trips can potentially impact the types of trips that are made. The Twin Cities has a variable fare depending on peak or off-peak hours. A downtown fare zone in both Minneapolis and St. Paul has $0.50 fares at all times. The bus and light rail fare is the same and express bus fare is higher. Transfers are free but a surchange is added when transferring to a more expensive mode.

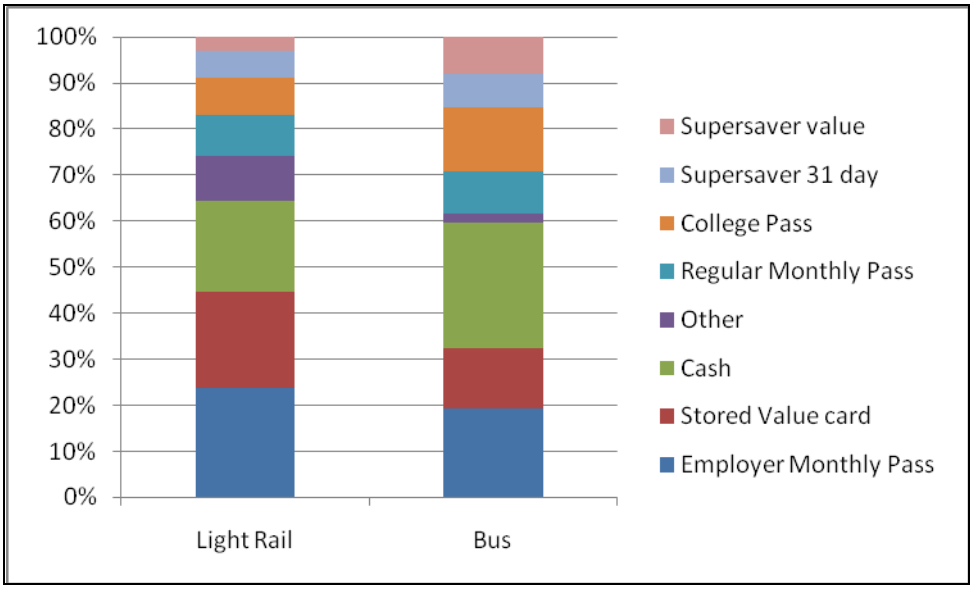
The fares in Denver vary by distance, not time of day. Regional and express buses have higher fares than local buses. Trips to the airport are the most expensive. The light rail uses a system of four zones to calculate fare. The transfer policy is the same as the Twin Cities.

The Sacramento Regional Transit District (SRT) has a flat fare for buses and light rail. The other 11 transit agencies in the region have their own pricing; transfer policies between agencies vary.

All three regions have special youth fares. Denver and Sacramento give half price up to age 18, while the Twin Cities give a discount for youth up to 12 during non-rush hours. All three regions have various student passes for colleges and university students. Sacramento has a program for community college students that actually makes it cheaper to enroll as a college student to get a transit pass than buy the regular transit pass. In 2008, these passes accounted for nine percent of light rail trips and seven percent of bus trips (Drake 2010).

All three regions sell transit passes through employers, especially to state employees. However, Metro in the Twin Cities has made a deliberate effort to sell passes through employers. They found it is easiest to access potential riders through employers, which allows people to take advantage of tax incentives (Filipi 2010). The monthly unlimited ride card available through participating employers is $76 compared to

$85 for a similar monthly pass for the general public. Half of all light rail and 37 percent of bus riders reported that their employer offers transit passes. Of those offering passes, 80 percent of light rail and 74 percent of bus riders report that the employer pays part of the cost. The pass usage for bus and light rail is shown in Figure 6.5. The employer monthly pass is the most used payment method on light rail.

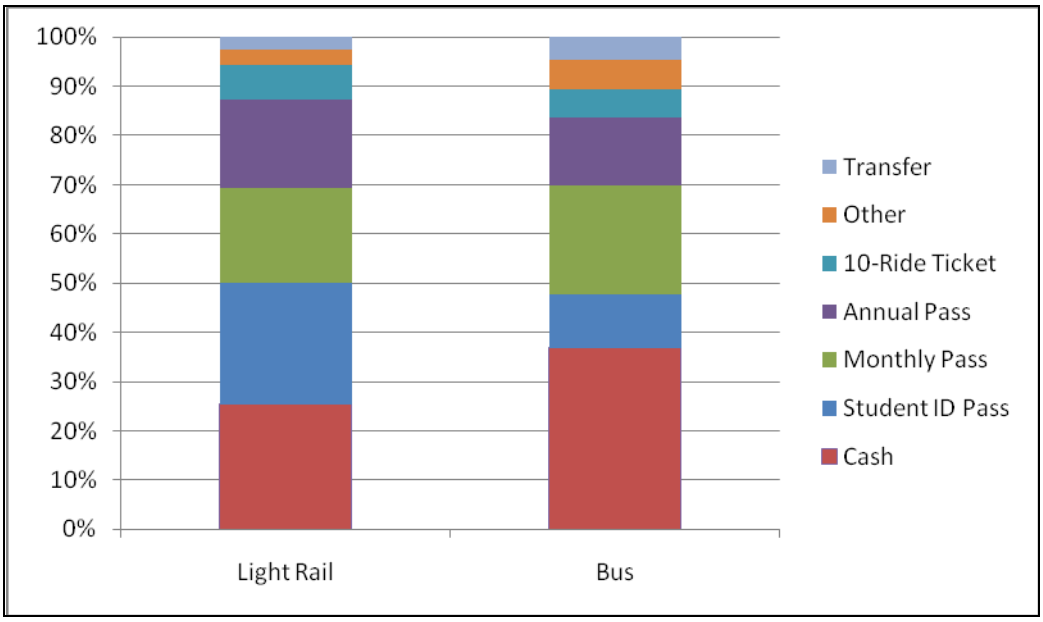


Source: (Periscope 2008)

Figure 6.5 Twin Cities Method of Fare Payment by Mode

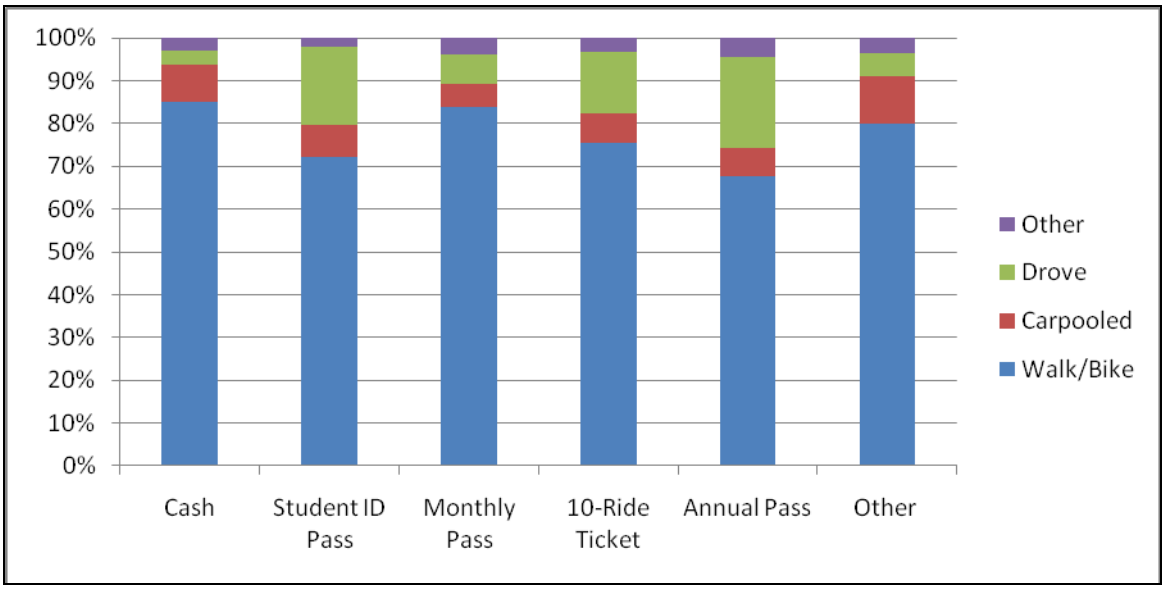
Denver also has a special pass program for employers called the eco pass. These passes are purchased on an annual basis so there is no price comparison to the monthly unlimited ride passes available to the public. A similar annual pass is also available for neighborhood organizations to purchase for households. The pass usage by mode is shown in Figure 6.6.

The raw data from Denver's on-board survey allows a comparison of trip type and access mode by fare payment method. Figure 6.7 shows the access mode by fare and Figure 6.7 shows the trip type by fare.



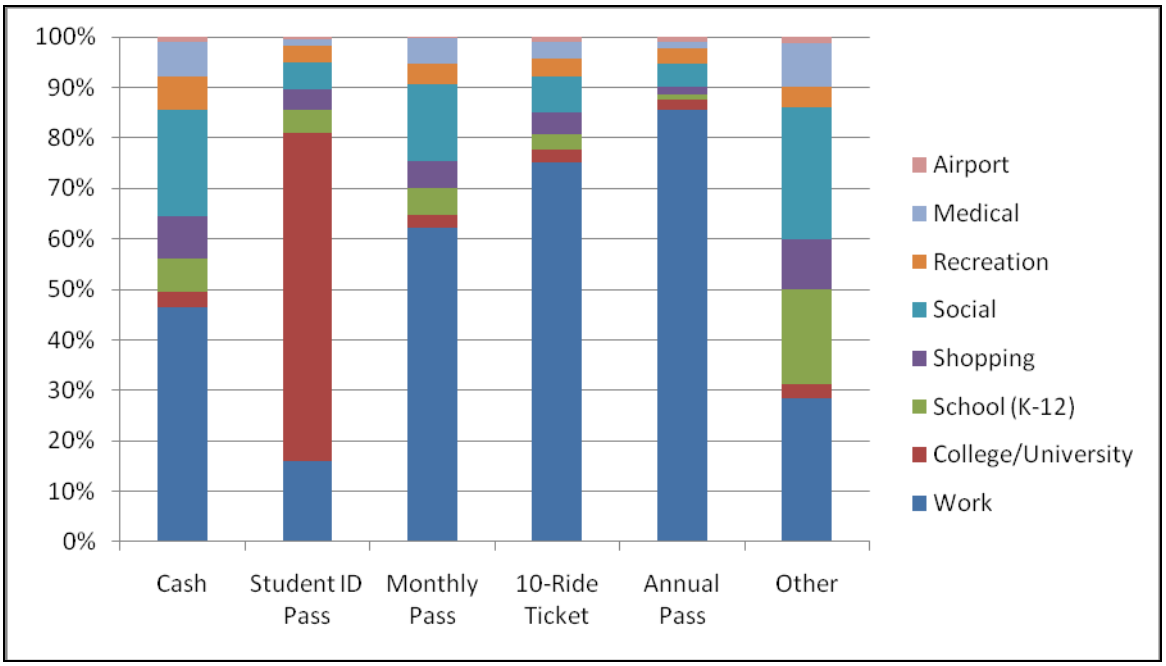
Source: (Regional Transportation District 2008)

Figure 6.6 Denver Method of Fare Payment by Mode



Source: (Regional Transportation District 2008)

Figure 6.7 Denver Access Mode to Transit by Fare Type



Source: (Regional Transportation District 2008)

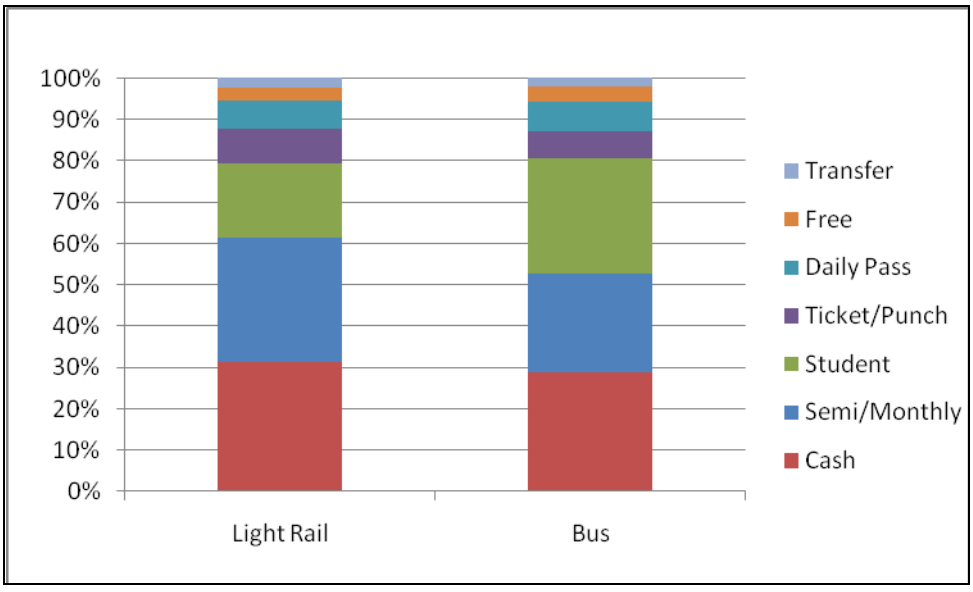
Figure 6.8 Denver Trip Type by Fare Type

Users of the pass obtained through an employer are the most likely to drive to transit followed by student pass holders. People who pay cash or use a regular monthly pass are most likely to walk or bike to transit. However, there is less than a 20 percentage point difference between the non-motorized access of cash payers and those using the annual employer pass. The differential for the trip types by payment method is far larger. Of the annual employer pass users, 86 percent are making work trips. This is compared to 62 percent of monthly pass users and 47 percent of riders paying cash. Clearly, student pass users are considerably more likely to be taking college or university trips.

SRT does not have a special employer pass program. It does have a program for passes for the Department of Human Assistance, which assists low-income residents. In 2008, these passes counted for seven percent of bus trips and six percent of light rail

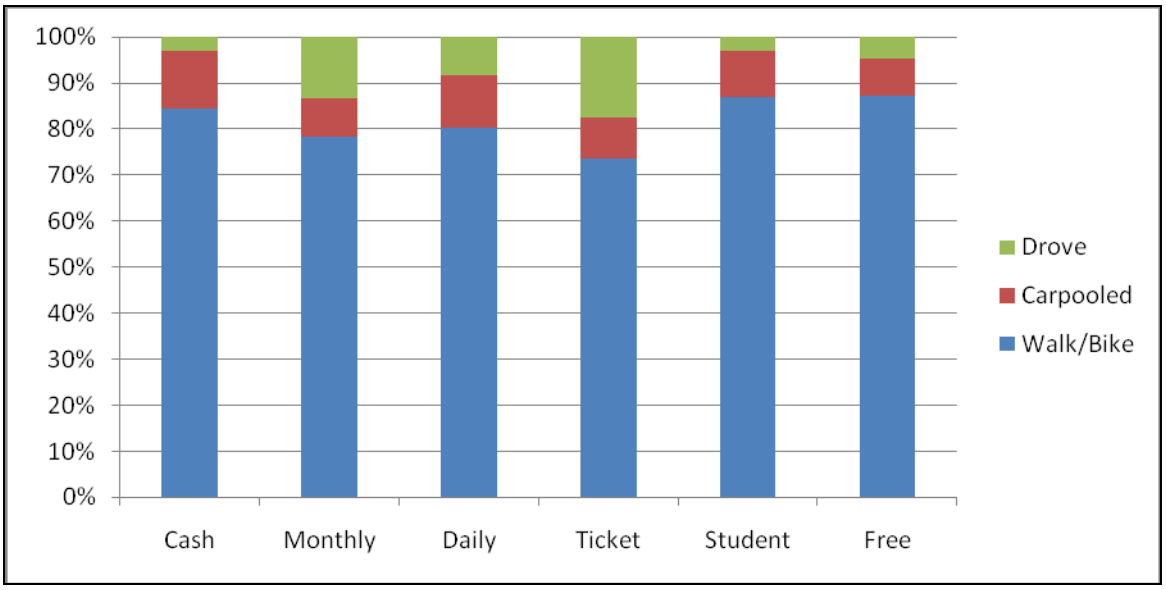
trips. In addition, paratransit riders were able to ride fixed route transit for free, which accounted for just over three percent of all trips (Drake 2010). The usage of pass types is shown in Figure 6.9.

The raw data was also available for Sacramento allowing a comparison of access mode and trip type by payment method. The access mode broken down by mode is shown Figure 6.10. The trip type by fare type is shown in Figure 6.11. There is less variation in access mode by payment in Sacramento compared to Denver. Those paying cash or riding for free are most likely to use a non-motorized mode. There is also less variation in the trip purpose in Sacramento than Denver. The highest work trip usage in Sacramento are monthly and ticket users at 60 percent compared to 86 percent work trips on the annual pass in Denver. In part this is due to fewer work trips overall in Sacramento.



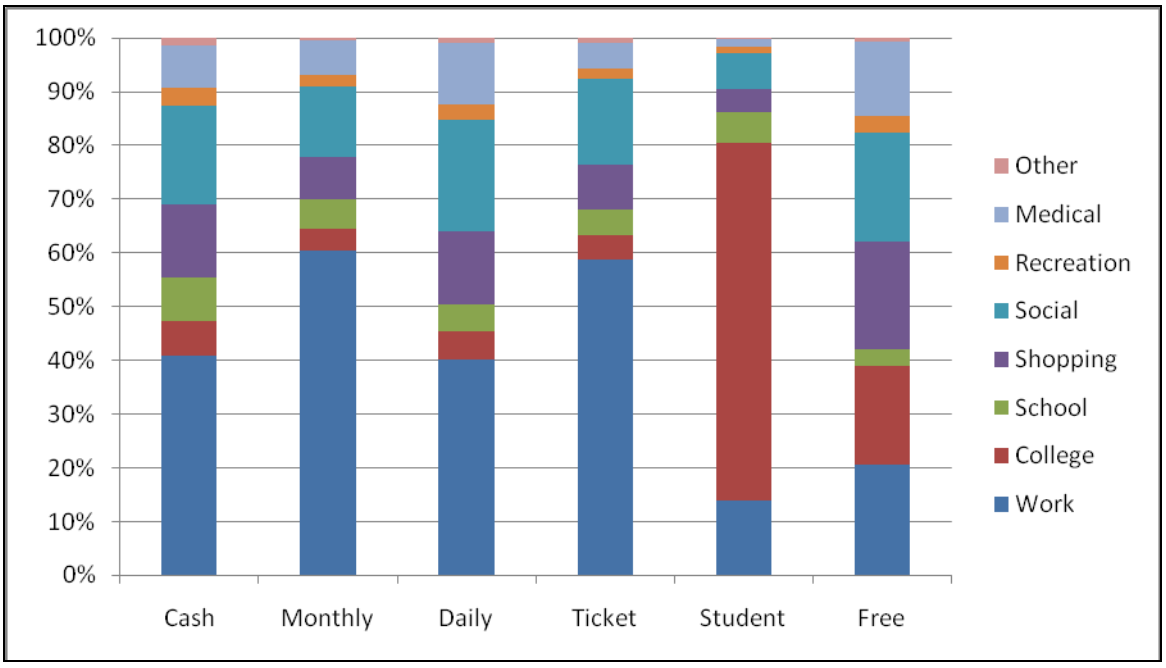
Source: (Sacramento Regional Transit District 2006)

Figure 6.9 Sacramento Method of Fare Payment by Mode



Source: (Sacramento Regional Transit District 2006)

Figure 6.10 Sacramento Access Mode to Transit by Fare Type



Source: (Sacramento Regional Transit District 2006)

Figure 6.11 Sacramento Trip Type by Fare Type

6.5 Network Design

All three regions use different network design models. The Twin Cities has the most traditional CBD model, only they have two CBDs rather than one. Within the urban core, they have a high frequency bus network where buses run every 15 minutes. The buses operate on arterials that feed into the two downtowns and the job rich suburb of Bloomington. A network of transit centers facilitates transfers between buses.

Denver has a regional model with bus service connecting Denver and multiple surrounding suburbs. Again a network of transit centers is used for transfers between regional and express service to local service. In areas with low demand Denver has a call and ride system for flexible curb to curb service.

Sacramento has multiple transit agencies. The SRT operates the light rail and bus service in Sacramento and 11 other transit agencies operate service in the surrounding towns and regional service to and from Sacramento.

As shown in Table 6.1 the Twin Cities has the highest percentage of its bus routes that enter the CBD (Minneapolis) and the highest percent of express routes. Almost 60 percent of the Twin Cities' bus routes are express routes designed to serve commuters during peak hours. In contrast only a third of the routes in Denver and Sacramento are express or peak only service. Denver has the most frequent local service while Sacramento has the least frequent.

Table 6.1 Network Design Descriptors

	Routes which are Local	Routes in CBD	Peak Local Bus Headway (min)
Denver	66%	41%	24
Sacramento	64%	28%	43.6
Twin Cities	39%	58%	30

Sources: (Sacramento Regional Transit 2008; Regional Transportation District 2008; Metropolitan Council 2008)

Denver operates a very successful free downtown shuttle on a street otherwise reserved for pedestrians. The shuttle gets regional and express buses off the downtown streets and concentrates them into northern and southern downtown bus terminals. Downtown Minneapolis takes a different approach with bus stops spread out in the downtown area. It employs real-time technology to inform passengers of the next bus arrival time at stops throughout downtown. A section of one downtown street functions as a transit and pedestrian only mall with free bus service being added. Downtown Sacramento lacks the amenities in Denver and Minneapolis. Regional and express bus stops are clustered around the state capitol.

All three regions have park and ride lots to facilitate drive to transit access and carpooling. In 2008, the Twin Cities had 111 park and ride locations with 26,000 spots. Denver had 24,500 spots in 76 locations. Sacramento has only 12,000 spots in 87 locations.

6.6 Light Rail Station Access and Land Use

The land use around and ease of access to the light rail stations can explain both type of trips served and mode of access. Figure 6.8 shows a map of each light rail system with each station coded by the surrounding land use and how many sides are accessible by pedestrians. Each system has a similar percentage of stations in their downtown area. But Denver and the Twin Cities have 21 percent and 22 percent of their stations, respectively, surrounded by suburban land uses, primarily office parks, park and ride lots, and shopping malls. Sacramento only has 10 percent of its stations in suburban land uses (Google Inc. 2010).

Only 56 percent of Denver's stations can be accessed on both sides by pedestrians compared to 80 percent of the stations in the Twin Cities and Sacramento (Google Inc. 2010). All three systems have bicycle racks and lockers at light rail stations.

A limited number of bicycles are allowed on trains in each city. Denver and the Twin Cities have low floor train cars with special bicycle hanging racks. Sacramento has old high floor train cars, which makes loading bicycles much harder.

Denver has vehicle parking at just over half of its stations for a total of 10,750 spots. This is an average of 290 spots per station in the system. Sacramento has parking at 38 percent of its stations with a total of 7379; this is an average of 157 spots over their 47 stations. The Twin Cities has parking at only three stations with a total of 2800 spots and an average of 165 spots per station. At the time of the on-board surveys, parking was free in all regions.

Denver uses modeling to determine the level of parking needed on a light rail corridor; however, when the Southwest line opened, there was not enough parking. The transit agency's policy was to build as much parking as needed to accommodate demand. Currently the transit agency staff and board members are re-evaluating whether they want to prioritize parking at transit stations. Sacramento and the Twin Cities have not had a problem with parking lots filling to capacity. In Sacramento the larger concern about parking is safety (Cryer 2010; Griesenbeck 2010; Filipi 2010).

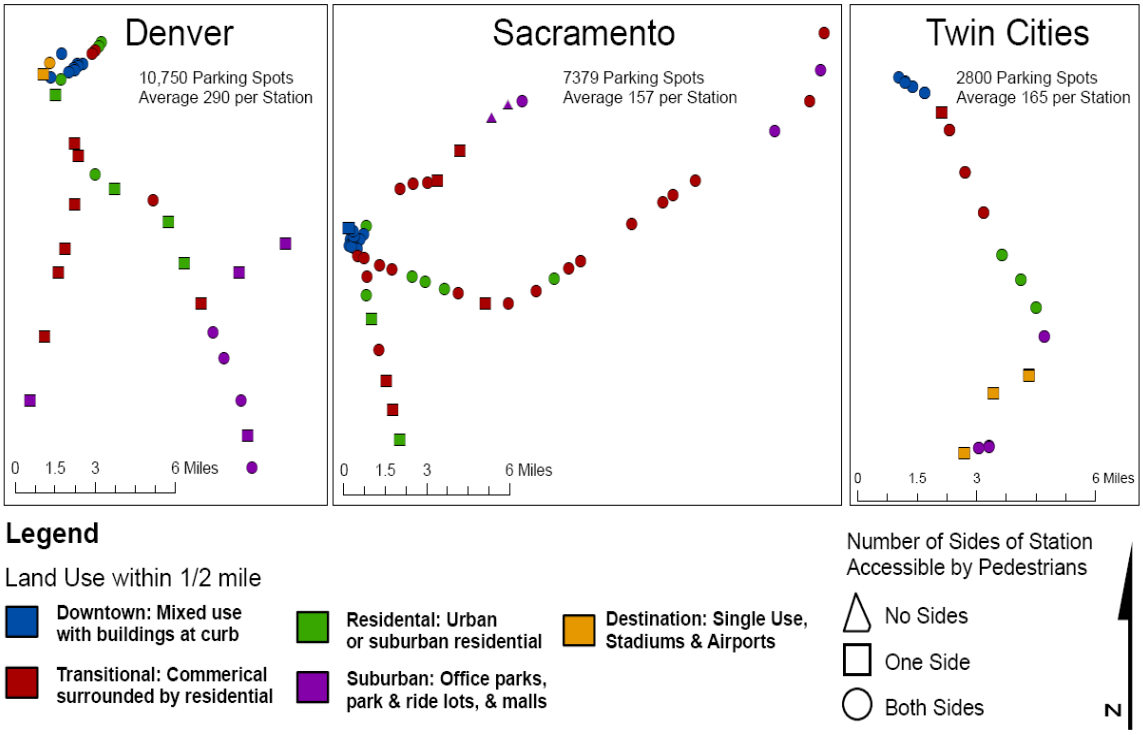


Figure 6.12 Land Use and Access to Light Rail Stations

Agency staff members in all three regions explained how the corridor selection process was a result of politics, availability of cheap right of way, and estimated transit demand. The initial Sacramento light rail lines were built with federal funds allocated for interstate projects. The lines were chosen in part for future expansion potential and where right of way was available in freight corridors. The final Environmental Impact Study from 1983 justified the project citing traffic congestion, transit crowding, future urban growth, air quality and energy concerns, and the opportunity to develop transit that might not be available in the future (Sacramento Transit Development Authority 1983; Koegel 2010).

The Denver light rail corridors were chosen in congested highway corridors, where travel times saving could be demonstrated in order to get federal funding, and in markets where transit could be competitive. The first line built was the cheapest, not the

one with the highest expected ridership. The south-east line was built as part of a $1.6 billion interstate expansion project (Cryer 2010).

The Hiawatha line in the Twin Cities region was built as part of a deal surrounding the expansion of the Minneapolis airport. The state had promised a busway as part of a highway expansion; grassroots and downtown Minneapolis interests pushed for a light rail line. The Central Corridor, currently set to begin construction, was the first priority of the MPO (Filipi 2010).

6.7 Regional Priorities

All three regional councils have policy language in their regional transportation plans encouraging transit usage and transit oriented development. In 2004, the MPO for the Twin Cities adopted a goal of doubling regional transit ridership by 2030 from 2003 levels. By 2008, they were 22 percent above the pace for meeting the goal.

The board of the Denver MPO is considering adopting goals to reduce the percent of trips to work by single-occupant vehicles to 65 percent by 2035 and reducing regional per capita VMT by 10 percent by 2035. These are part of a strategy to meet a goal of reducing per capita greenhouse gas emissions from transportation by 60 percent by 2035 (Sandal 2010). The Sacramento MPO has no set regional goals for transit use, but is working on their plan to comply with California's greenhouse gas emission law (Griesenbeck 2010).

All three major transit agencies have some form of transit service standards. Sacramento has a process for evaluating existing service, but does not have standards based on land use to determine minimum service levels (Sacramento Regional Transit District 2007). The Twin Cities identifies service type and minimum frequency using a transit market index that considers population and employment density and transit dependent population. It also sets goals for transit travel time compared to auto time

(Metropolitan Council 2008). Denver's standards set minimum frequency levels by types of service and minimum service levels based on land use. Special consideration is given to routes with high transit dependent ridership (Regional Transportation District 2002). Denver is explicit that actual service levels are dependent on the agency budget.

In 2008, RTD in Denver had an operating budget of over $435 million. In the Twin Cities, Metro's operating budget was over $258 million. SRT and the six smaller operators in the MPO had a combined operating budget of just under $200 million. Similarly the Sacramento region's capital budget of $42 million is dwarfed by a capital budget of $283 million in Denver and $158 million in the Twin Cities (Federal Transit Administration 2008).

Sacramento faces more competition for funds within the state of California than the other regions. It is the fourth largest MPO out of 18 MPOs in the state. Denver is the largest of five in Colorado and the Twin Cities is the largest of four in Minnesota.

6.8 Comparison

While the three metropolitan areas share some key regional characteristics, the case studies paint a picture of three different transit environments.

Sacramento

The Sacramento region has not prioritized transit at the same level as Denver and the Twin Cities. It has the largest light rail network, but the lowest transit operating budget. A former staff member of the MPO pointed to Sacramento's inability to compete within California for funding (Koegel 2010).

The lack of funding has led to service cuts and fare increases in Sacramento. SRT had a major service cut in June of 2010 due to budget shortfalls. While Sacramento's transit pass programs are aimed at serving lower-income riders, they have the most expensive basic monthly pass of the three regions. The cycle of decreasing

resources and service cuts makes it harder to attract or retain choice riders. The most striking difference between Sacramento and the other regions is the lower income ridership, especially on light rail.

The low median income, along with the lower per capita transit usage, begs the question of why higher income people are not using transit in Sacramento. The motivations of non-riders was not examined in this study; however, only in Sacramento did the transit agency staff bring up safety and cleanliness as concerns. The system is showing its age in comparison to the new systems in Denver and the Twin Cities. Recently a board member of SRT proposed a ban on passengers wearing hooded sweatshirts on light rail because they can be intimidating (Barnard 2010). Whether actual crime or stereotypes about the low-income passengers is the problem is not clear.

The level of low-income riders on light rail can in part be explained by the fact that light rail in Sacramento does serve several low-income neighborhoods. This is not the case in all cities. Activists in the Twin Cities won a victory in 2010 when the Federal Transit Administration asked that three stations serving low-income neighborhoods be added to the plans for the Central Corridor line. In addition, light rail in Sacramento carries 38 percent of transit trips, the highest of the three regions.

Sacramento does have the lowest number of stations surrounded by suburban land use patterns. However, Sacramento has had light rail for over 20 years and the land use has still not evolved around most of the transit stations (Griesenbeck 2010). Because the initial light rail lines in Sacramento were built in place of an interstate highway, in contrast to Denver where light rail was built as part of an interstate project, the lines are more accessible to pedestrians. Sacramento has also made efforts to install safety features to improve pedestrian access across freight lines.

Twin Cities

In contrast to Sacramento, the Twin Cities region is making a concerted effort to attract choice riders. The region has set a goal to increase transit ridership and is meeting its goal by serving work trips. The focus on serving commuters was motivated by a desire to use peak hour express bus service in High Occupancy Vehicle (HOV) lanes to preserve the capacity on interstate investments (Filipi 2010). The transit marketing and pass program is designed for commuters. This effort is reflected in the high levels of work trips and employer pass usage.

The Twin Cities' bus and light rail lines are centered on serving work trips. Almost 60 percent of the Twin Cities' bus routes are commuter service and over half of all routes serve downtown Minneapolis. The Twin Cities do have a high frequency network and a number of transit centers that could be the basis of a regional network.

The light rail line connects downtown Minneapolis with the suburban job center of Bloomington and the Mall of Americas. Job density around the light stations is very high. A low level of school trips is in part due to the lack of direct access to a major college or university. Once the Central Corridor line serving the University of Minnesota is completed, the university/college trip usage will increase.

Despite having only three stations with parking, 45 percent of light rail riders are using a motorized mode to access transit. There are a number of factors for the low pedestrian access. First, physical access from the eastside of the light rail line is difficult. The southern half of the line is surrounded by land use that discourages pedestrian access. There is not enough residential land use in the corridor to attract high levels of walk access to stations; only 26 percent of riders walk to a station. The other option is walking to a bus and transferring to light rail, which is done by 27 percent of riders (Periscope 2008).

The Twin Cities has only one rail line; a mere 13 percent of Metro's annual trips are on light rail (Federal Transit Administration 2008). Bus riders end up on the light rail line if it happens to be on the way. People not willing to take buses, or without bus access, drive to a station. Over 40 percent of light rail riders say they traveled over 2 miles to reach their initial station. Parking is free; 30 percent of light rail riders report that one of the main reasons they use transit is to save money on parking (Periscope 2008). It is likely once the light rail network expands, the level of non-motorized access will increase.

Denver

Denver has the lowest job and population density of the three regions and the highest transit usage per capita. It has the largest transit budget of the three regions and is continuing to expand. Denver also provides transit access to the highest percentage of its population and jobs.

Denver has three times the mileage of light rail as the Twin Cities. The larger network allows Denver to carry more diverse trip types and light rail to play a larger role in the network. Light rail carries 21 percent of all trips in Denver (Federal Transit Administration 2008). The high level of school trips is explained by light rail stations at two major university centers. In addition, Denver's pass programs and overall regional network design does not cater to the work trip as much as the Twin Cities.

Denver has fairly high levels of non-motorized access considering its emphasis on parking, difficulty in pedestrian access, and low density suburban land use. Close to 60 percent of light rail riders walk to start their transit trip (Regional Transportation District 2008). Denver's larger network light rail network has a larger residential capture area than the Twin Cities. In addition, downtown Denver is oriented to the pedestrian with its successful 16th Street Pedestrian Mall.

CHAPTER 7
ANALYSIS

There are two related questions this research is answering. Do higher levels of non-work trips and non-motorized access imply that social and environmental goals are being met and what factors increase non-motorized access and non-work trip usage on transit.

7.1 Meeting Social and Environmental Goals

As stated in the introduction, at a minimum for transit to meet social sustainability goals it must increase mobility and accessibility for everyone, regardless of car ownership. Mobility refers to the ability to move about the region; in this case it is measured by peak hour frequency for local buses. Local buses were chosen because local bus service exists in all 17 regions, its service is accessible on foot, and in general buses carry the majority of transit trips.

There are three variables that measure the accessibility of the region. The land area cover measures what percent of the land area of region is accessible within a half mile of transit access. The population cover and job cover measure the percent of the population and jobs that are within a half mile of transit access.

There are multiple environmental goals for transit, but a primary goal is for transit use to replace personal vehicle trips and reduce the emissions of air pollutants and greenhouse gases. In order for this to occur, transit has to be used by people who otherwise would be driving personal vehicles or people who can afford to own a car but choose not to use it. This is measured by the median income of transit riders and a measure that normalizes for differing costs of living by calculating the median rider

income as a percent of the region's median income overall. In addition, the overall use of transit in a region is measured by the per capita transit trips in the region.

For non-work trips, the results in Table 7.1 indicate that systems with higher non-work trip usage do not meet either social or environmental measures. In fact, the opposite is true, non-work trips are highest on systems negatively correlated to social and environmental indicators.

Table 7.1 Non-Work Trips Social and Environmental Goal Indicators

Goal	Indicator	Result
Social	Peak Headway of Local Bus	Positive correlation – More non-work trips correlated to long wait times
Social	Land Area Cover	Negative correlation – More non-work trips correlated to less accessible area
Social	Population Cover	No correlation
Social	Job Cover	No correlation
Environmental	Median Income	Negative correlation – More non-work trips correlated to lower median income
Environmental	Percent of Region's Median Income	Negative correlation – More non-work trips correlated to lower percent of region's median income
Environmental	Unlinked Transit Trips per Capita	No correlation

The results are less conclusive for non-motorized access. There are no significant correlations between non-motorized access and any of the social indicators. For environmental indicators, non-motorized access is negatively correlated at the 90 percent confidence level for one test to both income variables. There is higher non-motorized access on systems serving primarily lower income riders.

High levels of non-work trips and non-motorized access do not indicate social or environmental sustainability. This does not mean that non-work trip usage and non-motorized access are unimportant sustainability goals; instead these results indicate a

divide between transit service primarily serving low income riders and transit serving more income groups.

Transit serving primarily low-income riders lacks the funding to provide more frequent bus service or to serve a large percent of the region. As shown in Table 5.6 transit spending per capita is positively correlated to income of riders and to the social goal indicators. Regions that spend more per capita on transit have higher income transit riders and more frequent local bus service and a higher percent of accessible land area.

Correlations do not show causation; this research does not assess which comes first- higher income riders or more transit spending. It is likely there is a synergetic effect between better service due to higher spending and the influence of higher income riders to increase spending.

In addition, in order for transit to operate more frequent and widespread service efficiently it needs to serve a large pool of transit riders, not just the lowest income groups. Transit spending per capita is also positively correlated to transit trips per capita (Table 5.6). Higher transit trips per capita is positively correlated to more frequent bus service and more accessible land area and population (Table 5.8). In order for transit to meet social (and environmental) goals, it has to serve more than just the lowest income segments of the community.

This follows not just from the correlations, but the case studies. Sacramento primarily serves low-income riders; both bus and light rail riders have a median income under $30,000 per year. Light rail riders make 36 percent of the region's median income and bus riders 30 percent. Denver and the Twin Cities have higher median incomes for bus and light rail riders. Sacramento has the lowest transit trips per capita, least frequent bus service, and smallest accessible land area, population, and jobs. Sacramento also spends the least on transit.

The case studies point to a second corollary; serving higher income riders does not imply that transit is meeting social goals. The transit system in the Twin Cities has the highest income riders as a percent of the region's median income. However, its design for commuters hinders its ability to meet social goals. It has less frequent local bus service and less accessible land area, populations, and jobs than Denver. This point is backed up by the correlation analysis. Median income of transit riders is not correlated to peak bus headway, a social sustainability measure (Table 5.7).

Given that higher income riders are needed to meet both social and environmental goals, but having high income riders does not ensure social goals are met, deliberate policies are needed to ensure social sustainability goals are met. In addition to increasing funding for transit, service and design standards can ensure desired levels of mobility and accessibility.

7.2 Non-Work Trips

Non-work trip and non-motorized access levels are not indicators of sustainability given the divide between transit systems based on the income of riders. It is clear that lower income riders are most likely to make a non-work trip or use non-motorized access to transit. This is demonstrated in the correlations in Table 5.1 and Table 5.4 and non-motorized access and non-work usage by income levels in Figure 5.1 and Figure 5.2. However, higher non-work trip usage and non-motorized access to transit by all income groups have the potential to increase environmental and social sustainability. The correlations are not very helpful in determining factors that increase either variable for higher income riders, but the case studies do contain useful policy tools.

Network Design

Both Denver and the Twin Cities serve higher income riders, but Denver has higher non-motorized access on its light rail and serves more non-work trips. The Twin

Cities has made a policy choice to focus on serving commute trips and this is reflected in its transit network. Sixty percent of its bus routes are express service and 58 percent of its bus routes enter the Minneapolis CBD. Metro has invested in transit amenities for commuters, including extensive real time information for bus stops throughout downtown.

Denver's network design is more conducive to non-work trips than the Twin Cities. Denver has a regional bus network that includes express service that runs all day, not just in peak periods. While downtown Denver is a central hub, only 40 percent of routes enter the CBD and only 34 percent of its bus routes are peak-hour only. Denver's free downtown shuttle system encourages transit (and pedestrian) non-work trips during the work day. Denver's two downtown bus terminals allow easy transfer between express, regional, and local bus service. Similar transfer centers exist in Boulder and other surrounding towns.

The benefits of a non-CBD network model are backed up by the correlations in Table 5.8. More transit trips per capita is significant and negatively correlated to percent of routes in the CBD. There is higher transit usage on systems that do not concentrate bus routes in the CBD.

Denver also increases its non-work trip usage by designing routes for school trips and integrating the transit service for its major universities and colleges into its entire network. In the Twin Cities, the University of Minnesota provides its own shuttle service (which may deflate the school trip numbers for the Twin Cities survey data). This service, in some places, is duplicative to the service provided by the transit agency and makes a less coordinated and cohesive network.

Local bus service at park and ride lots and number of transit modes are the two network design variables that came up as significant to non-work trips. Both are correlated with income of riders (Table 5.7) and transit spending per capita (Table 5.6).

Systems with primarily low-income ridership are more likely to only have bus service and to have local bus service at park and ride lots. While local bus service at park and ride lots in these systems is likely a reflection of the ridership, it does point to a useful design criteria. Local bus service at park and ride lots, often the origins of express bus service, provides integration between service types.

Most work trips made in a car include other types of stops or trip chaining. The same desire to combine trips exists for the transit user. Single purpose transit types, whether commute service or campus shuttles, re-enforce single trip purpose. The ability to transfer between service types (local, regional, express) at multiple points and times increases the flexibility of the system to serve multiple trip types. This result is supported by the recent literature on network design from Brown and Thompson (Brown 2009, 2009; Thompson 2003).

Transit Pass Program

In addition to its network design, the Twin Cities has a transit pass program that focuses on work trips. Passes are sold through employers at a less expensive rate. Denver also has a special employer pass program. The Twin Cities employer pass program is more popular; 24 percent of light rail riders and 19 percent of bus riders use employer passes compared to 18 percent of light rail riders and 14 percent of bus riders in Denver. Selling passes through employers indicates a high likelihood the passes will be used for work trips; however, it does not preclude the passes being used for other types of trips.

Unfortunately, the raw data for the Twin Cities was not available, but it was available for Denver and Sacramento. In Denver, 86 percent of the users of the employer transit passes were taking work trips, the highest percent of work trips for all fare media. Only 62 percent of users of the non-employer unlimited pass were taking

work trips. In addition, users of the employer pass were most likely to drive to transit. The regular monthly pass users in both Denver and Sacramento had work trip usage at 60 percent. Even without the raw data, due to the high work trip usage in the Twin Cities, it can be assumed that there is high work usage on the employer passes.

It is encouraging that transit passes through employers are being used by people who in all likelihood would not ride transit otherwise. However, one would hope that having an unlimited transit pass, people would use it for multiple purposes. Work trips are approximately 20 percent of all trips, but 86 percent of the trips on employer passes in Denver are work trips.

There are advantages for transit agencies to concentrate on selling transit passes through employers. There are federal incentives for employers and employees that allow purchase of transit passes as a tax free benefit. Transit agencies can market more directly to companies than thousands of individuals. In many cities, there are Transportation Management Organizations or Associations, TMOs or TMAs, in dense employment districts that encourage transit usage. Unfortunately, the incentive system for most TMA/TMOs is based on the transit ridership, primarily work trips, to their location. This focuses transit marketing campaigns on work trips, often to the exclusion of other types of trips. If transit agencies are going to focus on selling passes through employers, there should be a deliberate effort to encourage pass users to take transit for more than their work trip.

7.3 Non-Motorized Access

All three case study regions have barriers to non-motorized access to their light rail lines, particularly interstate highways and freight rail lines. Both Denver and the Twin Cities have suburban land uses at the ends of their rail line(s), difficulty accessing the rail lines from both sides, and a large number of parking spots. Denver's more extensive

rail network allows for more non-motorized access since it is more integrated into the entire transit network. Over 20 percent of transit trips in Denver are on light rail compared to 13 percent in the Twin Cities. The level of non-motorized access on the entire network is essentially the same.

The higher level of non-motorized access on light rail in Sacramento can be explained by the low-income ridership and a more extensive network. However, it is worth noting that Sacramento has the lowest suburban land use around stations and most stations accessible on both sides (Figure 6.8). Sacramento built their initial light rail lines instead of interstates, in contrast to Denver where the light rail was built with the interstates. This raises an important policy question regarding determining fixed guide-way transit corridors.

The three case studies all demonstrate that a mixture of politics, travel demand, and right of way cost determine fixed guide-way corridors. Unfortunately, often the cheapest right of way is in a freight corridor or along an interstate. This creates a barrier for pedestrian access from at least one side. All three regions, especially Denver, have built pedestrian access bridges to allow access to light rail stations. Sacramento has installed safety features to assist pedestrians crossing active freight rail lines. Even with pedestrian features there are physiological barriers to access. Also the placement of light rail stations along interstates and freight lines limits potential transit oriented development as both increase noise and air pollution. The decision-making process for fixed guide-way right of way should include barriers to pedestrians and limits to transit oriented development.

7.4 Limitations to the Research

There are limits to the theory, method, and the results of this research. A major theoretical limitation is the focus on social and environmental sustainability goals,

without explicit analysis of economic sustainability goals. Economic sustainability goals for transit include both the financial stability and efficiency of the transit system itself and the ability for transit to contribute to the economic viability of the community and region. Some variables were included that address the efficiency and funding of the transit system. Only the per capita funding for transit variable was significant. It is worth noting that cost per passenger trip is positive and significant for transit trips per capita, confirming that there are economies of scale in transit.

The exclusion of economic sustainability goals is mostly due to the lack of consensus of how to measure the economic contribution of transit projects. The FTA is currently determining how to assign value to economic development benefits for transit projects in the New Starts application process.

This emphasis on social and environmental goals in this project is not meant to diminish the importance of economic sustainability. The economic stability of a region is closely tied to its ability to provide quality transit service. The main indicator of a region's ability to increase transit service between 1996 and 2007 is job growth in the region (Table 4.1).

The number of regions that do not collect data on transit access mode limited the correlation analysis for non-motorized access. The difference between 16 non-work data points and 13 non-motorized access data points did have an impact. In an ideal situation, a larger sample of regions would have been used. Give the effort needed to collect on-board surveys and calculate the 41 explanatory variables for each region, a larger sample size was impractical.

Having the raw data, which allowed the additional calculations of non-work and non-motorized access by income group and fare type, for all of the regions would have strengthened the analysis. Particularly, the data from the Twin Cities would have been useful in order to compare employer passes to regular passes. Multiple unsuccessful

attempts were made to obtain the raw data or the necessary cross-tabs from the MPO in the Twin Cities.

Some important factors in transit service did not end up significant in the results. Clearly, land use plays a role in the ability of transit to serve multiple type types and non-motorized access to transit. None of the land use variables were significant for non-work and non-motorized access. Unfortunately, the income of transit riders overshadows any relationship between land use and non-work access and the lack of data limits the findings for non-motorized access. Accessible population and population density are positive and significantly correlated at the 90 percent level to per capita transit trips in each region (Table 5.8). This indicates that population density and accessibility to transit is important for overall transit usage. In this case, the case studies do not provide many other answers. Denver has the lowest population and job density of the three case studies. However, Denver spends the most on transit and provides service to the highest percent of its population and jobs.

One possible reason that land use is not significant is that this research analyzes land use at the level of the region. The population and job densities were calculated for the entire transit accessible area within the region. The impact of land use, particularly on non-motorized access to transit, is likely at the local level.

CHAPTER 8
CONCLUSIONS

8.1 Policy Considerations

This study was conceived in response to the prioritizing of transit for the goal of congestion relief in Atlanta. As seen in the case of the Twin Cities, congestion relief as the primary aim of transit service can limit meeting broader sustainability goals. Congestion relief was a major focus of transportation policy at the federal level under the Bush administration. The US DOT, under the Obama administration, has shifted transportation policy to focus on livability through its Partnership for Sustainable Communities with EPA and HUD.

Public transit is seen as an important method for increasing sustainability in the transportation sector. The ability of transit to increase environmental sustainability is closely linked to land use changes; higher density land use can reduce emissions by decreasing VMT and making transit more effective and efficient (Ewing et al. 2007). An important policy question for regions is how to balance building transit that serves their existing land use and building transit to encourage land use changes. Commuter service originating in park and ride lots is the only transit service that makes sense for large sections of suburban and exurban areas. However, focusing on transit that serves the existing land use may result in no land use changes.

Commuter service has a role in a transit system; the question is how much emphasis is placed on commuter service and how it is integrated into the entire system. Express bus commuter service was the most common new service added in the 17 study regions between 2000 and 2008 (Table 4.2). With relatively low capital costs,

express bus service is an easy way to extend service. Three regions also started commuter rail; the same number of regions that opened light rail in same time frame.

One of the limitations of commuter service in most regions is the emphasis on serving the CBD. Jobs shifting away from CBDs to suburban locations make commuter service less effective. Increasingly there are multiple job centers in a region. Single seat commuter service between multiple suburban residential locations and multiple employment districts is not efficient. In addition, service that only serves two types of locations limits its flexibility and discourages trip-chaining on transit.

A regional transit network operates the same way as a regional road network. Just as interstates, arterials, and local roads have roles in the road network, local, regional/crosstown, and express service have roles in a transit network. The key in both types of networks is the ability to transfer to a different part of the network. Multi-destination regional network design increases transfers points and the ability to use transit for multiple trip types.

Transit policy decisions are made by a variety of agencies and levels of government. The transit agencies and MPO play an important role in prioritizing potential new transit projects. Non-motorized access and multiple trip usage can be used as factors in evaluating new transit service. The federal government can also use these criteria to prioritize projects for federal funding.

The project by project funding and selection process can hinder consideration of the transit network as a whole. Unfortunately, especially in regions with multiple transit agencies, regional network design is not always an explicit policy decision. New service should be evaluated on how well it enhances overall connectivity of the network.

8.2 Future Research

This research leaves a lot of unanswered questions and potential for future work. One of the sustainability goals often identified for public transit is for transit to encourage denser land uses and combat sprawl. All three regions studied in the case studies have regional policies to encourage transit-oriented development and connect their land use and transportation decision-making. Previous research has demonstrated the impact of local land use on the access mode for transit (Cervero 2001). What influence does transit with high levels of park and ride access have on land use, both directly around the transit stop and in the capture area for that transit stop? Does this type of transit encourage density? Or does park and ride transit, like commuter rail and express bus, actually sustain or encourage suburban sprawl? These services allow people to live significant distances from their jobs and limits the hardships of their commute. Additional research could quantify the emission reductions from park and ride transit, including the land use component.

This study suggests some design and operation factors that can increase non-work trips and non-motorized access. Since the income of riders played such a large role in the outcome of the correlations, it is possible other factors would be significant if income was held constant. This would require a much larger dataset. Another option would be to do a case study analysis with a larger group of regions with high income transit riders.

This research suggests marketing to encourage people who get transit passes through their employers to use transit for non-work trip purposes. Further research is needed to determine the barriers for employer pass holders using transit for other trip types. Data from other transit agencies with separate employer pass programs could back-up the results from Denver that users of employer passes are more likely to drive to transit and only take work trips.

Several questions remain about specific transit behaviors in the regions analyzed. The primarily low-income ridership on light rail in Sacramento explains the high non-work and non-motorized access. However, the question remains, why does light rail not attract higher income riders in Sacramento? The opposite question exists for Seattle, Washington. The median income of transit riders in Seattle is 80 percent of the region's median. This is the highest in the sample despite the fact that Seattle only had bus service at the time of the on-board survey. It is not a result from a low regional median income since Seattle had a regional median of $81,400, the second highest in the sample. Why are there so many high income bus riders in Seattle?

8.3 Conclusions

This study started with a hypothesis that transit systems serving higher level of non-work trips and non-motorize access meet social and environmental sustainability goals. This turned out to be incorrect due to the divide between transit systems that primarily serve low-income riders and have limited funding and systems serving higher income riders with more funding. The three case studies illustrate the spectrum.

On the surface it looks like Sacramento is achieving sustainability goals with its high usage for non-work trips and non-motorized access. However, with a low percent of choice riders it has limited environmental benefits. In addition, due to the lack of resources transit receives in the region, it fails to meet socials goals as well. The continuing service cuts and fare increases limit the mobility and accessibility of low-income residents.

On the other end of the spectrum, the Twin Cities attracts choice riders by serving downtown commute trips. The emphasis on serving the work trip limits its social benefits. But the ability to meet environmental goals is also limited; it is assuming that people will use their cars for all other trip types.

Denver provides an example of the middle ground. It attracts choice riders, supplies a lot of parking, and provides commuter service. However, its regional network design, with more local routes than express routes, allows transit to serve multiple types of users.

The premise of this project was to focus on overlaps between sustainability goals, instead of the tradeoffs. The correlations point to the need for overlapping goals; social goals are only being met when the environmental goal of serving higher income riders is also met. However, the converse is not true. Serving higher income riders does not ensure that social goals will be met. Regional policies regarding system design and operations are needed ensure both types of goals are met.

In order for transit to meet environmental goals, it must serve people with personal vehicles or the financial ability to have a personal vehicle. However, it is important to ensure that transit is also meeting the transportation needs of the transit-dependent and that the transit is reducing the most vehicle use possible. The danger is, in an effort to make transit as convenient as possible, transit will be designed for people with cars. It is unrealistic to assume transit can replace all of the personal transportation needs; however, transit design and operations should encourage, not discourage, other trip types and non-motorized access. Transit systems with the resources to attract choice riders, but designed to serve dependent riders can meet both environmental and social sustainability goals simultaneously.

APPENDIX A
DATA SOURCES

This appendix contains the sources of the dataset. Table A.1 provides the source of all the GIS layers used. Table A.2 lists unpublished data provided by transit agencies. Table A.3 lists the published on-board survey results. Table A.4 contains the websites consulted. Table A.5 lists the published documents consulted.

Table A.1 GIS Data Sources

Data	Agency Source	Received From	Date Received / Downloaded	Data Date	URL if Downloaded
Water Area	US Census Bureau	Downloaded	10/ 29-30/09	2009	www.census.gov/geo/www/tiger/tgrshp2009/tgrshp2009.html
Census Tracts	US Census Bureau	Downloaded	10/09	2000	www.census.gov/geo/www/tiger/tgrshp2009/tgrshp2009.html
Block Groups	US Census Bureau	Downloaded	10/09	2000	www.census.gov/geo/www/tiger/tgrshp2009/tgrshp2009.html
Jobs by Census Tract/Block Group	US Census Bureau	Downloaded	10/09	2000	www.transtats.bts.gov/DL_SelectFields.asp?Table_ID=1344&DB_Short_Name=CTPP%202000
MPO Boundaries	Bureau of Transportation Statistics	Downloaded	10/6/ 09	2009	www.bts.gov/publications/national_transportation_atlas_database/2009/
Fixed Guide-way Transit	Bureau of Transportation Statistics	Downloaded	10/6/09	2009	www.bts.gov/publications/national_transportation_atlas_database/2009/
Block Group Population	US Census Bureau	Downloaded	10/2009	2000	factfinder.census.gov/home/saff/main.html?_lang=en
Atlanta Routes	Atlanta Regional Commission	Atlanta Regional Commission	2007	2006	On Compact Disc
Baltimore Routes	Maryland Transit Administration	Katharine Daley	06/12/ 08	2008	
Boston Routes	Boston Metropolitan Planning Organization	Paul Reim	04/ 29/08	2007	
Charlotte Routes	Charlotte Area Transit	Thomas Ludden	06/ 5/09	2008	
CTA routes	CTA	Elizabeth Donahue	09/24/08	2008	
Metra routes	Metra	Ryan Richter	09/ 19/08	2008	
Pace routes	Pace Suburban Bus	George Katsambas	09/ 23/08	2008	

Table A.1 (continued)

Data	Agency Source	Received From	Date Received / Downloaded	Data Date	URL if Downloaded
Cleveland Routes	Northeast Ohio Areawide Coordinating Agency	Jonathan Giblin	07/ 21/09	2008	
Dallas Routes	North Central Texas Council of Governments	Mark Sattler	09/ 26/08	2005	
Denver Routes	Regional Transportation District	Downloaded	09/ 30/08	2008	gis.rtd-denver.com
Jacksonville Routes	Jacksonville Transportation Authority	Alesia Gee	10/ 9/09	2008	
Sunshine Bus	St. Johns County	Downloaded	11/ 5/09	2009	www.co.st-johns.fl.us/BCC/Land_Management/GIS/DataDepot.aspx
Las Vegas Routes	Regional Transportation Commission of Southern Nevada	Jeffrey Truby	08/11/09	2009	
Milwaukee Routes	Southeastern Wisconsin Regional Planning Commission	Sonia Dubielzig	08/ 25/09	2008	
Sacramento Routes	Sacramento Regional Transit	James Drake	10/14/09	2009	
Salt Lake City	Utah GIS Portal	Downloaded	11/12/09	2009	gis.utah.gov/
St. Louis Routes	Metro	Jayson Hagen	08/10/09	2008 (pre cuts)	
Seattle Routes	King County	Trang Bui	09/ 25/09		
Seattle Ferry and Park and Rides	Washington Department of Transportation	Downloaded	08/19/09	2008	www.wsdot.wa.gov/Mapsdata/geodatacatalog/
Minneapolis-St. Paul Routes	Metro GIS DataFinder	Downloaded	10/ 09	2009	www.datafinder.org/catalog/index.asp

Table A.1 (continued)

Data	Agency Source	Received From	Date Received / Downloaded	Data Date	URL if Downloaded
Pittsburgh Routes	Southwestern Pennsylvania Commission	Jeff Grim	02/24/10		
Community Transit Routes	Snohomish County	Jeff Anderson	11/ 11/09	2009	
Madison County Transit Routes (St. Louis)		Created in Google Earth	11/10/09	2009	www.mct.org/
Carroll County Transit Routes (Baltimore)		Created in Google Earth	11/12/09	2009	www.carrolltransit.org/
Hartford County Transit (Baltimore)		Created in Google Earth	11/12/09	2009	www.harfordcountymd.gov/services/transportation/
Annapolis Transit (Baltimore)		Created in Google Earth	11/13/09	2009	www.ci.annapolis.md.us/info.asp?page=1368
Kitsap Transit (Seattle)		Created in Google Earth	11/23/09	2009	www.kitsaptransit.org/
Everett Transit (Seattle)		Created in Google Earth	11/ 20/09	2009	www.everettwa.org/
Racine Transit (Milwaukee)		Created in Google Earth	11/ 23/09	2009	www.racinetransit.com/
Kenosha Transit (Milwaukee)		Created in Google Earth	11/ 23/09	2009	www.kenosha.org/departments/transportation/
Pierce Transit (Seattle)	Pierce Transit	Roger Holmes	11/ 13/09	2009	
Sacramento Regional Routes	Sacramento Regional Transit	Chris Pair	02/ 08/10	2010	

Table A.2 Unpublished Data Sources

City	File Name	Agency	Received From	Date Received	Data Date
Atlanta	FY08QOSIncome XAccessMode-TripPurpose.xls	MARTA	Robert Thomas	05/08/09	2008
Boston	DATA Request 040710.xls	Boston Central Transportation Planning Staff	Tom Humphrey	04/07/10	2008-2009
Chicago	PRELIMINARY_CTA_OD_data_2007.xls	Chicago Transit Authority	Jason Minser	10/14/09	2007
Denver	RTD_FinalDataset_BoardTimes.sav	Denver Regional Transit District	Lee Cryer	06/18/09	2008
Jacksonville	O and D Summaries by Route and Day 2006.doc	Jacksonville Transit Authority	Alesia Gee	10/0 9/09	2006
Las Vegas	LV_Onboard_Transit_Survey_Database_RTC_Copy.xls	Regional Transportation Commission	Jeffrey Truby	10/ 27/09	2006
Sacramento	On-Board Survey Results (Public).mdb	Sacramento Regional Transit	James Drake	10/14/09	2006
Salt Lake City	SLC Survey Final Results.sav	Utah Transit Authority	Barton Dean	10/18/09	
Seattle	Headways Sept 2008.xls	King County Metro	Downloaded	11/07/08	2008
St. Louis	Average Headways Feb 20 2009.pdf	Metro St. Louis	Todd Hennessy	03/02/10	2009

Table A.3 Published On-Board Survey Results

City	Conducted by	Report	Date
Atlanta	Georgia State University Public and Performance Management Group	Georgia Regional Transportation Authority Rider Survey	2008
Atlanta	MARTA	General Rider, Half-Fare Program, Mobility Program Demographics and System Usage Profiles	2008
Baltimore	Maryland Transit Administration	Customer Profile	2006
Charlotte	Charlotte Area Transit System	CATS Market Research Results 2000-2007	2007
Chicago	Metra	Metra Rider Profile	2005
Chicago	Pace Suburban Bus	Total Pace Ridership Characteristics	2007
Cleveland	Greater Cleveland Regional Transit Authority	On-board Survey Results- Snapshot	2007
Dallas	NuStats	Dallas Area Rapid Transit 2007 Transit Rider Survey	2007
Milwaukee	Milwaukee County Transit	Ridership Profile	2009
Pittsburgh	Southwestern Pennsylvania Commission	Southwestern Pennsylvania Transit Rider Survey_Final Report	2007
Seattle	The Gilmore Research Group (for King County)	2007 Rider Survey Findings	2007
Seattle	The Gilmore Research Group (for Pierce Transit)	2007 Fixed Route Customer Satisfaction Survey Results	2007
St. Louis	Missouri University of Science and Technology	Comprehensive Market Research Analysis of Metropolitan Bus and Rail Passengers	2008
Twin Cities	Periscope	Metro Transit Light Rail and Bus Rider Survey: Findings and Recommendations	2008

Table A.4 Websites Consulted

City	Agency	Website	Visited
Atlanta	MARTA	www.itsmarta.com	05/20/08
Atlanta	GRTA	www.xpressga.com	05/13/08
Atlanta	Atlanta Regional Commission	www.atlantaregional.com	08/18/08
Baltimore	City of Annapolis	www.annapolis.gov/info.asp?page=1368	06/16/08
Baltimore	Maryland Transit Administration	www.baltimoreredline.com	06/18/08
Baltimore	Maryland Transit Administration	www.mtamaryland.com	06/16/08
Baltimore	Metropolitan Council	www.baltometro.org	06/05/08
Baltimore	Howard County Transit	www.howardtransit.com	06/16/08
Baltimore	Carroll Area Transit	www.gobycats.org	06/16/08
Baltimore	Harford County	www.harfordcountymd.gov/services/transportation/	06/16/08
Boston	Boston MPO	www.bostonmpo.org	06/23/08
Boston	Cape Ann Transportation Authority	www.canntran.com	06/25/08
Boston	Massachusetts Bay Transportation Authority	www.mbta.com	06/25/08
Charlotte	Mecklenburg-Union Planning Organization	mumpo.org	08/26/08
Charlotte	North Carolina DOT	www.ncdot.org/transit/nctransit/#programs	08/26/08
Charlotte	Charlotte Area Transit	http://charmeck.org/city/charlotte/cats/Pages/default.aspx	08/26/08
Chicago	Chicago Metropolitan Agency for Planning	www.cmap.illinois.gov	09/20/08
Chicago	Metra	www.metrarail.com	09/10/08
Chicago	Pace Suburban Bus	www.pacebus.com	09/10/08
Chicago	Regional Transportation Authority	www.rtachicago.com	09/10/08
Chicago	Chicago Transit Authority	www.transitchicago.com	09/10/08
Cleveland	Ohio DOT	www.dot.state.oh.us/Services/Pages/Transit.aspx	09/17/08
Cleveland	Greater Cleveland Regional Transit Authority	www.gcrta.org	09/17/08
Cleveland	Geauga County	www.geaugatransit.org	09/17/08
Cleveland	Laketran	www.laketran.com	09/17/08
Cleveland	Lorain County	www.loraincounty.us	09/17/08

Table A.4 (continued)

Cleveland	Northeast Ohio Areawide Coordinating Agency	www.noaca.org	09/17/08
Dallas	Dallas Area Rapid Transit	www.dart.org	09/23/08
Dallas	Denton County Transportation Authority	www.dcta.net	09/23/08
Dallas	North Central Texas Council of Governments	www.nctcog.org	09/25/08
Dallas	Forth Worth Transportation Authority	www.the-t.com	09/23/08
Denver	Regional Transportation District	www.rtd-denver.com	09/29/08
Denver	Regional Council of Governments	www.drcog.dr	09/29/08
Jacksonville	Florida DOT	www.dot.state.fl.us/transit/default.shtml	10/03/08
Jacksonville	North Florida Transportation Planning Organization	www.firstcoastmpo.com	10/02/08
Jacksonville	Jacksonville Transportation Authority	www.jtaonthemove.com	10/02/08
Jacksonville	St Johns County	www.sunshinebus.net	10/02/08
Las Vegas	Las Vegas Monorail	www.lvmonorail.com	10/07/08
Las Vegas	Regional Transportation Commission of Southern Nevada	www.rtcsouthernnevada.com	10/06/08
Milwaukee	City of Kenosha	www.kenosha.org/departments/transportation/	10/14/08
Milwaukee	Ozaukee County	www.ozaukeetransit.com	10/09/08
Milwaukee	City of Racine	www.racinetransit.com	10/14/08
Milwaukee	Milwaukee County Transit System	www.ridemcts.com	10/09/08
Milwaukee	Washington County	www.ridewcce.com	10/09/08
Milwaukee	Southeastern Wisconsin Regional Planning Commission	www.sewrpc.org	10/08/09
Milwaukee	City of Waukesha	www.waukeshametro.org	10/09/08
Pittsburgh	Fayette Area Coordinated Transportation	www.factbus.com	10/22/08

Table A.4 (continued)

Pittsburgh	Washington City Transit	www.ggcbusride.com	10/22/08
Pittsburgh	Indiana County Transit Authority	www.indigobus.com	10/22/08
Pittsburgh	Mid Mon Valley Transit Authority	www.mmvta.com	10/22/08
Pittsburgh	New Castle Area Transit Authority	www.newcastletransit.org	10/21/08
Pittsburgh	Port Authority of Allegheny County	www.portauthority.org	10/22/08
Pittsburgh	Southwestern Pennsylvania Commission	www.spcregion.org/	10/21/08
Pittsburgh	Butler Transit Authority	www.thebusbutlerpa.com	10/21/08
Pittsburgh	Westmoreland County	www.westmorelandtransit.com	10/22/08
Sacramento	Unitrans	unitrans.ucdavis.edu	10/24/08
Sacramento	City of Auburn	www.auburn.ca.gov/dept/dept_pw_trnst.html	10/27/08
Sacramento	City of Lincoln	www.ci.lincoln.ca.us/index.cfm?page=282219	10/27/08
Sacramento	El Dorado Transit	www.eldoradotransit.com	10/24/08
Sacramento	City of Elk Grove	www.e-tran.org	10/27/08
Sacramento	City of Folsom	www.folsom.ca.us/depts/public_works/transit_division.asp	10/24/08
Sacramento	Placer County	www.placer.ca.gov/Departments/Works/Transit/PCT.aspx	10/24/08
Sacramento	City of Roseville	www.roseville.ca.us/transportation/roseville_transit/default.asp	10/24/08
Sacramento	Yolo County	www.yolobus.com	10/24/08
Sacramento	Yuba-Sutter Transit	www.yubasuttertransit.com	10/24/08
Sacramento	Sacramento Council of Governments	www.sacog.org	10/24/08
Salt Lake City	Wasatch Front Range Council	wfrc.org/cms	10/28/08
Salt Lake City	Utah Transit Authority	www.rideuta.com	10/28/08
Seattle	King County Metro	transit.metrokc.gov	11/07/08
Seattle	Pierce County Ferry System	www.co.pierce.wa.us/pc/abtus/ourorg/pwu/ferry/ferrymain.htm	11/07/08
Seattle	Community Transit	www.commtrans.org	11/07/08
Seattle	City of Everett	www.everettwa.org/default.aspx?ID=290	11/07/08
Seattle	Kitsap County	www.kitsaptransit.org	11/09/08
Seattle	Pierce County	www.piercetransit.org	11/07/08

Table A.4 (continued)

Seattle	Puget Sound Regional Council	www.psrc.org	10/30/08
Seattle	Seattle Monorail	www.seattlemonorail.com	11/07/08
Seattle	Sound Transit	www.soundtransit.org	11/07/08
Seattle	Washington State Ferries	www.wsdot.wa.gov/ferries/	11/07/08
Seattle	Washington DOT	www.wsdot.wa.gov/transit/	11/07/08
St. Louis	East-West Gateway Council of Governments	www.ewgateway.org	11/10/08
St. Louis	Madison County Transit	www.mct.org	11/10/08
St. Louis	Bi-State Development Agency	www.metrostlouis.org	11/10/08
Twin Cities	Metropolitan Council	www.metrocouncil.org	11/12/08
Twin Cities	Metro Transit	www.metrotransit.org	11/12/08
All	US Census Bureau - American FactFinder	http://factfinder.census.gov/home/saff/main.html?_lang=en	On-going
All	US Census Bureau - Transportation Planning Package	http://www.transtats.bts.gov/DL_SelectFields.asp?Table_ID=1344&DB_Short_Name=CTPP%202000	On-going
All	Bureau of Economic Analysis-Regional Economic Accounts	www.bea.gov/regional/reis	06/18/08
All	EPA- Green Book Nonattainment Areas	www.epa.gov/air/oaqps/greenbk	06/16/08
All	FTA National Transit Database	www.ntdprogram.gov/ntdprogram/	
All	HUD-Estimated Metropolitan Area Median Family Income Listing 2005-2009	http://www.ffiec.gov/cra/censusproducts.htm#MSAincome	11/23/09
All	FHWA-Highway Statistics	http://www.fhwa.dot.gov/policyinformation/statistics/2007/hm71.cfm	05/14/09
All	FTA	www.fta.dot.gov/	On-going

Table A.5 Published Documents Consulted

City	Agency	Report	Year
Atlanta	Atlanta Regional Commission	Envision6 RTP	2007
Baltimore	Baltimore Regional Transportation Board	Transportation Outlook 2035	2007
Baltimore	Baltimore Regional Transportation Board	TIP 2008-2012	2007
Boston	Boston MPO	Journey to 2030	2007
Boston	Boston MPO	Federal Fiscal Year 2008-2011 TIP	2007
Charlotte	Mecklenburg-Union MPO	2030 Long Range Transportation Plan	2005
Charlotte	North Carolina DOT	2007-2013 North Carolina TIP	2007
Chicago	Metropolitan Agency for Planning	2030 RTP for Northeastern Illinois	2008
Chicago	Regional Transportation Authority	2008 Proposed Budget, Two-Year Financial Plan and Five-Year Capital Program	2008
Cleveland	Northeast Ohio Areawide Coordinating Agency	TIP SFY 2008-2011	2007
Cleveland	Ohio DOT	2008-2011 Transit STIP	2008
Dallas	North Central Texas Council of Governments	Mobility 2030	2007
Dallas	North Central Texas Council of Governments	2008-2011 TIP	2007
Denver	Denver Regional Council of Governments	Transit Element of the 2030 Metro Vision RTP	2007
Denver	Denver Regional Council of Governments	2008-2013 TIP	2008
Denver	Regional Transportation District	2008 Adopted Budget	2007
Jacksonville	First Coast MPO	TIP: Fiscal Years 2008/09-2012/13	2008
Las Vegas	Regional Transportation Commission of Southern Nevada	RTP Fiscal Years 2006-2030	2006
Las Vegas	Regional Transportation Commission of Southern Nevada	Amendments to TIP Fiscal Years 2006-2008	2006
Milwaukee	Southeastern Wisconsin Regional Planning Commission	Year 2035 Regional Land Use and Transportation Systems Plans	2007
Milwaukee	Wisconsin DOT	Transportation Budget Trends	2006
Pittsburgh	Southwestern Pennsylvania Commission	Regional Transit Report Card	2008
Pittsburgh	Southwestern Pennsylvania Commission	2009-2012 TIP	2008
Pittsburgh	Southwestern Pennsylvania Commission	2035 Transportation and Development Plan	2008
Sacramento	Sacramento Area Council of Governments	Metropolitan Transportation Plan for 2035	2008

Table A.5 (continued)

Salt Lake City	Utah Transit Authority	2008 Budget and Strategic Plan Document	2008
Salt Lake City	Wasatch Front Range Council	2009-2014 TIP	2008
Seattle	Puget Sound Regional Council	Destination 2030 Update	2007
Seattle	Puget Sound Regional Council	2007-2010 TIP	2008
St. Louis	East-West Gateway Council of Governments	TIP Fiscal Years 2009-2012	2008
Twin Cities	Metropolitan Council	Twin Cities Transit System Performance	2007
Twin Cities	Metropolitan Council	2030 Transportation Policy Plan	2008
Twin Cities	Metropolitan Council	2009-2012 TIP	2008
All	Collier International	Parking Rate Survey	2008
All	FTA	Annual Report on New Starts: Proposed Allocation of Funds	2000-2009
All	Texas Transportation Institute	Annual Urban Mobility Report	2007
All	US Congress	SAFETEA-LU	2005

APPENDIX B

DATASET

This appendix contains the complete dataset used to perform the correlation analysis in Table B.1.

Table B.1 Full Dataset

City	Non-Work	Non-Motorized Access	Region	Economic Conditions	State Funding	Size of Metro	Out of Attainment
Atlanta	46.00%	75.5%	East	Over 20%	No	Over 3 million	2 or more
Baltimore	32.00%		East	10-20%	Yes	1-3 million	2 or more
Boston	30.70%	78.5%	East	10-20%	Yes	Over 3 million	Only 1
Charlotte	28.00%	76.0%	East	Over 20%	No	.5-1 million	Only 1
Chicago	30.62%	84.9%	Middle	10-20%	Yes	Over 3 million	2 or more
Cleveland	50.00%	66.5%	East	Under 10%	Yes	1-3 million	2 or more
Dallas	46.00%	80.0%	Middle	Over 20%	Yes	Over 3 million	Only 1
Denver	42.20%	83.0%	West	10-20%	No	1-3 million	Only 1
Jacksonville	56.00%		East	Over 20%	Yes	,5-1 million	Attainment
Las Vegas	58.00%	94.0%	West	Over 20%	No	.5-1 million	2 or more
Milwaukee	57.00%		Middle	Under 10%	Yes	1-3 million	Only 1
Pittsburgh	40.38%	87.7%	East	Under 10%	Yes	1-3 million	2 or more
Sacramento	57.00%	82.8%	West	Over 20%	Yes	1-3 million	2 or more
Saint Louis		73.0%	Middle	Under 10%	Yes	1-3 million	2 or more
Salt Lake City	42.00%		West	10-20%	No	1-3 million	Only 1
Seattle	41.04%	75.0%	West	10-20%	No	Over 3 million	Attainment
Twin Cities	36.50%	81.2%	Middle	10-20%	Yes	1-3 million	Attainment

Table B.1 (continued)

City	TTI Index - Top 25	Racial Composition of Central City	Rail	Unlinked Trips per Capita	VMT per capita 2005	Land Area Cover	Pop Cover	Job Cover
Atlanta	Yes	People of Color	Yes	42.4	11,199.40	13%	41%	60%
Baltimore	Yes	People of Color	Yes	52.3	9,481.80	16%	56%	64%
Boston	Yes	White	Yes	95.9	7609	27%	68%	72%
Charlotte	Yes	White	No	27.9	11545.6	26%	58%	72%
Chicago	Yes	People of Color	Yes	73.5	7540.5	34%	81%	82%
Cleveland	No	People of Color	Yes	39.3	7501.1	23%	71%	74%
Dallas	Yes	White	Yes	20.7	9693.1	14%	49%	63%
Denver	Yes	White	Yes	43.6	9846.8	23%	89%	88%
Jacksonville	No	White	No	13.2	13169.4	22%	64%	74%
Las Vegas	No	White	No	51.5	7408.1	3%	85%	86%
Milwaukee	No	People of Color	No	38.7	9240.2	10%	57%	60%
Pittsburgh	No	White	Yes	40.9	8190.2	10%	59%	69%
Sacramento	No	People of Color	Yes	24.9	9544	6%	70%	70%
Saint Louis	No	People of Color	Yes	25.2	11511.4	11%	56%	65%
Salt Lake City	No	White	Yes	43.5	9339.1	26%	81%	78%
Seattle	Yes	White	No	62.2	8552.6	15%	78%	87%
Twin Cities	Yes	White	Yes	35.7	9585	22%	74%	82%

Table B.1 (continued)

City	Pop Density	Job Density	Cost Per Passenger Trip	Passenger Per Vehicle Hour	Average Length of Trip	Daily Parking	Monthly Parking	Total Budget Per Capita
Atlanta	2616.6	2004.9	$ 2.38	65.8	5.52	$ 12	$ 90	$204.07
Baltimore	3889.6	2037.2	$ 3.64	45.8	6.31	$ 15	$ 150	$253.70
Boston	5573.8	3436.3	$ 2.67	93.9	4.94	$ 33	$ 460	$556.92
Charlotte	2007.3	1644.0	$ 3.78	25.6	4.5	$ 14	$ 104	$352.42
Chicago	4870.8	2354.5	$ 3.35	46.8	6.29	$ 30	$ 310	$327.08
Cleveland	3296.2	1665.0	$ 3.87	40.4	4.41	$ 10	$ 180	$159.82
Dallas	3592.0	2323.8	$ 4.31	38.9	5.46	$ 11	$ 90	$184.48
Denver	2623.5	1392.8	$ 3.31	29.2	5.57	$ 12	$ 160	$299.97
Jacksonville	1826.6	1049.8	$ 5.37	18.1	5.56	$ 13	$ 110	$84.43
Las Vegas	4559.1	2173.1	$ 1.77	40.6	3.64		$ 65	$131.07
Milwaukee	4209.0	2056.5	$ 2.65	40.3	3.01	$ 12	$ 120	$100.66
Pittsburgh	2134.1	1106.5	$ 4.41	32.8	4.72	$ 11	$ 235	$185.42
Sacramento	3613.8	1588.0	$ 4.21	47.4	4.35	$ 20	$ 210	$115.26
Saint Louis	2780.7	1571.8	$ 3.45	42.2	5.29	$ 14	$ 105	$117.94
Salt Lake City	3259.1	1571.1	$ 3.85	37.8	7.15	$ 5	$ 61	$378.70
Seattle	2753.7	1586.7	$ 3.68	38.9	4.59	$ 25	$ 260	$629.96
Twin Cities	3155.9	2015.2	$ 3.09	41.0	4.65	$ 13	$ 184	$198.54

Table B.1 (continued)

City	Peak Local Bus Headway (mins)	Number of Operators	Number of Modes	Percent Routes Local	Percent Routes Local (Main)	Percent in CBD	Percent in CBD (Main)
Atlanta	28.0	6	3	81%	100%	23%	15%
Baltimore	19.7	6	5	78%	70%	33%	47%
Boston	20.7	2	7	85%	84%	19%	20%
Charlotte	27.6	1	3	71%	71%	65%	65%
Chicago	11.6	3	4	64%	64%	14%	32%
Cleveland	32.9	4	5	80%	79%	52%	61%
Dallas	29.6	3	4	87%	92%	47%	48%
Denver	24.0	1	3	66%	66%	41%	41%
Jacksonville	46.8	3	3	79%	87%	63%	72%
Las Vegas	43.7	2	3	100%	100%	40%	40%
Milwaukee	16.5	6	4	70%	61%	29%	48%
Pittsburgh	32.0	10	5	65%	58%	63%	81%
Sacramento	43.6	12	3	64%	62%	28%	20%
Saint Louis	28.0	2	3	73%	73%	20%	27%
Salt Lake City	32.3	1	4	58%	58%	41%	41%
Seattle	28.0	9	6	72%	96%	37%	46%
Twin Cities	30.0	1	4	39%	39%	58%	58%

Table B.1 (continued)

City	Hubs	Hubs (Main)	Percent 2007 Unlinked Trips by bus	Percent White	Median Income	MSA Median Income	Percent of Median
Atlanta	3	2	50%	13%	$ 25,475	$ 69,200	37%
Baltimore	7	10	74%	23%	$ 39,463	$ 72,150	55%
Boston	1	1	28%	71%	$ 64,599	$ 83,900	77%
Charlotte	1	1	97%	30%	$ 31,800	$ 60,200	53%
Chicago	1	1	56%	31%	$ 24,708	$ 69,700	35%
Cleveland	1	2	82%	27%	$ 37,500	$ 60,700	62%
Dallas	2	1	74%	31%	$ 24,000	$ 63,200	38%
Denver	1	1	79%		$ 37,500	$ 71,800	52%
Jacksonville	4	5	91%		$ 25,000	$ 60,300	41%
Las Vegas	4	4	86%	31%	$ 22,750	$ 58,200	39%
Milwaukee	1	2	97%	50%	$ 21,560	$ 70,700	30%
Pittsburgh	1	1	88%	61%	$ 33,329	$ 57,900	58%
Sacramento	1	2	62%	42%	$ 22,500	$ 71,000	32%
Saint Louis	1	3	59%	33%	$ 37,436	$ 65,000	58%
Salt Lake City	3	3	54%	71%			
Seattle	1	11	81%	74%	$ 64,815	$ 81,400	80%
Twin Cities	3	3	0.83	0.66	$ 49,249	$80,900	0.61

Table B.1 (continued)

City	Percent on Unlimited Passes	Bus Service Between 1998-2008	Rail Stations with Parking	Bus Service at Rail Stations	Park and Ride with Local Bus	Transfer Fees	Fare Structure
Atlanta	63%	Increasing	71%	100%	42%	Free	Flat
Baltimore	75%	Increasing	60%	78%	0%	No Transfer	Flat
Boston		Decreasing	38%	56%		Free	Not Flat
Charlotte	61%	Increasing	47%	100%	50%	Small Fee	Not Flat
Chicago	59%	Increasing	86%	70%		Small Fee	Not Flat
Cleveland		Decreasing	42%	67%	57%	Free	Flat
Dallas	71%	Increasing	58%	93%	42%	No Transfer	Not Flat
Denver	53%	Increasing	51%	75%	70%	Free	Not Flat
Jacksonville		Increasing	38%	100%	100%	No Transfer	Flat
Las Vegas	82%	Increasing			100%	No Transfer	Flat
Milwaukee	27%	Increasing			80%	Free	Flat
Pittsburgh	64%	Decreasing	44%	56%	74%	Small Fee	Not Flat
Sacramento	59%	Increasing	38%	55%	56%	Small Fee	Flat
Saint Louis	82%	Decreasing	49%	100%	71%	Small Fee	Flat
Salt Lake City	59%	Decreasing	51%	74%	37%	Free	Flat
Seattle	43%	Increasing	68%	68%	37%	Free	Not Flat
Twin Cities	0.49	Increasing	0.18	0.59	24%	Free	Flat

APPENDIX C

CASE STUDY INTERVIEWS

This appendix contains the questions from the case study interviews. There are three types of questions: questions for MPO staff members, questions for transit agency staff members, and city specific questions. Table C.1 lists the details of all of the interviews.

Table C.1 Case Study Interview Details

Region	Name	Title	Agency	Date
Denver	Lee Cryer	Planning Project Manager	Regional Transit District	06/15/10
	Debra Smith	Transportation Planner II	Denver Regional Council of Governments	06/15/10
	Fred Sandal	Long Range Transportation Planning Coordinator	Denver Regional Council of Governments	06/15/10
Sacramento	Bruce Griesenbeck	Principal Transportation Analyst	Sacramento Area Council of Governments	06/21/10
	Joanne Koegel	Retired, private consultant	Sacramento Area Council of Governments	06/22/10
	James Drake	Assistant Planner of Short Range Planning	Regional Transit District	06/ 22/10
Twin Cities	Mark Filipi	Manager, Technical Planning Support, Metropolitan Transportation Services	Metropolitan Council	06/03/10
	Karen Lyons	Senior Planner	Metropolitan Council	06/03/10

Questions for MPO staff members

Is sustainability a goal? How is it defined? What are the performance measures?

How are transportation and land use decisions linked in the policy/decision-making framework? What are the challenges and successes in coordinating land use and transit investments?

What are the regional/agency criteria for transit investments?

How was the light rail corridor(s) chosen?

Are non-motorized access and non-work trip usage considered at all in planning process?

What jurisdictions are in charge of pedestrian infrastructure around transit stations? How are improvements funded?

What is the relationship between the MPO and transit agency(s)?

What is the relationship between the MPO and the State Legislature?

Questions for Transit Agency staff members

How was the light rail corridor(s) chosen?

How did the existing bus network change when the light rail service started?

Are non-motorized access and non-work trip usage considered at all in planning process?

What steps are taken to encourage non-motorized access to transit?

What determines parking levels/costs at rail stations?

What steps are taken to encourage non-work trip usage on transit? What are the challenges to serving non-work trips?

Is access to schools prioritized in route planning?

What is the relationship between the transit agency and the MPO?

City Specific- Denver

How successful is the neighborhood Eco Pass program?

City Specific- Twin Cities

Why are the unlimited ride passes through employers?

Are people who get their passes through their employer using transit for non-work trips?

Can Metro Council meet its long term transit ridership goal with 63% work trips? Is the focus shifting to capturing other trip types?

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