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The Influence of Urban Form, Socio-Demographics, And Transit-Oriented Development on Journey-to-Work Characteristics

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Abstract

A growing consensus among planners and policy-makers is that the automobile-oriented city, one that dominates the American landscape, is no longer sustainable. Such concerns demand a search for ways to promote alternative forms of travel. To this end, this study employs a multiple linear regression analysis in order to determine the relationships between the share of public transit and walking/bicycle commuting and variables representing three categories: urban form measures, socio-demographic and household characteristics, and the presence of a transit-oriented development. These relationships were examined in thirteen metropolitan regions.

Keywords: planning, transit, public transportation, walking, bicycling, transit-oriented development

Chapter 1 - Introduction

There is a growing consensus among policy makers, planners, and researchers that current urban growth patterns, characterized by uncontrolled, low-density sprawl and a declining central city, are not sustainable. The automobile, which initially contributed to the advent of urban sprawl, is now necessary to navigate most suburbs. The share of trips on public transportation has been on a steady decline. According to the National Household Travel Survey, while personal travel has increased dramatically between 1969 and 2001, the proportion of these trips taken on public transportation has declined by half (Polzin & Chu 2005). The implications of such land use and transportation trends on the environment, local economies, and quality of life promulgate the need for new approaches to urban development. One such approach that has increasingly been undertaken by cities nationwide is transit-oriented development.

Transit-oriented developments (TOD) can be succinctly defined as compact, mixed-use urban neighborhoods that are anchored by transit stations and contain urban form features, such as highly connected street networks, human scaled architecture and other amenities that promote pedestrian access and transit use. TODs do not exclude automobile travel. Ideally, however, they can provide an attractive and accessible alternative to car use within the development and, if implemented as part of a region-wide transportation strategy, throughout the metropolitan area (Bernick & Cervero 1997, Calthorpe 1993, Cervero et al. 2002, Cervero et al. 2004).

While TOD has showed promise in promoting increased transit-use, it is still, as a concept and implemented policy, relatively young, and reports of its success toward its purported ends are mixed. Despite this youth and lack of thorough examination, TOD does appear to positively influence non-automobile travel. Nationwide, the share of commute trips taken by transit declined from 12.6 percent to 4.7 percent between 1960 and 2000. During the same time, those using "other means" to travel to work, including walking and bicycling, fell from to 4.1 percent. In the thirteen regions that will be discussed in this study, the transit commute fell from 19 percent to 7.1 percent. Among the TODs that inhabit those regions, however, the percent trips to work on transit has actually shown increases, from 15.1 percent in 1970 to 16.7 percent in 2000 (Renne 2005).

It would seem, therefore, that for the most part TOD has succeeded in at least sustaining, if not increasing, relatively high shares of transit ridership. As implementation of this policy grows more common place, it will be useful to examine those qualities that promote non-automotive travel, and find ways to further incorporate such characteristics in, and attract the appropriate markets to transit-oriented developments.

It is well understood that certain socio-demographic characteristics result in high transit use and/or walking among urban residents, particularly those who are unable to acquire and maintain a personal automobile due to economic limitations,. In the interest of equity, those who implement TOD should endeavor to include affordable housing opportunities for such populations. Furthermore, TOD should provide alternative living and traveling opportunities for those whom automobile ownership and suburban residence are economically feasible, but not necessarily desirable, such as the growing number of non-family households and the aging baby boomer populations. Regarding urban form, certain characteristics, such as high densities and street connectivity, seem to correlate highly with walking and transit trips (Taylor & Fink undated, Weinstein et al. 2006).

The goal of this study is to examine travel behavior at a neighborhood, regional, and a national scale, in order to gain insight into the following question: what characteristics of communities positively influence transit ridership and walking? This study will also examine if the presence of a TOD, by leading to increased transit and pedestrian travel, is among these characteristics.

Research Questions and Hypotheses

Research Question 1: *Does urban form influence travel behavior?*

Hypothesis 1:

Urban Form measures, such as density, roadway connectivity, and distance to the city center, should have a statistically significant influence on travel behavior. The conjecture is that as density and connectivity increase and distance to the city center decreases, the use of public transportation and walking, as means of traveling to work will increase.

Research Question 2: *Do household and/or socio-demographic characteristics have influence on travel behavior?*

Hypothesis 2:

Household characteristics, such as household type (family versus non-family), housing tenure status (renting versus owning), and car ownership should have a statistically significant influence on travel behavior. It is expected that non-family households, renters, and those with zero or one car will be more likely travel to work via public transportation and/or walking.

Socioeconomic measures, namely income and race, will also show a statistically significant relationship with travel behavior. This hypothesis presumes that lower incomes should positively influence both walking and transit ridership, given the consequent limitations on automobile ownership. Because minority populations, including the foreign born, are more likely than white populations to live under these economic conditions in urban environments, it is presumed that their presence will also be associated with these travel behaviors.

Research Question 3: *Do Transit-Oriented Developments influence travel behavior?*

Hypothesis 3:

Because transit-oriented developments demonstrate the urban form measures described in the first hypothesis combined with a transit station, and because they seek to attract the markets described in the second hypothesis, they should demonstrate statistically higher shares of walking and public transportation shares relative to the regions they inhabit.

Summary of Research Design

This second chapter of this thesis, the literature review, will explore the origins of the current state of urban transportation and the implications of these conditions. Chapter two will also present a definition of transit-oriented development, and provide arguments as to why it may be an effective tool at promoting non-automobile travel behavior. Finally, the second chapter will examine literature that has previously explored the effects of urban form, socio-demographics, household characteristics, and transit-oriented development on travel behavior.

The third chapter will present the methodology used to answer the posed research questions. The study will be cross-sectional in nature, with census tracts of thirteen metropolitan regions as units of analysis. Among these census tracts, this study proposes to conduct a regression analysis in order to isolate and measure the effects that changes in various independent variables have on two dependent variables: share transit commuting and share walking/bicycle commuting. The independent variables representing urban form measures are created using geographic information systems software. Socio-demographic and household characteristics for each census tract are derived from data found in the 2000 U.S. Census. The TODs used in this study and their locations within the regions are derived from lists provided by two previous studies (Cervero et al. 2004, Renne 2005). The final two chapters present the results of the regressions analyses, and discuss how and to what degree they answer the questions posed above. The potential for other, alternative approaches to answering these questions are also raised.

Chapter 2 - Literature Review

The research questions and hypotheses which this study seeks to explore all relate to determining those qualities and characteristics of the city that appear to positively influence higher shares of non-automobile travel. The first section of this literature review will explore the history of the city. Prior to a relatively recent in which the automobile has come to dominate the urban landscape, the city was by necessity built in ways that facilitated these modes of transportation. An examination of how the former city was built may give insight into the urban form characteristics that can be emulated in order to promote those same forms of travel today.

Furthermore, exploring how the city has evolved into its current form, and what the implications of the modern, automobile-city are, reveals how seeking ways to promote alternatives to the automobile are becoming increasingly imperative. Transit-oriented development may be one way this is accomplished. The definition of TOD, and the ways it seeks to promote transit and walking/bicycle travel, is also included in this chapter. Some of the criticisms of TOD found in the literature are also discussed.

The final section of the chapter will explore the literature that has previously explored the influences of various characteristics on travel behavior. First, the literature that deals specifically with urban form measures, as described in the first research question, will be reviewed. Such characteristics include density, street connectivity, and the distance to the city center. Second, in order to gain further insight into those characteristics described in the second research question and hypothesis, the literature that examines the relationship between socio-demographic and household traits will be explored. The characteristics reviewed include race and ethnicity, foreign born status, income, and poverty status, household type and tenure, and car ownership.

Transportation History and the City

Newman and Kenworthy (1999) describe the city as evolving over the course of distinct eras according to the dominant means of transportation of the time: first the walking city, followed by rail-based cities, and finally, the modern day automobile city. In the walking city, housing selection was limited to locations within a walking distance of work and market destinations. This resulted in a city that was, by necessity, mixed-use, dense, highly connected by an organic path network, and limited in size to distances that could be traversed by foot. The vestiges of the walking city can still be found in neighborhoods in the heart of the nation's oldest cities, such as Philadelphia and Boston (Newman & Kenworthy 1999).

As Newman and Kenworthy note, the limits of the walking city were constrained by the distance a commuter was willing to travel, which they define as a 30 minute journey. Moreover, this 30 minute limit has remained relatively stable in commuting patterns. Due to advances in technology, however, the distance that can be traveled in 30 minutes has increased over time. One of these technological advances, the streetcar, allowed development in the middle of the 19th century to follow the rail into the hinterlands of the city (Newman & Kenworthy 1999, Hanson & Giuliano 2004).

This development model focused on nodes that surrounded stations and corridors along these tracks, commonly referred to as "streetcar suburbs". These nodes evolved into miniature versions of the walking city, mixed-use, and relatively dense, but were increasingly distant, albeit still connected via rail, to the city center (Hanson & Giuliano 2004, Pushkarev et al. 1982). As can be seen by this definition, in its most effective form, a transit-oriented development is no more than a modern manifestation of the streetcar suburb. Indeed, in the interest of urban revitalization (a key, though sometimes neglected component of any form of neo-traditional development), it is worth noting that the original traits of the streetcar suburb can still be found along the older streetcar corridors in the United States. TOD proponents of "new" transit-oriented developments often need look no further than these historic neighborhoods to find the foundations of all the characteristics that of modern TODs (Costello et al. 2003).

While the automobile predated World War II, it was shortly thereafter that this new form of transportation became commonplace, and rapidly began to reshape the metropolis. The freedom of mobility offered by the automobile allowed its owners to quickly fill in the interstices between the trolley lines.

Soon, the ease and speed of travel also allowed them to reside well beyond the former limits of the city, heretofore constrained by the extent of the rail network (Newman & Kenworthy 1999, Dittmar et al. 2004).

Zoning, a planning tool originally used to isolate residences from noxious, industrial land uses, now was implemented in order to create swaths of bedroom communities in the city's hinterlands. New laws and financing policies that facilitated the process of home ownership allowed the war's veterans to fill these communities with their new families. In later decades, the decline of the central city was accelerated as the national economy shifted away from manufacturing. Racial tension in the sixties further drew middle and upper class whites into the suburbs, with jobs soon following (Meyer et al. 1965, Kenworthy & Newman 1999, Burchell et al. 2002, Fishman 2000, Dittmar et al. 2004). The result of these events and trends can be summarized as a general outmigration from the city to the urban fringe and a corresponding decline of the urban core. The convenience offered by the automobile allows the city it helped bring about to be a much larger and less dense than that which preceded it, a patchwork of land-uses connected by a vast street and highway network.

The Need for New Directions

There is a widespread recognition among planners and policy makers that new strategies must be devised in order to confront growing automobile dependence and move into a new era of urban transportation and form. In the recent past, the responses to concerns over congestion have focused on increasing highway and road capacity. After years of investment of such projects, it appears these monumental and costly efforts are an insufficient means of meeting growing travel demand, and are exacerbating problems that face not only the transportation network of the city, but also quality of life of the city's residents, the global economy the city it is a member of, and the environment.

An unstable global market underlines the precarious nature of the nation's fuel supply. Even without political considerations, many researchers believe that the era of peak oil is rapidly approaching, if not already past, and that the planet's available reserve of fossil fuels, and the political feasibility of the United States' access to these fuels, will soon be unable to practically support a culture so reliant on the car. Alternative fuel sources may prove successful as stop-gap measures, but ultimately travel behavior and the city form that encourage these behaviors must be addressed (Kunstler 2006).

The environmental effects of automobile travel are also considerable. The view that human-caused greenhouse gases are responsible for rising global temperatures is becoming a more universally accepted one among Americans, as is the understanding of the implications and consequences of global warming, including rising sea levels, severe weather events, and regional ecosystem changes. While the transportation sector is not the sole contributor of greenhouse gases, it does, by accounting for 32 percent of carbon dioxide emissions, lead all other sectors, and is also responsible for the largest increases in carbon dioxide emissions between 1990 and 2000. Three-fifths of these emissions can be attributed to private car and light truck use (Cervero 1998, Litman & Burwell 2006, Millard-Ball 2007)

There are growing concerns over a nationwide epidemic of obesity, particularly among children. Automobile dependence, and the land use patterns that inevitably accompany it, not only discourage physical activity but can indeed prevent it, by encouraging streets that are at the least inconvenient, and at worse are dangerous for non-motorized travel (VTPI 2006, Handy et al. 2002).

The decentralization of wealth and opportunity in American urban areas has hastened the social, physical and economic decline of the city core. The job opportunities that follow migration to exurban locations may be inaccessible to the low-income residents, whether from the city center or from throughout the metropolitan region, insofar that most need them when car-ownership and long commutes become necessary (Meyer et al. 1965, Kain 1992).

The urban sprawl that automobile use encourages contributes to the decline of greenspace and the subsequent need for investment in infrastructure to provide for new development. Burchell, et al. (2002) estimate that, given uncontrolled, traditional growth scenarios, the United States will lose 18.8 million acres of land to urban sprawl by 2025. They further show that, under this scenario, local governments and developers will need to spend upwards of $190 billion in water and sewer infrastructure provision, $143 billion in public service expenditures, and $927 billion in roadway construction to serve these new developments.

Automobile reliance has a high costs to individuals, as well. According to the Bureau of Transportation Statistics, the average cost of owning and operating a vehicle in 2007 was 52.2 cents a mile, or $7,823 every 15,000 miles (www.bts.gov). Under an uncontrolled growth scenario, currently the status-quo, the costs of travel nationwide are 2.4 percent higher over the next 20 years than they would be under an alternative, smart growth scenario (Burchell et al. 2002).

At the least, alternatives to the automobile city demand attention, and it may very well be useful to examine the ways our city's transportation systems operated in the past, and the way many cities around the world function today. A complete return to the era of the exclusive transit corridor, wherein all development is entirely transit-oriented, is incompatible with current market demands and "…not viable in a democracy." (Dittmar et al. 2004). Nonetheless, sustainable transportation and sustainable cities are worthy attainable targets, and ones worth pursuing.

Sustainable growth meets the contemporary needs of inevitable growth without compromising the needs of future generations. Regarding the city itself, sustainability requires the reduction of resource consumption, the reduction of waste production, and an increase in livability. It is increasingly apparent that the automobile city is no longer sustainable (Newman & Kenworthy 1999, Litman & Burwell 2006). Responsible urban transportation planning must therefore involve attention toward these social and environmental concerns through reducing trip length and promoting alternatives to automobile transportation. A higher share of trips taken via public transportation, walking, and bicycling, and city neighborhoods built to encourage these shares, are essential steps in this direction. The pursuit of such goals is commonly termed as "Smart Growth".

Transit-Oriented Development is one of many strategies and that fall under the umbrella of Smart Growth. Smart Growth is a collective term for initiatives, and often supporting state and local legislation, that seek to contain urban sprawl and its subsequent social economic consequences while preserving the open space, farm, forest, or otherwise, that surrounds the city. (Daniels 2001, Smart Growth America 2002).

The practices of Smart Growth demonstrate the efficacy and practicality of integrating sustainable transportation and land-use policies. These practices include redevelopment and/or retrofitting of abandoned or otherwise underused suburban land with more mixed land-uses and highly concentrated development, the production of accessible public spaces, accessibility within the pedestrian realm, and sufficient provision of transit (Smart Growth America 2002, Daniels 2001, Bullard 2007). When applied individually or haphazardly, these policies can exacerbate problems. For example, when density is encouraged without adequate provision of transit, congestion may in fact worsen. When applied holistically, however, the result can be a human-scale environment wherein walking and transit are not only viable, but attractive alternatives to automobile use, and where communities are more inclusive, diverse, and cohesive (Littman & Burwell 2003).

Transit Oriented Development

The literature offers several definitions of Transit-Oriented Development. Most of these definitions can be summarized in the way that Bernick and Cervero define the Transit Village (a phrase, along with 'transit-focused development', that is synonymous with Transit Oriented Development) as "…a compact, mixed-use community, centered around a transit station that, by design, invites residents, workers, and shoppers to drive their car less and ride transit more." (1997 5).

Within the TOD, urban form measures such as density, a fine-grained mix of uses, and a highly connected street and walkway network provide accessibility to a variety of destinations via walking and/or bicycling. Beyond these macro-scale features, TODs often demonstrates additional "New Urbanism" amenities, such as green space, human-scaled architecture and streetscape, traffic calming measures, and limited parking, that promote and ease pedestrian and bicycle trips while providing alternatives to, if not discouraging, automotive travel (Cervero 1998). The transit station is not simply adjacent to this development, it is integrated into the fabric of the TOD and serves as its focal point: a community center, village square, and prominent public space. It should be within walking distance of all points in the TOD (Cervero et al. 2004).

As critical as these physical factors are, Dittmar and Poticha point out that the definition of a TOD must be expanded beyond these descriptive terms (2004). In their "performance-based" definition, five goals must be achieved for the term transit-oriented development to truly be applicable. One of these, location-efficiency, includes the physical amenities mentioned above, such as density and transit availability. The second, a mix of choices, includes not only the mix of land uses, but also a mix of housing choices suitable not only for traditional families, but for those who may find extra value in the transportation options offered by TOD, such as lower incomes families, single parent households, the elderly, and the disabled.

Thirdly, the phrase "value capture" refers to the economic value of TOD. This value can be to households, who see reduced costs in transportation and increased value in property, to local governments, who see increased tax revenue from higher property values, and to transit-agencies, who can benefit from joint development of property opportunities and from potentially higher fare box revenue. Fourth, place-making is a key component of TOD. This involves all the above components, but implemented with high quality design so as to make such neighborhoods not only convenient, but attractive and vibrant.

The final component described by Dittmar and Poticha is the resolution of tension between node versus place. In large part, this refers to ensuring that while the transit station continues to function as a transit access point, it also serves as the focal point of a living neighborhood. As a node in the region-wide network, the transit station is likely a significant source and destination for travelers throughout that region. Despite the fact that such stations often see the most activity during peak travel times, the successful TOD maintains its 24-hour vibrancy outside non-work hours by including non-work destinations, such as a variety of entertainment opportunities (Dittmar & Poticha 2004).

Criticisms of Transit Oriented Development

Criticism of transit-oriented development falls into two categories. The first of these concerns the efficacy of TOD in producing its purported benefits, namely, producing higher shares of transit ridership and reducing shares of automobile trips. Many of these criticisms have more to do with the relative youth of the concept as well as the subsequent difficulty in truly defining what constitutes a TOD and what does not. This criticism may be justified, insofar as there may be a need for further research into the outcomes of TOD by its proponents, as well as a more precise, strict definition of what qualifies as a TOD.

The most characteristic misapplication of the term transit-oriented development is to those developments that, while proximate to transit stations, are not truly "oriented" with them. These developments, referred to in the literature as "transit-adjacent developments", often fail to capitalize on potential transit ridership by not integrating with the urban fabric of the surrounding community, or by not containing the appropriate urban fabric (Cervero et al. 2004). As Dittmar and Belzer state, "Somewhere between the conceptualization and opening day, many projects end up being fairly traditional suburban developments that are simply transit adjacent…" (2004, p. 4). This shortcoming, therefore, may best be attributed to inadequate guidelines in determining what can be called a TOD more than the actual concept of TOD itself.

The second category of criticism is leveled not only at TOD, but at the tenets and outcomes of the neo-traditional development as a whole. Regarding this aspect, one of the most relevant criticisms is the displacement of low-income and/or minority populations that takes place in many urban redevelopment projects, and the subsequent gentrification of these neighborhoods due to their appeal to middle and upper class residents (Bohl 2000, O'Toole 2001)

These outcomes may be attributed to a lack of foresight in the planning process or, whether intentional or otherwise, the failure to implement specific policies at protecting the affordability of new housing against inevitable market forces. Alternative policies or strategies designed to maintain or create this affordability, and attract the multiplicity of ages, cultures, income levels, and race that the New Urbanists tout as key precepts, should therefore be a part of any such development. At the design level, a diversity of housing types is necessary. At the policy level, incentives and land-use provisions, such as density bonuses and inclusionary zoning measures should be included (Bohl 2000, Dittmar & Belzer 2004, Katz 1994).

Urban Form Measures

The first research hypothesis of this study states that urban form measures do have an influence on travel behavior. More specifically, density, street connectivity, and proximity to the central business district will have a positive effect in promoting non-motorized travel, while perhaps discouraging automobile travel. The following section reviews the literature that has previously explored, and to varying degrees, confirmed these notions.

Density and Travel Behavior

The effect of density on mode choice is demonstrated in several studies, with higher densities nearly always correlating with lower automobile usage and higher mode splits among walking, bicycling, and public transportation (TRB 1996). This effect is in large part attributed to the increased distances to destinations as densities decrease, and a subsequent need for an automobile to reach them. When that destination is a transit stop, there are simply not enough people within a conveniently walkable distance. When densities are low, even the most extensive provision of public transportation, be it bus or rail, will prove ineffective and show low ridership. In these circumstances, the provision of public transit becomes both impractical and uneconomical (Newman & Kenworthy 1989).

Another aspect of this affect is that while transit ridership is notably more convenient in higher density locales, automobile ownership and automobile use are often comparably less convenient. As Pushkarev et al. state, density alone can serve to lower automobile speeds as well as raise the costs of purchasing, maintaining, and operating a private vehicle (1982).

Frank & Pivo (2002) also record noteworthy impacts of density on transit ridership and walking. In a study conducted in Seattle, they demonstrate that employment density, in particular, can have substantial effects on mode choice, particular when a threshold of 75 employees per acre is reached. Even at lower densities, between 20 to 50 employees, the result was a significant decreases in single-occupancy vehicle travel. The authors also found that when population density reaches a threshold of 13 persons per acre, or approximately seven to nine dwelling units, a notable shift from single occupancy vehicle (SOV) to walking or transit use occurs. Holtzclaw (1994) concludes that a doubling of residential population would result in a 20 to 30 percent per capita or household decline in annual vehicle miles traveled.

Street Connectivity

A highly connected street network is generally presumed in the literature as being positively correlated with higher mode splits among walking, biking, and public transportation. The San Diego Regional Planning Agency's *Planning* *and Designing for Pedestrians* (2002) describes the challenges presented to walking by a dendritic street pattern, one that is characterized by a hierarchy of smaller streets feeding into one or few major arterials, a pattern often seen in more suburban environments (figure 1). The walking distance between two points in such a pattern is often so much higher than the straight-line distance that automobile travel is preferable. An interconnected "grid-iron" road network (figure 1), by comparison, offers more linkages, nodes, and, therefore, alternate, and subsequently shorter routes to potential destinations, including transit stops.

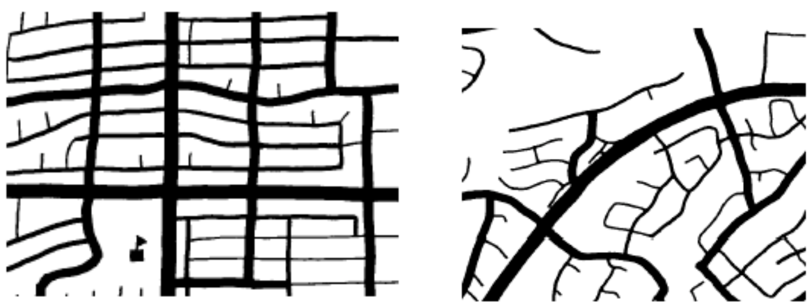

Figure 1: Gridiron (Left) and Dendritic Street Patterns (Right) (SANDAG Planning and Designing for Pedestrians (2002)

Porta and Renne (2005) similarly identify the network connectivity within a "pedshed", or the walkable catchment around a transit stop, as a key measure of social sustainability in a community. Cervero and Gorham (1995) cite studies that, through land-use/transportation modeling, show that gridiron street patterns can reduce vehicle miles traveled by at least ten to fifteen percent, and in one case, as much 43 percent.

Another study includes a survey in both the San Francisco Bay and Portland areas, inquiring of those who walked to one of six transit stations what the primary factor was as to how they selected their preferred pedestrian route. By far, the leading answer is that the chosen route is the shortest and/or fastest, above other considerations such as safety, aesthetics, or habit (Weinstein et al. 2006). Implicit in the study and in its results is that walking trips may best be encouraged through provision of a navigable, highly connected path network, such as that provided by a traditional, gridiron street pattern.

Song and Knapp (2004), in measuring the effects of Portland, Oregon's land use policies in controlling sprawl, use network connectivity as a measure of sprawl. While their study did not specifically examine how these factors influence travel behavior, this paper draws from their research by using a similar methodology in measuring connectivity, a counting of links and nodes, and correlates these measures with transit ridership.

Proximity to Central Business District

Newman and Kenworthy state that proximity to the central business district (CBD), or a dense commercial and economic core of the city, strongly correlates with public transportation use (1989). Even as employment and activity centers form throughout the "polycentric city", workers in the CBD are still far more likely to use transit. According to one study, workers in the Houston CBD are five times more likely to use public transportation. When a San Francisco firm relocated to three suburban campuses, transit use among its employees fell from 58% to 3%, although commute times between shares remained about the same (TRB 1996). A similar study in Vancouver found that 61% of the employees at a firm's downtown office used public transit to get to work, while at its suburban, satellite location, 83% commuted by car (Ley 1987).

These examples stand to reason, given that, despite the increasing metropolitan dispersion of jobs to the suburbs, the CBDs of many cities contain those physical characteristics, including employment density, that promote transit ridership, and are therefore more likely to be better served by all forms of public transportation. (TRB 1996, Pushkarev & Zupan 1977). It may also stand to reason that the closer a worker resides to the CBD, the more likely they are to commute via public transportation, simply because there are more opportunities to do so. The exception may be light rail and commuter rail systems, which generally radiate from the city center and ideally run along developed corridors or through pockets of density, such as transit-oriented developments, wherein ridership is more reliant on proximity to stations than to the CBD. These systems work well to feed workers from even fairly distant suburban locales to the downtown, but are generally less effective at moving workers among the suburbs themselves (TRB 1996).

Socio-Demographic and Household Characteristics

The second hypothesis of this study presumes that certain socio-demographic and household characteristics will influence the selection of automobile, public transportation, or walking/bicycle as the primary mode of commuting. These characteristics can be divided into two categories. Of the former category, this study examines race and ethnicity, income and foreign-born status. Of the latter, family versus non-family households are considered, housing tenure, and car ownership are considered. The following section explores the literature that examines the relationship between these characteristics and transportation mode choice.

Income

The relationship between income and public transportation use is, for the most part, an intuitive one. The cost of purchasing and maintaining an automobile is often prohibitively expensive for low income families, and therefore their share of transit trips should be higher. Murakami and Young. (1997), in a review of the *1995 National Personal Transportation Survey*, confirm, in large part, these assumptions.

Low income households in this study are defined as those with 1-2 persons making $10,000 or less, 3-4 person making $20,000 or less, or over five persons making less than $30,000. They found that while 26% of these households do not have a car (compared to four percent of other households), private automobile use is still prevalent, with many trips shared in the cars of friends or relatives (eight percent, as compared to less than percent among the rest of the population). The cars that such households do own average 2.7 years older than cars in other households (Murakami and Young 1997). The age of these automobiles undoubtedly has implications on maintenance costs.

That said, transit use is definitively higher in low-income households, with five percent of work trips taken by public transportation (Murakami et al. 1997). Also noteworthy is that low income households are twice as likely to travel to work by foot. Consequently, 60 percent of trips taken are within three miles or less. This increases to 66 percent for households with a single parent (Murakami et al. 1997).

Race and Ethnicity

Race and ethnicity, in this study, will include examinations of the relationship between minority populations, including the foreign born, and public transportation use and walking travel behaviors. While the overall percentage of trips taken by public transportation has fallen substantially, the proportion of transit trips taken by non-whites has increased steadily (Garrett & Taylor 1999). Pisarski further shows that while the number of African-American Households with no vehicle has declined between 1990 and 2000, the 24% that remain is still three times as high as the percentage of whites with no car (Pisarski 2006). Given the spatial mismatch that often occurs when concentrations of minorities in the inner city are left without adequate access to jobs in the suburbs, the need to provide adequate and appropriate public transportation, and the need to create new housing and proximate work opportunities for minority populations, is crucial (Garrett & Taylor 1999, Kain 1994).

Trips taken by walking and/or bicycling are also worth commenting on for the African-American urban population, although for different reasons. Obesity, while a national epidemic, disproportionately affects the black population, particularly African-American women, of whom 77% can be classified as overweight and 50% as obese (Kumanyika et al. 2005). The Center for Disease Control further reports that African Americans are 1.7 times more likely to suffer from diabetes than whites, and among those affected, are more likely to suffer its debilitating effects (CDC 2004). While the range of public health disparities that contribute to these issues goes far beyond the built environment, it has been argued that the neighborhoods in which minority populations often reside are inimical to the walking and/or bicycling allowed by more pedestrian friendly environs (Crespo et al. 2000, Cervero & Duncan 2003).

Of equal importance is attention to the influence of foreign born, or immigrant, populations, on non-private automobile travel. According to the US Census, the size of the foreign-born population, and its rate of growth, has increased dramatically in recent three decades, from approximately 9.6 million in 1970, to 19.8 million in 1990, to 31.1 million in 2000, and even these figures likely represent a vast undercount due to unaccounted levels of illegal immigrants. The origin of these populations is mostly Latin America, primarily Mexico, though significant numbers also hail from Asia and elsewhere. (Casas et al. 2004, Passel & Suro 2005).

Studies have found that it is the first generation of immigrants who are most likely to depend on public transportation. In California, one study demonstrated that as much as 47 percent of all transit users were born on foreign soil (CTOD 2005, Blumenberg & Evans 2006). This can mostly be explained by economic limitations newcomers are presented with, although it is worth noting that in at least one study that controlled for income, recent immigrants still show higher transit ridership than the native-born population. This may in part be explained by the nations of origin these immigrants hail from, many of which exhibit a different culture of public transportation use (Blumenberg & Evans 2006). Regardless, this prevalence of transit use tends to decline, and private automobile ownership increase, as immigrant populations assimilate, and this trend is even more pronounced among second and third generations (Blumenberg & Evans 2006, Casas et al. 2004).

Household Type

The changing housing, transportation, and lifestyle demands of an aging baby boomer population and their children, the "echo-boomers", are indicative of trends in the population denoting what is, and what looks to increasingly become, a need for smaller dwellings in more compact, urban environments. The baby-boomer population can be defined as the generation born during the economic boom following Second World War, generally defined as the years between 1945 and 1964, the members of which, in 2007, are aged from 44 to 62. In terms of this study, this cohort is significant for two reasons, the first being the size of this generation (over 76 million, or 28% of the adult population (Dohm 2000). The second reason is that this generation either has reached, or is rapidly approaching, the age of retirement and, as children move out, the age of the empty nest.

The suburban environment may not be suited to meet the needs of this generation, and it is possible that empty nesters may opt out of their suburban homes in favor of more urban contexts. In these contexts, apartments and condominiums are more suited to smaller families, lifestyles are more suited to families without children, and diverse services and cultural amenities are more accessible (CTOD 2005, Fishman 2000). According to the *Commuting in America III* report, this shift is already taking place. The share of workers over 55 traveling to work in single-occupant vehicles declined from 80% to 68% between 1990 and 2000, while shares of those travelling via transit, carpool, and walking or simply working at home, showed respectively, moderate to significant gains (Pisarski 2006). Furthermore, given the physical limitations of the elderly, the safety concerns that arise when such limitations are combined with automobile use, and the health concerns that may arise among seniors when mobility and physical activity is limited, the need to supply this cohort with alternative transportation options can only be expected to rise in coming decades (Berke et al. 2007).

This increased need for smaller housing units and the cultural diversity offered by the city is emulated by many among the younger generation.

Demographics show that the size of the household is shrinking. Not only are married couples having less children, the number of households consisting of a married couple with any children, a demographic that defined previous generations, has itself declined from 40 to 26 percent between 1970 and 2000. The remaining three quarters of households are typically characterized by non-traditional arrangements, such as married couples with no children, single parents, non-married couples, or single persons. These trends may lead toward a population shift away from the suburbs and back into the city centers where accommodations, such as apartments and condominiums, are more suited for smaller families and households (Fishman 2000).

There are also signs of an accompanying shift within the national economy away from the manufacturing and service industries and toward information and technology based sectors. At the forefront of this shift is what is known as the "creative class", the members of which are in many cases the same demographic tending toward smaller households and subsequent migration back into the city. Having been, in many cases, raised in the suburbs themselves, these workers are seeking the economic opportunities, cultural amenities, and 24-hour lifestyles offered by the city. Cities are noticing the potential this demographic has to offer toward reviving declining urban centers, and the competition toward attracting them involves improving housing opportunities such as condominium style apartments, rejuvenating streetscapes, and restoring and enhancing attractive public transportation (Clark et al. 2002, Fishman 2000, CTOD 2005, Florida 2005).

Car Ownership

Overall, in 2000, about five million workers lived in households with no vehicles. As noted above, the discussion of car ownership is difficult to isolate from a discussion of income because, with rare exceptions, the lack of a car is tied closely with the inability to afford a car. That said, there are workers with the financial wherewithal to purchase a vehicle who choose not to, presumably due to alternative transportation preferences and/or opportunities. As an example, among households with an income meeting or exceeding $100,000 a year, 4% do not own a car (Pisarski 2006).

Nonetheless, despite these exceptions, when even the $35,000 a year threshold is reached, the shift from one car households to two or more begins to show substantial increases. Given that around 70% of U.S. households have at least two workers present, it is worth noting that the number of cars available affects commuting habits nearly as much as does the absence of a car (Pisarski 2006).

For example, Holtzclaw (1994) found, in a study of communities in the San Francisco Bay area, a strong correlation between auto-ownership and vehicle miles traveled (VMT) by individuals and households. VMT, he reports, increases by an average of 1703 miles for each car added to a household. Pushkarev et al. (1982) found that bus and rail transit ridership correlated strongly with household with no cars. They further note that when one car is added to households, while bus ridership declines drastically, rail transit ridership remains the same as it would with no car, provided that the transit station is within 2000 meters of the residential origin. If, however, two or more cars are available, all forms of transit ridership decline significant.

Chapter 3 – Methodology

The following chapter describes the methodology used to conduct this study. The hypotheses propose relationships between transit and walking/bicycle commuting and three categories of characteristics: urban form, socio-demographic/household type, and transit-oriented development. Data representing each of these categories was either created, as in the case of the urban form variables, or collected from other sources, such as the 2000 U.S. Census and previous research efforts, as in the case of socio-demographic and household characteristics and transit-oriented developments. The unit of analysis is the census tract, the level at which data for each variable was created and/or collected. In total, there are over 19,346 census tracts divided among thirteen metropolitan regions considered in this study.

This study then utilizes a multiple linear regression analysis in order to test the existence, direction, and strength of the relationships between each of these independent variables and the dependent variables: transit commuting and walking/bicycle commuting. These regression analyses were conducted at two scales: all regions and individual regions. The first examines relationships among all regions, and includes every census tract in the regression. The second looks independently at the relationships that exist within each of the thirteen regions and the census tracts contained therein.

Units of Analysis

The unit of analysis in this study is the census tract, the scale at which data was collected. A larger unit, such as a county, is far too large to accurately distinguish differences in community or neighborhood level characteristics. Similarly, while census blocks or census block groups may have had the advantage of a more precise delineation of TOD limits, the amount of data available at this scale was insufficient for the purposes of this study.

This census tracts studied occupy thirteen metropolitan regions. To provide consistency between the data and the geographies they represent, the extent of these regions, i.e., the counties and/or cities included, follows the Metropolitan Statistical Area (MSA) definitions used for the 2000 U.S. Census. The regions in this list are appropriate for this study for two primary reasons:

First, in order to accurately compare the performance of transit-oriented development to regions as a whole, all MSAs must contain at least one TOD that matches the definitions provided above. Second, the cities represent a diverse selection, i.e., different population size and types, economies, transit types and ages, and locations throughout the nation. The variations in public transportation use can be expected to differ from city to city for various reasons, such as well-documented and understood dissimilarities between national regions due to differences in city age, forms, and cultures. Furthermore, what qualifies as dense development in some areas, such as the Midwest, will differ from what is considered dense in east coast cities. This diversity was therefore considered helpful in accounting for such disparities. The MSAs, and the TODs identified for this study that occupy those MSAs, are listed in Table 1.

Dependent Variables

The two dependent variables in this study describe the commuting mode splits among residents of census tracts, and were derived from the 2000 United State Census Summary File 3 (See Table 2 for a list of both the dependent and independent variables). The first of these includes the percentage of trips taken to work via public transit. The second includes the percentage of trips taken to work via other means. These are percentages of all workers aged sixteen and over, including those that drove to work alone (in a car, van, or truck), drove to work in a carpool, or worked at home. The phrasing of the census questionnaire asks the way that a worker traveled to work the most in the week prior. If a mode transfer was included (for example, walking most of the way, then taking the bus, or taking a car to a park and ride), the respondent was instructed to report the mode "used most of the distance" (Reschovsky 2004).

The work trip via public transportation is an aggregate of all such trips taken by any form of transit, including taxi, ferry, bus, streetcar, subway, railroad, or light rail. While the former two are less relevant to a study of public transportation, it should be noted that in 2000 the latter five only accounted for four percent of all such trips. Trips via public transportation accounted for 4.7 percent of all commutes in 2000.

Atlanta, GA MSA	**New York, NY**	**Salt Lake City**
Pop - 4,112,198	***Pop - 21,199,865***	***Pop - 1,333,914***
Georgia State	Mount Vernon Station East	Delta Center
Midtown Station	Ossining	4400 South Station
Arts Center	New Rochelle	Pop -21,199,865
Lindbergh City Center	Yonkers	
	White Plains	**San Francisco, CA**
Chicago, IL MSA	Rutherford	***Pop - 7,039,362***
Pop - 9,157,540	South Orange	Concord BART
Evanston-Davis St.	Morristown	Rockridge BART
Evanston-Dempster	Metuchen	Daly City BART
Evanston-Main	Rahway	El Cerrito del Norte BART
Marion Street Station	South Amboy	Downtown Berkeley BART
Arlington Heights Station	New Brunswick	Lake Merritt BART
Riverdale Metra	Cranford	Fruitvale BART
Woodstock Metra	Ridgewood	Hayward BART
Franklin Park	Linden	Fremont BART
	Elizabeth	Embarcadero BART
Dallas, TX MSA	Denellan	16th-Mission BART
Pop - 5,221,801	Plainfield	24th-Mission BART
Mockingbird Station	Summit	Colma BART
Southside on Lamar	Westfield	Bay Meadown (San Mateo)
Galatyn Park	Bound Brook	Davis Station
Plano Transit Village	Somerville	Martinez Station
Westwide Village	Belmar	Emeryville Station
Cedars Station	Mattawan	
	Bloomfield	**Washington DC-Baltimore, MD**
Denver, CO		***Pop - 7,608,070***
Pop - 2,581,506	**Philadelphia**	Owings Mill Metro
Englewood City Center	***Pop - 6,188,463***	Cultural Center
I-25/Broadway	Collingswood	Lexington Market Metro
		Silver Spring Metro
Los Angeles, CA	**Portland, OR**	Bethesda Metro
Pop - 16,373,345	***Pop - 2,265,223***	Grosvenor Metro
Hollywood/Highland	LaSalle Apartments	Twinbrook Metero
Central Park Market at Del Mar	Greshem Civic Neighborhood	Gallery Place - Chinatown
Pine Court (Long Beach)	Russellville Commons	White Flint
Holly Street Village (Pasadena)	Stadium Station Apartments	Rosslyn
North Hollywood Arts District	Collins Circle	Courthouse
Montage at Village Green (Sylmar)		Ballston
	Miami	Claredon
San Diego	***Pop - 3,876,380***	Virginia Square
Pop – 2,813,833	Dadeland North	Pentagon City
American Plaza	Dadeland South	Crystal City
Rio Vista West		
Hazard Center		**Denver, CO**
La Mesa Village Plaza		***Pop - 2,581,506***
Village of La Mesa		Englewood City Center
Mercardero at Barrio Logan		I-25/Broadway

Table 1: List of MSAs and TODs. List was derived from Cervero et al. 2004 and Renne (2005)

The work trip via other means is an aggregate of all commute trips taken via some mode other than the private automobile or public transportation, including walking, bicycling, or motorcycling. Such trips accounted for 4.1 percent of all commutes in 2000.

Dependent Variables	
Percent Commuting to Work via Public Transportation	
Percent Commuting to Work via Walking	
Independent Variables	
Socio-Demographic	**Urban Form**
Percent White	Population Density (per square mile) *
Percent Non-white Hispanic	Household Density (per square mile)
Percent African American *	Number of Links
Percent Foreign Born *	Number of Nodes *
Percent Non-Family Households *	Distance from City Center (miles) *
Average Household Income	Presences of Transit-Oriented Development
Average Family Income	
Average Per Capita Income *	
Percent At or Below Poverty Rate *	
Percent Renter Occupied Housing *	
Percent Owner Occupied Housing	
Percent Married with No Children	
Percent Households with one or no cars	

Table 2: List of dependent and independent variables. An asterisk indicates that the independent variable was included in study after the test for collinearity.

Urban Form Independent Variables

The author used ESRI ArcView 3.3 and ESRI ArcMap 9.0 software to create the following urban form variables. Census tract boundaries and street centerline shapefiles, derived from TIGER Line files, were created and downloaded from the ESRI online dictionary. At times, these files were altered in order to perform the necessary analyses. For example, the census tract shapefiles, which are initially downloaded for each county and/or city in an MSA, were merged into one shapefile representing the entire region so as to perform analyses at that scale. The same process was necessary for, and performed on, street centerline files.

Links and Nodes

This study defines a link as a road segment between two intersections, or as a "hanging" road, a cul-de-sac style street that intersects another street at one end. The following process was used to create a ArcView shapefile that included all the links in an MSA's roadway network. All streets in each MSA, after conversion to a single shapefile (as described above), were dissolved into one single-attribute line[1]. An ArcMap script was then used to "break" this solid line into several line features, or distinct segments, at each intersection point. This process was warranted due to the nature of the original TIGER line files where the road segments of which are not always distinguished from its neighbors when it meets an intersection. By manually breaking the lines at each intersection, it was possible to count each distinct link.

Nodes, in this study, are defined as the point at which two or more links meet, essentially a street intersection. "Hanging" nodes, or nodes at the

[1] That is, whereas the original shapefile may have included thousands of individual "features", or street segments, each with attributes such as name, type, or geo-coding end-points, the dissolving process merges them into one, unbroken line with only one set of attributes. Though this dissolve by necessity eliminates all of these unique attributes, they were not deemed relevant to the study.

terminus of a cul-de-sac type street-way, were not considered. A shapefile including all of the nodes in an MSA was created using an ArcMap script on the line file created in the previous step. The script automatically created a point feature at the intersection of any two line features.

Finally, the created street links and nodes shapefiles were spatially joined with a shapefile containing the boundaries of all census tracts in an MSA. This created a new attribute for each census tract showing the total number of links and nodes contained within it. When a link crosses a census tract boundary it is counted twice, once for each tract it occupies.

Distance from City Center

A point feature was created in ArcView for the central train station in each region. Another script created a shapefile containing the centroid, or geometrical center, of each individual census tract. When these two shapefiles were joined, an attribute class was created in the latter shapefile describing the distance between each centroid and the "city center" point.

The decision to use the central station as the "city center" was made for two primary reasons. First, a city's main terminal is generally connected to the entire rail network in the region, including the metropolitan area's transit-oriented developments, and therefore the station could arguably be considered the true center, if not of the city itself, then at least of its transit network. Secondly, it is expected that if distance from the city center becomes a factor in influencing transit ridership, this influence will not become considerable until more substantial distances from the CBD are reached. While other city center features could have been selected, it is assumed that they would not have effectively altered the results due to their presumed proximity to the station.

Transit-Oriented Development Independent Variable

The 103 TODs selected for this study were derived from a list compiled in *Transit Oriented Development in the United States: Experiences, Challenges, and Prospects* written for the Transit Cooperative Research Project by Cervero et al. (2004) and modified by Renne (2005). For the purposes of this study, a census tract was considered to be a "TOD" census tract if it intersected in any way the stated boundaries of these TODs. If the tract did intersect, it was assigned a dummy variable of "1". All other census tracts were assigned a "0". This methodology had one obvious shortcoming, which is that even if the TOD only clipped the periphery of a tract, it was still considered a TOD census tract. Thus, the characteristics of the tract may not have been representative of the TOD itself. A lack of knowledge as to how often and exactly where such discrepancy took place prevented a more specific analysis, and therefore discrepancies had to be overlooked. Given the scale of the study, regionally and among all regions, it was hoped that such a limitation would not have a drastic effect on the results.

Another potential limitation, as mentioned above, is that the TODs were, in many cases, self-reported for the TCRP study. While the TODs generally meet the basic qualifications that the development be mixed use, relatively dense, and within a given radii of a transit station, the degree to which each achieves the necessary distinction between transit-oriented development and transit-adjacent development varies.

Socio-Demographic Independent Variables

Socio-Demographic variables in this study were derived from the 2000 United States Census. Regarding race and ethnicity, the share of a census tracts White, African American, Hispanic, Foreign Born populations was considered. Regarding income, the study looked at the census tract's average household income, average family income, average per capita income, and percent at or below the poverty level. Household type variables include renter and owner occupied households, families that are married with children, non-family households, and households with one or no cars. Densities of both populations and of households were also considered. These variables are listed in Table 2. Descriptive statistics were also calculated for all regions, and are listed in Appendix I.

While the base data was derived from the census for all of these variables, in some cases it was by necessity manipulated for inclusion in the model. As an example, while the aggregate number of African American persons residing in a census tract was available from census data, the regression model required relative comparisons between census tracts, and therefore the percent of such households out of all total persons was calculated. Another example includes population and household densities, which are not available from the census. The total number of persons and households, however, was available, and densities were determined by dividing the tracts square mileage by this figure.

Multiple Linear Regression

This study measures the relationships between the independent variables and the dependent variable by way of a linear regression model analysis. The regression analysis determines the relationship between an independent variable (in this case, the commute to work patterns) and a series of dependent variables, isolating the effects of all other variables considered in the model. While a linear regression analysis is unable to indicate underlying causation (i.e., the model cannot reveal that the reason the percent commute to work via walking is high is because density is high), it does reveal statistical relationships and predictors (if density is increased to a certain degree, it can be expected that walking would to work would increase by a statistically determined degree).

Before the regression can be run, variables were tested for colinearity via a test of correlation among available variables. Colinearity refers to instances wherein two or more variables correlate highly enough that the regression model is unable to isolate their individual effects on the dependent variable. A good example of this within this study is the variables representing the number of links and the number of nodes. Given the geographical relationship between links and nodes, they naturally correlate so highly that only one should remain in the regression model. Table 2 indicates those variables that were, by this necessity, discarded from the study. In many cases, as can be seen, it would have been useful to show the relationships between, for example, both Hispanic populations and Foreign Born populations and transit ridership, the former of which was eliminated to maintain the validity of the model. This difficulty is, regrettably, common in such studies wherein linear regression is used to explain ridership, as many explanatory variables are so often economically intermingled (Blumenberg & Evans 2006). One solution is to run the regression twice, one with one variable and then again with the collinear variable. While this solution was not pursued in this study, it may be useful to do so in later studies of a similar nature.

Potential Limitations of the Analysis

The primary determinants of transit ridership fall into two categories. The first of these, demand-side, refers to those factors that have an external influence on transit ridership, such as income, race, density, etc., that are outside of the policy decisions of cities and transit-agencies. The study focuses almost solely on demand-side factors. In doing so, however, it neglects the second category, supply-side, which refers to those factors that are controlled by the transit agency itself, such as fare rates, coverage, and frequency. The effects of supply-side factors is perhaps just as significant as demand-side (Cervero 1998). The limited availability of supply-side data among all the regions examined, however, prevented examination of the former, and this limitation undoubtedly warrants further consideration in later studies.

A second significant limitation was the exclusive use of travel-to-work by way of both public transportation and walking/bicycling data, which excludes other substantial trip generators and destinations, such as travel-to-retail or travel-to-school, etc. This limitation may be significant, given that, according to the 2001 National Personal Transportation Survey, only 11.1 percent of total trips taken were commute to work trips (NPTS 2001). This is, however, the only type of trip reported by the US Census, the source of data used in this study due to its geographical extent and availability.

Chapter 4 – Results and Analysis

Over the 13 regions examined, the characteristics of 19,346 census tracts were tested for their relationship to both transit ride-to-work and walk-to-work mode shares. The results of the regression model for transit ride-to-work are summarized in Table 3, and the regression model for walk-to-work is summarized in Table 4.

The significance, or the "fit", of the relationship between the independent variable and the dependent variable is determined with the level significance value. A level of significance value of .001 or lower indicates a strong fitting relationship (signified with three stars, "***", in the summary tables), a value between .01 and .001 a moderately good fit (**), a value between .01 and .05 a weak, albeit existing relationship (*), and a beta value above .05 a statistically non-existant relationship (NS).

A positive Beta value indicates a positive relationship between the two variables, whereas a negative value points toward a negative relationship. This value indicates to what degree the dependent variable could be expected to change if the independent variable is altered, either increasing in the case of a positive relationship, or decreasing in the case of the negative relationship. The further from 0 the beta value is, the more substantial the effect will be.

	Adj R-Sq	Total df	Share Foreign Born		Share African American		Per Capita Income		Population Density	
ALL REGIONS	0.671	19346	0.029	***	0.25	***	0.126	***	0.571	***
Atlanta, GA	0.737	656	-0.101	***	0.186	***	0.069	*	0.123	***
Chicago, IL	0.689	2043	-0.211	***	0.088	***	0.168	***	0.227	***
Dallas, TX	0.621	1023	-0.107	**	0.237	***	0.056	*	0.174	***
Denver, CO	0.535	598	0.075	*	0.208	***	0.088	*	0.211	***
Los Angeles, CA	0.642	3319	0.122	***	0.05	***	0.063	***	0.396	***
Miami, FL	0.721	618	-0.155	***	0.155	***	0	NS	0.057	NS
Philadelphia, PA-NJ	0.728	1565	0.037	*	0.403	***	0.11	***	0.293	***
Portland, OR	0.744	467	-0.084	*	-0.064	NS	0.053	NS	-0.029	NS
New York, NY-NJ-CT	0.772	5060	0.119	***	0.144	***	0.11	***	0.333	***
Salt Lake City, UT	0.597	279	-0.032	NS	-0.142	*	-0.037	NS	-0.093	NS
San Diego, CA	0.567	595	0.128	***	0.079	*	0	NS	0.125	**
San Francisco, CA	0.694	1438	0.003	NS	0.042	*	-0.015	NS	0.364	***
DC-Baltimore, MD	0.734	1673	0.023	NS	0.33	***	0.15	***	0.265	***

	Percent Renting		Percent Below Poverty		Percent Non-Family HH		Nodes		Distance to City Center		TOD Present	
ALL REGIONS	0.07	***	0.099	***	0.013	*	-0.033	***	-0.123	***	0.001	NS
Atlanta, GA	0.146	**	0.511	***	-0.172	***	0.009	NS	-0.235	***	0.053	*
Chicago, IL	0.192	***	0.15	***	0.069	**	-0.053	**	-0.368	***	-0.009	NS
Dallas, TX	-0.002	NS	0.538	***	-0.028	NS	0.127	***	-0.334	***	-0.061	*
Denver, CO	-0.045	NS	0.457	***	0.159	**	-0.013	NS	-0.055	NS	0.04	NS
Los Angeles, CA	0.035	NS	0.379	***	-0.041	**	0.059	***	-0.106	***	-0.664	NS
Miami, FL	0.161	***	0.467	***	0.072	*	-0.026	NS	-0.298	***	0.031	NS
Philadelphia, PA-NJ	0.006	NS	0.281	***	-0.016	NS	0.017	NS	-0.177	***	0.017	NS
Portland, OR	-0.157	*	0.359	***	0.682	***	0.056	NS	0.064	NS	0.175	***
New York, NY-NJ-CT	0.054	***	0.169	***	0.073	***	-0.065	***	-0.306	***	-0.072	***
Salt Lake City, UT	0.067	NS	0.516	***	0.25	***	-0.01	NS	-0.302	***	0.08	NS
San Diego, CA	0.078	NS	0.45	***	0.018	NS	0.039	NS	-0.078	*	0.151	***
San Francisco, CA	-0.001	NS	0.097	***	0.172	***	0.011	NS	-0.458	***	-0.001	NS
DC-Baltimore, MD	0.028	NS	0.325	***	0.081	***	0.015	NS	-0.218	***	0.074	***

Table 3: Results of regression analysis between share commuting via public transit and independent variables.

	Adj R-Sq		Total df		Share Foreign Born		Share African American		Per Capita Income		Population Density	
ALL REGIONS	0.327		19346		-0.067	***	-0.181	***	0.058	***	0.151	***
Atlanta, GA	0.311		656		-0.193	***	-0.397	***	-0.294	***	0.052	NS
Chicago, IL	0.238		2043		0.007	NS	-0.225	NS	0.063	*	-0.035	NS
Dallas, TX	0.36		1023		0.146	***	-0.144	***	0.04	NS	-0.061	NS
Denver, CO	0.523		598		-0.097	**	-0.096	**	0.171	***	0.013	NS
Los Angeles, CA	0.281		3319		-0.16	***	-0.213	***	-0.11	***	-0.133	***
Miami, FL	0.299		618		-0.332	***	-0.201	***	-0.099	NS	0.03	NS
Philadelphia, PA-NJ	0.395		1565		-0.241	***	0.048	*	0.021	NS	0.203	***
Portland, OR	0.618		467		-0.084	*	-0.064	NS	0.053	NS	-0.029	NS
New York, NY-NJ-C	0.408		5060		0.021	NS	-0.192	***	0.178	***	0.034	*
Salt Lake City, UT	0.665		279		-0.289	***	0.183	***	0.118	**	0.006	NS
San Diego, CA	0.33		595		-0.313	***	0.12	**	-0.001	NS	-0.294	***
San Francisco, CA	0.531		1438		-0.022	NS	-0.267	***	0.021	NS	0.174	***
DC-Baltimore, MD	0.364		1673		-0.153	***	-0.342	***	-0.024	NS	0.086	**
	Percent Renting		**Percent Below Poverty**		**Percent Non-Family HH**		**Nodes**		**Distance to City Center**		**TOD Present**	
ALL REGIONS	0.133	***	0.331	***	0.239	***	-0.012	NS	-0.02	*	0.051	***
Atlanta, GA	0.186	*	0.125	*	0.194	**	-0.04	NS	-0.231	***	0.105	**
Chicago, IL	0.235	***	0.259	***	0.199	***	-0.024	NS	-0.044	NS	0.042	*
Dallas, TX	0.203	***	0.372	***	0.115	*	0.059	NS	0.062	NS	0.176	***
Denver, CO	-0.187	**	0.703	***	0.44	***	0.005	***	-0.009	NS	-0.012	NS
Los Angeles, CA	0.168	***	0.459	***	0.172	***	-0.035	*	-0.05	**	0.002	NS
Miami, FL	0.407	***	-0.01	NS	0.134	*	-0.053	NS	-0.281	***	-0.614	NS
Philadelphia, PA-NJ	0.2	***	0.341	***	0.201	***	0.01	NS	0.024	NS	-0.017	NS
Portland, OR	-0.157	*	0.359	***	0.682	***	0.056	NS	0.064	NS	0.175	***
New York, NY-NJ-C	0.148	***	0.407	***	0.255	***	-0.028	NS	-0.073	***	0.008	NS
Salt Lake City, UT	0.158	*	0.664	***	0.074	NS	-0.011	NS	-0.148	***	0.04	NS
San Diego, CA	0.656	***	0.235	***	-0.269	***	0.006	NS	-0.161	***	0.025	NS
San Francisco, CA	-0.037	NS	0.469	***	0.4	***	0.038	NS	-0.048	NS	0.098	***
DC-Baltimore, MD	0.137	***	0.322	***	0.015	***	0.036	NS	-0.154	NS	0.048	*

Table 4: Results of regression analysis between share commuting via walking,/biycling and independent variables.

The R-squared value was used to determine to the degree to which the independent variables explain variation in the dependent variables, and is also included in the summary tables. Among all regions, 67.1 percent of variation in commute to work via transit can be explained by the independent variables. Only 33 percent of the variation in commuting to work via walking was explained.

The following three sections correspond to the three research questions and hypotheses introduced in chapter one. These sections describe the relationships between the dependent variables and independent variables for all regions, and for individual regions. Urban form measures will be considered first, followed by socio-demographic measures, and concluding with the presence of transit-oriented developments. Following each section, an analysis of the results will include a reiteration of the relevant research question and hypothesis and a discussion as to whether or not the hypothesis was valid or invalid in light of the data.

Urban Form Results

Population Density

Among all regions, and compared to all other urban form variables, population density proved to be the strongest indicator of commuting to work via public transit, with a beta coefficient of .571. Among individual regions, the results were slightly more mixed. Los Angeles, New York, Washington, D.C., and San Francisco maintained these strong relationships in public transportation, with beta coefficients of, respectively, .396, .333, and .265. The coefficient was still positive for most other regions, with the exception of three regions: Miami, Portland, and Salt Lake City. These three regions showed no statistical relationship between density and public transit commuting trips.

Regarding the share of walking and bicycling trips, the relationship with population density for all regions was also significant, though somewhat less of a predictor as compared to that of public transit, with a beta coefficient of .151. Again, however, there was substantial variation among individual regions. Only six of the thirteen regions showed any significance at all with the density variable, and of those, two demonstrated negative relationships (San Diego and Los Angeles). The remaining four, Denver, New York, Philadelphia, and San Francisco, all had density as a positive predictor of walking or bicycling to work, although, as seen in Table 2, the strength of these relationships was generally less than those found for public transit commutes, ranging from .13 in Denver to .203 in Philadelphia.

Distance to Central Business District

As with population density, the distance to the city center demonstrated a relationship with transit commuting at both the all-regions scale (.151) and most individual regions, with the exception of Denver and Portland, which showed no statistical relationship. Unlike population density, the relationship, when existent, proved to be a negative one, which is consistent with the notion that the share of commuting via transit will generally decline as the distance from the city center increases. Chicago, Dallas, and San Francisco showed particularly strong relationships, with beta coefficients of, respectively, -.368, -.454, and -.308. Variance was high among all other regions, from -.078 in San Diego to -.306 in New York.

While there is a statistical difference in walking and bicycling to work between the CBD and the surrounding region, it proved to be a small one, with a beta coefficient of -.02. At least at this scale, there appears to be little difference between this commuting pattern in the CBD and in the surrounding areas of a region. At the individual region level, however, there were noteworthy exceptions. While only six regions showed any statistical relationship, of those, two showed distance to CBD as a fairly strong predictor: Atlanta (.231) and Miami (.281). Los Angeles, New York, Salt Lake City, and San Diego also showed significance. In all cases, when there was a relationship present, it was a negative one, indicating that shares of walking and bicycling increased the closer a census tract was to the CBD.

Nodes

The presence of nodes showed a slightly negative relationship with transit commuting when looking at all regions (-.033). Only four regions (Chicago, Dallas, Los Angeles, and New York) showed any statistical relationship, and in all of these, network connectivity was similarly proven to be a weak predictor of this behavior. Of these four, the strongest indicator was found in only one region, Dallas, which also happened to be the only one that showed a positive relationship (.127).

Nodes and links proved to be a statistically unreliable at predicting walking and bicycling commutes at all regions, and in all but two of the individual regions. The two regions that did show a relationship, Denver and Los Angeles, also had mixed results, with the former's beta coefficient being positive (.005) and the latter's negative (-.035).

Analysis of Urban Form Results

The first research question asks whether urban form has an influence on travel behavior. The hypothesis is that many urban form measures, such as density, roadway connectivity have a positive influence on the share of commutes taken by transit and/or walking and bicycling. Distance to the city center, however, should have a negative impact, which is to say that as that density increases, these shares should decrease.

Hypothesis one held true, although with notable exceptions. The relationship between population density and non-automobile commuting patterns proved to be significant and strongly positive in nearly all cases, a fact consistent with the literature. Similarly, the distance to the city center was found to be, in nearly all regions, a negative one. This was expected and, as mentioned, an intuitive outcome, given the nature of employment density and transit provision in most American cities, where such features are focused on the central business district.

Contrary to what was expected, connectivity, as measured by the number of nodes and links, was insignificant in most cases, and when it was significant, in fact resulted in a negative predictor. There are three suggestions for these results. The first is that the hypothesis was simply incorrect, and that connectivity has little if any effect on the transit or walking/bicycling commute. This, however, seems unlikely, as such a conclusion would refute the evidence offered by the works discussed in the literature review and common planning and urban design practice.

Another possibility was that the methodology used to measure connectivity was faulty. A higher count of links and nodes seems to intuitively amount to higher street connectivity. In reality, a very large, suburban tract may have comparatively high numbers of these features, even relative to a dense, heavily connected area in an urban center. A more accurate measure may be the density of links and nodes, as opposed to their total count. A third possibility is that high street connectivity does not necessarily amount to a walkable environment if poor sidewalks, or no sidewalks, accompany the street network. In future studies, a measure of the actual connectivity of the pedestrian network, i.e., the sidewalks, pathways, and the bike paths, would possibly be more informative in this regard.

Socio-Demographic Results

Race and Ethnicity

Two race and ethnicity variables were included in the regression model: the share of foreign born residents in a tract, and the share of African American residents in a tract. In nearly all cases, when considering either all regions or individual regions, both of these variables proved to be statistically significant predictors of transit ridership, although the direction of theses predictors varied.

In "all regions", and in the majority of individual regions, a higher percentage of foreign born persons was a positive, although somewhat weak, predictor of commuting to work via transit. In two of these cases, this predictor was significantly weak, with the beta coefficient in San Francisco in .003 and that in Washington DC-Baltimore .023. Los Angeles, San Diego, and New York showed slightly stronger relationships (.122, .128, and .199, respectively). All other regions demonstrated a negative relationship between foreign born populations and transit commutes, the most notable being Chicago, with a beta coefficient of -.211.

The results for the transit commute were markedly different for the African American population. At the all regions analysis, and in all but one region (Portland), the relationship was significant. Similarly, in all but one case (Salt Lake City), the presence of African Americans was a positive predictor of transit commuting. The strongest of these relationships were in Philadelphia

(.401) and Washington DC-Baltimore (.33). Only the three Californian regions and Chicago had beta coefficients below .14.

The relationship between percent foreign born and the walking/bicycling commute, and the relationship between African American and the walking/bicycling commute, were both nearly universally significant and negative. Regarding foreign born populations, only Dallas showed a positive relationship, where it was found to be a fairly strong predictor (.143). Only three of the regions showed no statistical relationship, and of the remainder, the predictor was not only negative, but strong. Miami, for example, had a beta coefficient of -.332, and Salt Lake City's was -.289.

The results were similar for the African American population and the walk/bicycle commute. Only Chicago and Portland showed no statistical relationship between the percent African American population in census tracts and this type of commute, and of the remainder, only Salt Lake City and San Diego demonstrated positive relationships.

Income and Poverty

Given the strong colinearity with lack of car ownership, it was not surprising that the relationship between persons living at or below the poverty level showed positive relationships with higher shares of transit commuting at both the "all-region" scale and in every individual region. In most cases, this relationship was strong, particularly in western regions, such as Dallas (.538), Salt Lake City (.516), and Denver (.457) and in the southeastern regions of

Atlanta (.538) and Miami (.467). Only three regions, New York, San Francisco, and Chicago (notably, all with well established public transit systems) had coefficients less than two.

Poverty also proved to be a strong, positive predictor for commuting to work via walking or bicycling almost universally. These relationships were strongest in the western regions of Salt Lake City (.669) and Denver (.703). Unlike transit commuting, however, the weakest relationships between poverty and the walk/bicycle commute were in the southeast, with Miami being the only region showing no statistical relationship in this category, and Atlanta having a beta coefficient of .125, the lowest of all statistically relevant regions.

Given the results above, it was surprising to see that the relationships between per capita income and transit commuting were also positive in the seven regions that showed statistical significance in this category, with a coefficient .121 for all regions. The strength of these relationships, however, was not as strong as seen with poverty, with beta coefficients ranging from .056 in Dallas to .168 in Chicago. In Miami, Portland, Salt Lake City, San Diego, and San Francisco, no linear relationship existed.

The results were somewhat mixed regarding the relationship between walking/bicycling to work and per capita income. Among all regions, the relationship was positive, albeit as a fairly weak predictor (.058). Only six of the thirteen regions showed any linear relationship, and the direction of the relationship varied. In Atlanta, for example, where the strongest predictor was found, it appears that higher per capita incomes would predict significantly lower amounts of walking to work. A similar, albeit slightly weaker relationship, existed in Los Angeles. Chicago, Denver, New York, and Salt Lake City, on the other hand, all demonstrated positive relationships.

Housing Tenure and Household Type

The relationship between transit commuting and renting tenure status was positive among all regions, and statistically significant in five of the study regions. In four of the five cases, Atlanta (.146), Chicago (.192), Miami (.161), and New York City (.054), the presence of renters is a positive predictor of transit commuting. Only in the case of Portland did the opposite hold true, possibly indicating that there home owners are more likely to take transit to work than renters.

The relationship between the walking/bicycling commute and renting, however, showed significance at the all regions scale, as well as in twelve of the thirteen regions (San Francisco was the exception). While the relationship was a positive one when considering all regions, the direction of this relationship was varied slightly among individual regions. For the most part, the relationship was positive throughout, with coefficients ranging from .137 in Washington, DC-Baltimore to a very strong .656 in San Diego. In Portland and Denver, however, the relationship was a negative one, with coefficients of, respectively, -.157 and -.187.

Considering all regions, the relationship between the percent of non-family households and both transit and walking/bicycling commuting was positive, though the strength of the predictor was notably higher for the latter (.331, as compared to .099 for the former). Furthermore, the strength and variation of the relationship varied significantly among individual regions when looking at the public transit commute. In three of the regions, Dallas, Philadelphia, and San Diego, no linear relationship was found. Of the remaining, two demonstrated a negative relationship, Atlanta (-.172) and Los Angeles (-.041). In other cases, the strength of the predictor was also mixed, mostly in the .5 to .25 range, with the significant exception of San Diego, which had beta coefficient of .682.

The walking commute-non-family household relationship, however, was positive in all cases, with the exception of San Diego, which had a negative relationship (-.269) and Miami, which showed no relationship at all. In all other cases, the percentage of non-family households, or households consisting of only one member, or more than one non-related members, is a positive predictor of commuting via walking or bicycling, and in some cases a fairly strong predictor. Portland, for example, had a beta coefficient of .682. Another west coast city, San Francisco, had a coefficient of .4, and Denver's was .44.

Analysis of Socio-Demographic and Household Characteristic Results

Research question two asks whether household and socio-demographic characteristics have an influence of travel behavior. Hypothesis two states that household characteristics such a household type, housing tenure, and car ownership should have a statistically significant relationship with transit and walking/bicycle commuting. The expected relationships are that non-family households, renting, and having zero or one car are positive predictors of higher shares of these modes of commuting. Regarding socio-demographic characteristics, this hypothesis also presumes that lower incomes should positively influence both walking and transit ridership, given the consequent limitations on automobile ownership. Because minority populations, including the foreign born, are more likely than white populations to live under these economic conditions in urban environments, it is expected that their presence will also be associated with these travel behaviors.

The predicted results for those populations living at or below poverty proved to be true for both transit commutes and walking/bicycling commutes. Due to the prohibitive costs of private automobile ownership, alternative forms of transportation such as public transit and walking appear to be, in nearly all regions examined, the norm for commuting among those living under these circumstances.

High percentages of African American populations were also a consistently positive predictor of the transit-to-work commute trip. The lack of the walking commute among this population appears to be problematic given the prevalence of health concerns among African Americans, as discussed in the Chapter two, though it is important to state that these concerns are hardly exclusive to this black community. Such concerns seem to point toward the need for more walkable communities and, more importantly and the necessity of diversity, both in wealth, race, ethnicity, and background, within those communities.

Concerning the foreign born community, there was significant variation between transit, walking, and bicycling commuting among regions. This is to be expected, given that the percent, as well as the type, of immigrant populations varies from region to region, and that economic conditions among such populations are often less favorable than they are to the populace as a whole. It is therefore important that appropriate provisions be made to provide alternative transportation means to accommodate those new to the country, particularly in those regions, such as Southern California, Florida, and Texas, where the immigrant population is highly concentrated.

The disparity between transit commuting and walking/bicycling commuting from region to region in renting households was interesting, with very few cases of significance regarding the former, and almost universally positive significance found in the latter. The same disparity was found among non-family households. It may follow that non-family households and renters prefer to live, or at least tend to live, in locations where working opportunities are within walking and bicycling distance, but are still in many cases following the commuting habits of the general population.

These results seem to support the hypothesis. Walkable communities are often diverse, vibrant communities, with a high percentage of non-family households. The fact that this relationship was strongest in cities such as Portland and San Francisco, which are known for their abundance of such populations, further supports this notion.

Related to these facts is the finding that higher per capita incomes related in many cases to higher shares of transit and walking/bicycle commutes appears to indicate that wealth does not necessarily preclude one from utilizing non-automobile travel opportunities. The significance of this fact is that there appears to be a substantial population who, when accessible and convenient opportunities are presented to walk, bicycle, or take public transportation, would in fact favor these modes over car travel regardless of affluence. External factors, such as the time expended on alternative modes of transportation, and the convenience of these modes, may prove a stronger influence on these behaviors. These factors are not included in this study, but may require further examination.

Transit-Oriented Development Results

When considering all regions, the presence of a TOD showed no statistical relationship with the share of transit commuting. The same also held true for seven of the individual regions. For those six regions that did show a relationship, the strength and direction was mixed. Atlanta, Portland, San Diego and Washington, DC-Baltimore all had TOD as a positive indicator of transit ridership, with beta coefficients ranging from .053 in Atlanta to .175 in Portland. The remaining two, Dallas and New York, demonstrated negative relationship, though in both cases the strength of the predictor is weak (-.061 and -.072, respectively).

Walking and bicycling, on the other hand, did have a relationship with the presence of a TOD when testing all regions, and it proved to be a positive one, albeit a somewhat weak (.050). At the individual region scale, however, the results were again fairly mixed. Six of the thirteen regions showed a statistically significant relationship: Atlanta, Chicago, Dallas, Portland, San Francisco, and Washington DC-Baltimore. In all of these, the presence of a transit-oriented development was a positive predictor of this commuting pattern, though the strength of that predictor varied, from .048 in Washington DC-Baltimore to .176 in Dallas.

Analysis of TOD Results

The third and final research question asks whether transit oriented development has an influence on travel behavior. The hypothesis presumes that, because TODs demonstrate the urban form measures described in the first hypothesis, and because they seek to attract many of the markets described in the second hypothesis, the presence of a TOD should indicate higher shares of both public transit and walking/bicycling commuting.

In nearly all cases, Transit-Oriented Development was found not to be a significant predictor of transit commutes. It was slightly more significant as regards the walk/bicycle to work trip, at least in a few cases, though still not to the degree as was expected. While the hypothesis itself did not stand up to the analysis across the board, it may be worth noting those exceptions where it did prove to be a predictor, whether negative or positive.

Chapter 5 – Conclusion

The first hypothesis stated that urban form has an influence on travel behavior. Specifically, it was expected that density and street connectivity would have a positive influence on shares of transit and walking/bicycle commuting, while distance to the central business district would have a negative influence. Of these, density turned out to have the strongest relationship with these travel behaviors. Practitioners of transit-oriented developments should recognize that this relationship with density appears to be crucial in order to maintain high transit ridership and pedestrian accessible environments. What may be of value is further insight into specific thresholds of density required to produce significant transit trips, as well as the effects of different types of density, i.e., employment or housing density.

The expectation that as one gets further from the central business district, the transit and bicycle/walking commute would decrease also held true. Future studies may benefit from an examination of whether the same distance decay effect holds true along developed transit corridors or at transit nodes in suburban locations.

Nodes and Links appeared, in this analysis to have no consequence as regards transit and walking/bicycle commuting. This seems to indicate that an aggregate count of these features within a given area, as performed in this study, is an insufficient means of measuring connectivity. A more accurate assessment may be a measure of the density of such features. Even more insightful would be an in-depth, qualitative study of a given location's street network, in order to determine whether high street connectivity is accompanied by similarly high pedestrian and bikeway connectivity, and whether these features are ultimately served by a transit stop or station.

The strong positive relationship between poverty and transit and walking/bicycle commuting was expected. What is not shown in the results is whether or not these means of transportation are effective alternatives for what are essentially captive transit riders. While a stated policy goal may be increased shares of public transportation travel or more walking trips among the general population, such outcomes are undesirable for those with no other choice when these options are difficult, time-consuming, and themselves almost prohibitive. This is particularly true and problematic when considering that the commute trip often must be balanced with the multiple transportation needs presented by supporting a family, attaining education, or meeting social demands. Cities designed exclusively for the automobile cannot meet these needs, and poor public transit and urban design will only exacerbate them.

These same facts held true for the foreign born populations, who can be expected in many cases to suffer from poorer economic conditions than the population as a whole. Cities are obligated to seek alternatives that facilitate convenient alternatives. Transit-Oriented Development may provide one such way to accomplish this, by increasing accessibility between housing, jobs, social services, and other necessities via means other than the automobile, but only if policies are in place that ensure affordable housing for those who are in most need of such opportunities.

An example of such a policy is the Low Income Housing Tax Credit (LIHTC). LIHTC is a federal funding program that, by offering tax incentives, encourages developers to provide rental housing at below market rates. Some states, such as Texas and Illinois, have taken this initiative further, by giving higher qualifying scores for this incentive to developers who develop such housing near transit. In the state of California, a Housing Incentive Program offers grants to developers who develop affordable housing at specified densities, but only if this development is within one third of a mile of a bus stop or within one half of a mile of a rail station (Shoemaker 2006). If such programs prove successful, they may be worth adoption in other regions in order to ensure that the benefits of transit accessible housing are available to those most reliant on them.

Give the results regarding housing tenure, it could be concluded that renting households rely on transportation alternatives for the same reason that lower income households do. Nonetheless, it is important to note that tendencies away from suburban homeownership among non-family households, and the mobility of these populations, may indicate that renting is becoming less a choice of necessity and more one of preference. This could also point toward the need to provide a diversity of housing options in those communities that promote walking and public transit.

Transit-oriented development was expected to have more of an influence on transit and walking/bicycle commuting than was demonstrated by the study. As noted in the literature review, the relative youth of the transit-oriented development concept has in many cases lead to anything from a general misunderstanding of the elements of implementation to a broad misapplication of the term. Under such circumstances, it is unlikely that a TOD will produce the benefits and outcomes it is designed toward. The results may indicate that many of the TODs included in this study may suffer from these shortcomings.

What may be lacking, therefore, is a standard typology for what makes a successful transit-oriented development. In order to create such a typology, it is worth looking at those regions where the practice is more long-standing, evolved, and aggressively pursued, and standards are subsequently more exacting and refined. It is perhaps no coincidence that TODs in such regions, such as San Diego and Portland, performed best in this study's analysis. A more in-depth, qualitative study of those regions, and of the TODs in those regions, that have found success may be necessary in order to determine how these ends were achieved, and how these successes can be translated into a standard typology.

Another possibility for expanding upon this research design is to supplement the cross-sectional nature of the study with a temporal aspect, i.e., comparing the results of similar analyses on previous census data. As Frank & Pivo state, “In a cross-sectional research design there is no ability to conduct a pretest; therefore, the impact of the stimuli (e.g., urban form) cannot be longitudinally isolated in an experimental design.” (2002 2). If such a longitudinal approach was undertaken, accounting for changes in variables and their relationships over the course of several decades, it might be possible to isolate not only relationships, but also a degree of causation.

One final conclusion can be drawn from noting the variation in significance, strength, and direction of all variables as predictors among the regions studied. The results indicate that the reasons people walk or take public transit vary throughout the country. Even regarding transit-oriented development, some regions, such as San Diego and Portland, were found to have more success in influencing the transit commute, while regions such as Dallas, Atlanta, and San Francisco had TODs as more substantial predictors of the walking commute, and others seemed to have very little success in either regard. Even those predictors that were almost universally positive, such as density and race, were much stronger in some regions as compared to those in different parts of the nation.

Therefore, while a standard typology for transit-oriented development is undoubtedly necessary, policy makers must take into account the differences in the age, forms, and transit systems of cities' that exist from region to region, as well as their diverse demographic characteristics, and understand that a universal application of guidelines will not necessarily result in universally positive results. The implications of the idiosyncrasies that exist in cities and regions must at the least be taken into account, and should provide guidance when pursuing policies to promote transit ridership and walking and bicycling travel.

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Vita

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