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16. Abstract

The Capital Area Metropolitan Planning Organization (CAMPO) in the Austin, TX region is incorporating a new regional growth concept, the Activity Centers for its Long-Range Transportation Plan. The planned Activity Centers would present such features as mixed uses, medium to high densities, and pedestrian-friendly environmental design, which are expected to influence travel. This study reports the needed local empirical evidence of trip making behavior in association with the Activity Centers' attributes. From telephone interviews of local planners and work sessions with experts, the study identifies 42 mixed-use districts (MXDs) in the Austin area. In GIS, urban form indicators are derived for the MXDs and trip records from the 2005 Austin Activity Travel Survey are geocoded. The following analyses are then carried out for the MXD related travel: trip length distribution, trip generation rates and internal rate of capture, person miles of travel, vehicle ownership, departure time, and travel mode choice. With the empirical results, CAMPO models can be modified or refined to capture the potential effects of the Activity Centers growth strategy on regional travel.

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Trip Internalization and Mixed-Use Development: A Case Study of Austin, Texas

by

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EXECUTIVE SUMMARY

Capital Area Metropolitan Planning Organization (CAMPO) in the Austin, TX region is currently incorporating a regional growth concept of 'Activity Centers' for its 2035 Long-Range Transportation Plan. Practically it has been a challenging task to operationalize the concept in CAMPO's travel demand modeling process mainly due to lack of local empirical evidence on urban form-travel connection.

The literature is extensive in analyzing the influence of density, diversity, and design on travel. Density is inversely related to mode choice for automobile trips and directly related to nonmotorized travel. Land use mix has a relatively weak relationship to driving, vehicle ownership, and distance traveled. Design also matters. The magnitude of the influence ranges from 0.002 to 0.6 in elasticity terms.

Based on telephone interviews of local planners and expert work sessions, the study identifies 42 mixed-use districts (MXDs) in the Austin area. In GIS, urban form indicators are derived for the MXDs and trip records from the 2005 Austin Activity Travel Survey are geocoded. The following analyses are then carried out for the five-county region in Austin: trip length distribution, trip generation rates and internal rate of capture, person miles of travel (PMT), vehicle ownership, departure time, and travel mode choice. Main results of the study are: MXD trips are 1.9 miles shorter for HBW trips, 0.65 mile / 0.9 minute longer for HBNW trips, and 1.2 miles/3 minutes shorter for NHBW trips. MXDs show 40% higher internal rate of capture than TAZs (non-MXDs). People living in MXDs make 0.2 more daily trips /person for HBW and 0.3 fewer daily trips/person for NHBO purposes. MXDs have more zero- or one-car households. Travelers from MXD households leave homes ~10 minutes later than others in the morning. Daily PMT is ~6 miles less for MXD households than otherwise. Population and job densities at origins and destinations influence travel mode choice independent from the effects of system performance and socio-demographic factors. Network connectivity and sidewalk provision also matter.

The results suggest areas in which CAMPO models can be modified or refined to capture the potential effects of the Activity Centers growth strategy on regional travel. This may include re-calibrating friction functions for trip distribution analysis, revising trip rates for trip production calculation, improving estimation of internal trip making, re-estimating vehicle ownership models, which in turn affect trip generation and parking demand, fine-tuning time-of-day distribution; and re-fining travel mode choice models by including urban form indicators.

1. INTRODUCTION

Capital Area Metropolitan Planning Organization (CAMPO) in the Austin, TX region is currently incorporating a regional growth concept of 'Activity Centers' for its 2035 Long-Range Transportation Plan. The concept emerges in response to the region's sprawling growth in recent decades that has generated tremendous pressures to maintain regional mobility, protect air quality, and preserve the Hill Country amenity. In less than three decades, population in the five-county region nearly tripled, growing from 585 thousand in 1980 to 1.65 million in 2008. Most of this growth took the form of single-family residential development, followed by similarly low-density office, retail and industrial development located across the suburban fringe of Travis, Williamson and Hays counties. The rate of population growth has been accompanied by ever-increasing development of the region's land. Based on satellite data, the USGS estimates a 260% increase in the amount of urban land between1983 and 2000 in the area. If current population growth and land use trends continue, CAMPO foresees worsening congestion by 2030 in the region even after spending an anticipated $23 billion on the region's roadway and transit infrastructure. The resulting long commute, degradation of air quality, and loss of sensitive environmental areas and rural land eventually will lead to decline of quality of life in the region. The Activity Centers concept aims to preserve regional quality of life in the face of continued high growth rates.

Activity Centers echoes development initiatives happening in other parts of the country, namely Smart Growth, Transit-Oriented Development (TOD), Traditional Neighborhood Design (TND), Mixed Use District (MXD). Through planning and financing future transportation improvements, the growth concept encourages an alternative pattern of land use across the region. City and neighborhood cores as well as important transportation nodes offer prime locations of activity centers. Future developments are channeled into these centers and multimodal transportation services provide mobility and access to/from the centers from/to the rest of the region (Figure 1-1).

While conceptually Activity Centers presents an attractive growth alternative to the capital region, practically it has been a challenging task to operationalize the concept in CAMPO's travel demand modeling process. Would trip length distribution (in both time and distance) be the same with Activity Centers as with the business as usual land use? Would trip rates differ between households living in Activity Centers and those in the rest of the region? Would alternative land use development influence travelers' decisions on travel mode choice? It is expected that households living in such land use as Activity Centers own fewer number of vehicles and more likely to do personal business near homes (hence higher internal trip rates) than otherwise; but to what extent? Answering these questions is critical for CAMPO's travel demand models to capture the potential effects of Activity Centers on regional travel outcome. The questions need to be answered with empirical evidence from the Austin region. Yet to date the needed empirical evidence has not been documented.

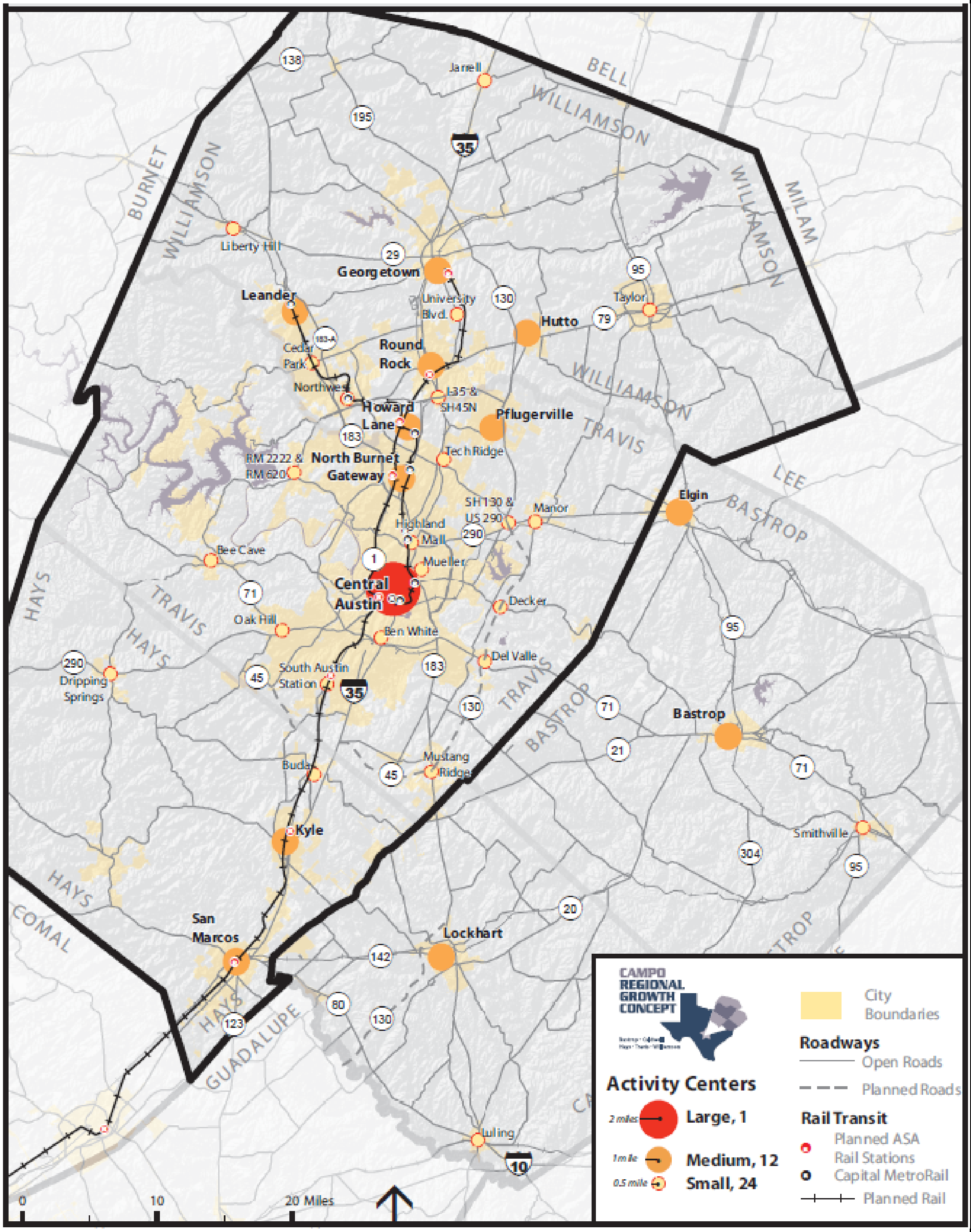


Figure 1-1 CAMPO Regional Growth Concept (CAMPO, 2007)

This study is intended to answer the empirical questions by analyzing travel survey data from the Austin region. Specifically, the study carries out the following tasks:

1) Review the literature on the effects on travel of the built environment in terms of density, diversity, and design;
2) Develop a method of using GIS to quantify TOD-featured urban form; and,
3) Conduct a case study based on the most current travel survey data collected in 2005 for the Austin metropolitan area and present the research results from the above tasks to CAMPO for model refinements in the CAMPO's 2035 Plan and future updates.

The rest of the report is organized according to the above task list. A note on terminology: TOD refers specifically to transit related development, which does not exist yet in the Austin region. Activity Centers is a generic concept. For reference convenience, the report uses MXD (or mixed use development) to represent TOD and alike.

2. REVIEW OF RELATED STUDIES

The literature review of this report focuses on the empirical findings of urban form and travel behavior relationships and attempts to summarize the findings in elasticity values and interpret the relationships that the values display. The review is structured around three main sections: Density, Diversity, and Design as they relate to vehicle trips in general, vehicle miles traveled, auto ownership, and mode choice (trips made by automobile, transit, and walking or biking).

More than 200 journal articles and books were reviewed. Density was the most common topic found in the body of research. The main finding is that higher densities encourage people to shift transportation modes.

The research approach encompassed database searches from the University of Texas library system website, individual journal searches from most current issue and down to the year 2000, following the paper trail through the references of the most relevant articles, and through Transportation Research Board conference CDs.

2.1 The Role of Density

The formation of cities is not only a technological innovation more than 5,000 years ago but places of continued technological innovation, trade, and most importantly, people and lots of them. Cities and urban regions are places of density and the literature to date breaks density into measurements by people, jobs, housing units, and activities per square foot, parcel, acre, block, neighborhood, census tract, and square mile. The common hypothesis centered on density asks if density increases, will more people be apt to switch transportation modes and take less polluting modes such as transit, walking, biking or simply drive less or own fewer automobiles. The landmark research study testing this hypothesis was conducted by Pushkarev and Zupan in 1977 and finds that density does increase travel by nonmotorized modes. Since 1977 density has continued to be the main urban form indicator studied by researchers, due in part to the ease of measurement and data collection. The body of literature analyzed for this report breaks density into four categories for displaying elasticity values: population density, employment density, density at the place of origin, and density at the place of destination. The elasticity values for density are displayed in Table 2-1.

Further research over the past few decades has verified the results of Pushkarev and Zupan for other metropolitan regions across the United States, but the numerical elasticity values describing the interaction between density and travel behavior vary between regions. The density of people, jobs, and activities in New York are not the same as say those in Austin, Texas but researchers have continued to prove the high correlation between density and travel behavior (Newman & Kenworthy 1989) (Holtzclaw 1990; 1994) (Frank & Pivo 1994) (Dunphy & Fischer 1994) (Kitamura, Mokhtarian, Laidet 1994)(Steiner 1994). The following sections will explore what the elasticity numbers mean and frame them in the context of related studies. The studies are categorized by All Trip Purposes, Mode Choice, VMT, and Vehicle Ownership.

Table 2-1. Density Elasticities					
Density Type	All Trip Purposes	Auto Trips	Transit Trips	Walk/Bike Trips	VMT
Population	-0.013 ~ -0.14	-0.039 ~ -0.044	0.005 ~ 0.19	0.105 ~ 0.34	-0.05 ~ -0.16
Employment	-0.002 ~ -0.04	-0.031 ~ -0.26	0.011 ~ 0.59	0.026 ~ 0.43	-0.03
Origin	-0.151	-0.163	0.511	-	-
Destination	-0.259	-0.137	0.268	-	-

All Trip Purposes

Frank and Pivo in 1994 and Kockelman and Cervero in 1997 point to the usage of the term 'All Trip Purposes' to mean all trips regardless of being home-, work-, or shopping-based. In modal terms it refers to specifically vehicle or automobile trips. In the 1990s a good deal of travel behavior research began by exploring not density or design or diversity but examining the relationships of why one neighborhood has a significant difference in travel patterns from another, for example a suburban neighborhood compared to an urban one. To the travel demand modeler the two are cases with different sets of characteristics that when combined together form a complete sample set, but to a planner examining the role of the built environment and urban pattern, the two neighborhoods require separation into separate travel demand models in order to be more accurate. Thus the researchers took a middle road an examined select neighborhoods with the different urban pattern characteristics and examined how each displayed different home-based, work-based, and shopping-based vehicle trips. The net effect is empirical evidence pointing to the distinction between the neighborhoods in the sample sets.

The summary of elasticities from the studies as found in Table 2-1 represent a range in percentage increase as density increase. As population density increases by 1 percent, trips for all purposes (home based, work trips, non-work trips, non-home based, etc) decrease from a low of 0.013 percent to a high of 0.14 percent. Remarkably the low figure represents research conducted in the San Francisco Bay area while the high figure represents Orange County, California. Possible explanations for the difference may be attributable to differences in constraining geographic features and extensive infrastructure for different modes. In other words, San Francisco has more constraining geographical features combined with more extensive transport networks for different modes of travel and differences in density will be absorbed by the different modes of travel.

For employment density the trips are not as high: for every one percent increase in employment density, trips for all trip purposes decrease from a low of 0.002 percent to a high of 0.4 percent. The two figures are closer together and both represent West Coast metropolitan areas.

The results are much different for measuring density at the place of origin and place of destination. For every one percent decrease in density at the place of origin there is a decrease in trips for all purposes by 0.151 percent and 0.259 percent at the place of destination. The figures for both place of origin and place of destination represent Montgomery County, Maryland, a suburban but transit served county. This numerical finding is revealing considering most households average 7-10 trips per day and points to the role of density as reducing the number of trips or put another way, density shapes travel behavior.

Mode Choice

Mode Choice or modal split has been studied widely to examine the built environmental effects on travel behavior. Transportation mode is the most common consideration for any person or household when deciding how to transport from one place to another. As represented by Table 2-1, Mode Choice is generally divided into three categories: Auto Trips, Transit Trips, and Walk/Bike Trips. For every one percent increase in population density, automobile trips reduce from a low of 3.9 percent to a high of 4.4 percent. The low figure is represented by Hong Kong and the high figure by Boston, which are very different urban forms. Hong King is highly constrained by geographical features and exhibits one of the highest densities in the world. Boston is dense for the United States but the region is far more dispersed across multiple states with a large highway and arterial network. Thus increased densities are more likely to impact vehicle trip rates in Boston where the market share of nonmotorized modes has great potential to expand converse to Hong Kong where nonmotorized modes are the dominant choice of travel and roads are too few and too little capacity.

The values change to an increase of 0.5 percent to 19 percent for transit trips and 10.5 percent to 34 percent for walking and biking. The lower figures for both ranges represent Hong Kong again and the higher figures in the two ranges represent American metropolitan regions where densities are lower and transit and walk or bike are not dominate modes of travel. Frank & Pivo report that walking trips are the most sensitive mode to an increase in population density and state that a threshold of 13 residents per acre or 7-9 dwelling units per gross acre is necessary to see the effects (1994). Kitamura, Mokhtarian, and Laidet found that high residential densities are positively related to the proportion of nonmotorized trips (1997). The figures missing from this report such as mode share between the studied regions would help the reader to better understand the context of why the ranges appear so vast. Lastly, more recent research focused on walking finds that high residential density promotes walking for travel whereas low density residential promotes walking for leisure.

The results change dramatically for employment density where every one percent increase in employment density results in a reduction of automobile trips between 3.1 percent at the low to 26 percent at the high. For transit trips, the results show an increase in trips from a low of 1.1 percent to 59 percent. This is a dramatic difference accentuating the difference between urban environments in different metropolitan regions and the availability and extensive network of transit in each respective region. The results are also highly varied for walking and biking where a one percent increase in employment density yields a range of 2.6 percent to 43 percent. Frank and Pivo point out that 75 employees per acre is the threshold for when transit trips begin to rise dramatically (1994).

The results for density at the place of origin and destination are far less varied. For every one percent increase at the place of origin, automobile trips reduce by a reported 15.1 percent and 13.7 percent at the place of destination. For every one percent increase at the place or origin there is a 51.1 percent increase for transit and at the place of destination it is 26.8 percent for transit. Additional findings on mode choice assert that mode choice appears to be more related to employment densities at destinations than on residential densities at origins (Rodriguez and Joo 2004).

A great amount of literature examines walking trips and findings show that higher density environments promote travel walking whereas lower density environments promote leisure walking (Forsyth, Oakes, Schmitz, Hearst 07). More recent research suggests that for every increase of 1.5 employees or 1,000 per gross acre, the result is a reduction in auto use by 3 percent, whereas for every increase of 1.5 housing units or 1,000 per gross acre, the result is a reduction of 12 percent (Chatman 2003). The elasticity results vary highly from a reduction of 26 percent for automobile trips for every one percent increase in employment density to a high of 59 percent for transit trips also for every one percent increase in employment density.

In the Austin Metropolitan region jobs are concentrated in the downtown or central business district, state capital area, the University of Texas, Breaker and MOPAC or Loop 1, and other employment centers are scattered along major arterial roadways such as Guadalupe or Lamar Boulevard and urban expressways or highways such as 183 or Loop 1. Much of the office development being constructed in Central Texas can be labeled edgeless and does not locate in concentrations or suburban centers but along arterials and linearly along highways. Recent investments into Austin's CBD represent a continued interest in living and working downtown but it is also a bottleneck for access from the limited number of interchanges, connecting streets, and bridges. Regional investments into Metrorail will permit Austin's downtown to continue to grow and buildup, but more importantly investments in transit will continue to slow the rate of employment decentralization from the downtown, possibly attract office uses, and allow the region to experience a higher proportion of trips made via transit and fewer walking as the elasticities in Table 2-1 point out.

Vehicle Miles Traveled

The research is much more limited for vehicle miles traveled or VMT. Holtzclaw points out that as residential density doubles, VMT per household reduces by 25 percent (1994). The table of elasticities only takes population and employment density into consideration. As population density increases by one percent, VMT decreases by 5 percent to 16 percent. For employment density the elasticity reported is 3 percent reduction in VMT. VMT is a widely used measure in studies especially for studies examining congestion and pollution but less the case for trip generation as is the case in this summary of findings.

Auto Ownership

The summary of elasticity findings which are presented in Table 2-1 do not calculate auto ownership as it relates to density. On a different note, much research has discovered that, in general, an increase in density causes a reduction in auto ownership (Ewing, DeAnna, Li 1996) (Holtzclaw 1994). For population density, Kockelman finds that the relationship is significant (Kockelman1997) (Cervero 1996). Another major researcher in this topic is Robert Cervero of the University of Berkley in California who finds that the number of automobiles per household discourages transit use (Cervero 2007); he also finds that higher automobile ownership influences more auto-commuting (Cervero 1996). His research is replicated for other modes by researchers Boarnet and Greenwald as the number of available cars per driver per household reduces the likelihood of walking (Greenwald & Boarnet 2001). Lastly, researchers conclude that vehicle availability is the best predictor of mode choice (Greenwald 2006). If CAMPO or Austin desires to influence travel behavior, pricing and education are good methods for influencing travel attitudes.

Other Factors

Density is one of the most studied urban form indicator influencing travel behavior. Based on empirical research it has been proven to be the most important and significant indicators of the three. Other factors related to density or point to the other underlying components of density. Some assert that residential location is more important in determining density (Ewing, DeAnna, Li 1996). Others point out that it may be attitudinal factors (McNally & Kulkarni 1996) or self-selection (Krizek 2000). Regardless there is a positive utility by household residential location with population density since neighborhoods are proven to be more established, have higher accessibility, and more opportunities (Chen, Chen, Timmermans 2008). The same authors point out that household choice in past residential location and the experiences will influence future location choices. This finding is similar for auto ownership as reported by Weinberger and Goetzke: low levels of auto ownership and high levels of auto ownership are learned and self-reinforcing (2009).

2.2 The Role of Diversity

Diversity typically refers to land use mix. Land use mix is the heart of the discussion on trip generation and land use but few studies agree on a standardized definition for what constitutes mixed use or how to measure the mixture of land uses in close proximity. The research for elasticities for diversity is displayed in Table 2-2. For every one percent increase in land use mix all trips reduce between 6 percent and 12 percent. For land use diversity at the place of origin this figure is 14.1 percent, and at the place of destination it is 19.7 percent reduction. Little is written about the effects of mixed use on vehicle trips.

When examining land use mix by mode choice the numbers appear more promising. As Land use mixing increases by 1 percent, driving trips reduce by 13 percent, transit trips increase by 15 percent, and walking and biking trips increase by 21percent. When examining land use diversity at the point of origin vehicle trips reduce in general by 14.1 percent, driving trips reduce by 34 percent, and transit trips increase by 61.5 percent. For land use diversity at the point of destination vehicle trips reduce by 19.7 percent, driving trips reduce by 29.1 percent, and transit trips increase by 45.2 percent. These results are derived from Cervero 2002. Many researchers agree that land use mix or diversity influences mode choice (Zhang 2004)(Cervero 2002)(Cervero & Radisch 1996). Researchers conclude that mixed use means more walking but not necessarily less driving (Joh, Boarnet, Nguyen, Fulton, Siembab, Weaver 2008). Greenwald finds that the impacts of land use on pedestrian behavior are highly localized (2006). Lastly, Cervero found that retail and non-residential land uses within 300 feet of residences increases walking and lowers auto use. For land use mix to be effective, alternative modes to the automobile must be available.

Cervero and Kockelman found that mixed use reduces vehicle miles traveled and the elasticity results confirm this. For every one percent increase in land use mix the result is 5 percent to 11 percent reduction in VMT. Overall the results are less complete than for density but more complete than design. Design, however, has been researched at greater length and is discussed in the following section.

Table 2-2. Diversity Elasticities					
Diversity Type	All Trip Purposes	Auto Trips	Transit Trips	Walk/Bike Trips	VMT
Land Use Mix	-0.06 ~ -0.12	-0.13	0.15	0.21	-0.05 ~ -0.11
Land-use diversity, origin	-0.141	-0.34	0.615	-	-
Land-use diversity, destination	-0.197	-0.291	0.452	-	-

2.3 The Role of Design

Robert Cervero defines the design component as reflective of the quality of the walking environment and the physical configurations of street networks (Cervero 2002). Out of the growing body of literature examining design variables, he highlights mode choice and more specifically the ratio of sidewalk miles to centerline miles of roadway. Although Cervero describes the design component as a relatively weak land use factor in shaping travel choice (Cervero 1993) (Handy 1996) (Crane & Crepeau 1998), a growing body of literature has shifted the argument into the physical health arena (Frank and Engelke 2001) (Frank 2000) (Lee and Moudon 2004) (Forsyth, Oakes, Schmitz, Hearst 2007) (Forsyth, Oakes, Schmitz, Hearst 2008).

- The variables used to measure design:
- Highly connected street networks
- Connectivity of streets
- Grid street network
- Continuous and integrated sidewalk network
- Fine grids with many blocks and intersections
- Block size
- Sidewalk length
- Sidewalk ratio at the point of origin and destination
- Bike lanes
- Route directness
- Reduced building setbacks

Design considers many factors but few are transformed into elasticity figures for the purposes of this study. The available values are listed in Table 2-3.

Table 2-3. Design Elasticities					
	All Trip Purposes	Auto Trips	Transit Trips	Walk/Bike Trips	VMT
Design	-0.14	-	-	-	-0.03 ~ -0.09
Sidewalk ratio, origin	-0.39	-	-	-	-
Sidewalk ratio, destination	-0.448	-0.366	0.062	0.327	-

Vehicle Trips

The literature exploring design and vehicle trips begins with the type of roadway network (grid, superblock, cul-de-sacs, etc) and urban pattern type (suburban, urban, exurban, etc). For the past 60 years development patterns have changed from the traditional grid to present and various suburban auto-centric designs (Ewing 1994) (Hess 1997) (Southworth 1997) (Southworth and Ben Josef 1995) (Untermann 1987). The New Urbanist movement has reintroduced the traditional street grid layout but with more unique alterations, meaning the grid alters course and rarely becomes monotonous. Roadways are designed to accommodate vehicles but the layout and pattern of the system ultimately favors the pedestrian due to the scale, variety, and emphasis on the public space. The literature to date affirms the role of the neo-traditional grid pattern increasing nonmotorized travel trips in New Urbanist communities. Earlier research into new urbanism stated that neo-traditional design results in fewer and shorter auto trips (Handy 1992) (Rutherford 1995). Since then recent evidence indicates that trip generation for automobile trips does not reduce and only more walk trips are taken (Greenwald 2003; Joh, Boarnet, Siembab, Weaver 2008). A sizable number of new urbanist communities are constructed on greenfield sites away from existing public transit infrastructure. In the urban core, transit neighborhoods lower auto-drive alone trips and generates more transit trips than auto-oriented neighborhoods (Cervero & Gorham 1995). For transit usage to be successful, a distance of less than one-half mile has been proven to be significant. In light of these findings the elasticity values in Table 2-3 indicate that for every one percent increase in general design measures, the effect are 14 percent decrease in all trip purposes. Many studies have analyzed the design principle, but few present elasticity values. One study provides elasticity values for sidewalk ratio at the place of origin and the place of destination. At the place or origin, a one percent increase in sidewalk ratio yields a 39 percent reduction in all trip purposes while at the place of destination the result is greater at 44.8 percent. Such high numbers are reflective of research conducted in downtown environments which are served by extensive and high quality transit service.

Dock and Swenson have developed models for different growth scenarios. The result is that conventional urban patterns would result in a 10 percent increase in auto trips compared to a one to three percent decrease in auto trips for the transit-oriented growth scenarios. In addition transit would increase by a projected 23 – 33 percent. The authors conclude that the transit-oriented growth scenarios are would result in more efficient trip making (2008).

Mode Choice

Mode Choice is one of the most extensively researched and discussed subjects. Measures of the dynamics of urban patterns reveal significant and positive relationships between street connectivity, extent of sidewalks, shorter block sizes and pedestrian count (Rodriguez 2009). In addition, pedestrian and cycling trips increase in the presence of mixed land uses, improved street connectivity, and higher population and employment densities at the point of origin and destination. In Table 2-3, auto trips decrease by 36.6 percent as sidewalk ratio increases at the point of destination by one percent. Inversely, transit trips increase by 6.2 percent and walk or bike trips increase by 32.7 percent. Handy and Clifton state that walking is a net effect of attitudes to have the option and the desire to walk (2001). Accessibility is an influential factor just as connectivity, sidewalk availability, and attitudinal factors in determining whether people walk; higher accessibility is associated with a greater number of walking trips to destinations and urban form influences perceptions which induce walking (Handy 1996). Beyond the availability of sidewalks, the connectivity of streets, the attitudes and perceptions, and the other factors discussed is the function and design of the street environment. A large roadway with wide lanes for vehicular traffic and few pedestrian amenities such as bulb-outs or pedestrian islands at intersections serves to discourage walking (Tetreault & El-Geneidy 2009). Mode choice is an extensive topic beyond the scope of this research and explores the minute details of the pedestrian supportive environmental elements.

Vehicle Miles Traveled

The most well known study on vehicle miles traveled or VMT for design purposes is LUTRAQ which analyzed Portland, Oregon. The result of transit-oriented development is an overall reduction in vehicle trips by 77 percent and reduction in VMT by 13.6 percent. A study complete in 2006 for Capital Area Metropolitan Planning Organization by Zhang estimated VMT reductions as high as 21 – 27 percent for two different TOD scenarios (206). It also found that congested roadways would not increase but reduce by 2.2 percent which is consistent with model scenarios developed by Dock and Swenson. Zhang writes that congestion at TOD sites would be higher but at the regional level, lower. Similar to the Dock and Swenson study, the emphasis is on efficient pattern of travel across the region and the benefits that TOD serves in aiding this shift in travel patterns. The elasticity values find a higher rate of difference for VMT of three to nine percent reduction as design variables increase by one percent.

Auto Ownership

Similar to the topic of auto ownership for diversity, research for design is limited. Holtzclaw, Clear, and Dittmar in 2002 found that urban design and transportation infrastructure are highly significant on influencing auto ownership. The degree depends on the metropolitan or core urban area. New York, Boston, and San Francisco each exhibit very high densities where transit systems are built out to the degree that many people opt to live without vehicles in high density transit neighborhoods while others may own fewer vehicles and drive less in the urban environs. Austin and Central Texas in general, like many other Sunbelt regions, has experienced an explosive share of growth primarily during the era of auto-centric design. Although policymakers chose to build few roads in order to deter extensive low density development, people continued to come and the region lags behind many in the nation in the built up nature of the arterial and highway system. This presents a challenge when transit networks such as light rail, bus rapid transit, or exclusive busways do not make up the difference. For auto ownership to reduce in Austin, not only must densities increase in transit served locations but extensive transit systems constructed to supplement the bus network. Only then will the region experience noticeable differences in auto ownership. The likely case will be that citizens will continue to own automobiles but fewer than the national average.

2.4 Summary

The body of literature analyzing density, diversity, and design is extensive when exploring the many tangential works but the net result is that mixed use and transit-oriented development has the effect of reducing vehicle trips, shifting travel to non-motorized modes, decreases vehicle miles traveled, and reducing auto ownership. The degree varies region by region. Each region is replete with a variety of densities, land use mix composition and types, and various design elements which contribute to varying degrees to the success of the whole. In the end mixed use acts to make travel more efficient and patterned. Trip generation in the presence of land use mixing is proven to change and in some cases reduce by significant percentages compared to standard ITE rates.

The field of travel behavior from the research collected appears to have peaked and slowed down in recent years as researchers discover the relationships of association and not causation between the topics of density, diversity, design, land use, vehicle trips, vehicle ownership, and vehicle miles traveled. The most important association have been proven consistently: density is inversely related to mode choice for automobile trips and directly related for nonmotorized modes. Land use mix or mixed land uses experiences a weak relationship to vehicle- trips, -ownership, and –miles traveled. Design also exhibits a weak relationship. More important than the correlation or association between any of these factors is the role of socioeconomic demographics. Each demographic population experiences travel differently by the constraints of price, time, and access. The emerging body of research explores the travel behavior and transportation demand for individual demographic groups whether they are low income, immigrant, minority, or elderly. A second path has been the intersection between travel behavior and public health or more specifically physical activity.

Gaps in the research exist in the selection of a random sample since the built environment is highly varied in its types. Research of mixed use environments around rail transit stations will most likely yield highly significant results whereas the selection of districts containing shopping centers, offices, and apartments all surrounded by parking lots and designed in automobile oriented design will likely yield very low or no significant relationship results. This differentiation in the selection of candidate sites as what can be considered mixed use results in highly varied and possibly inaccurate results. The researcher enters into a dilemma in which to be random in selection is to be statistically sound, but to select specifically good candidate sites will skew the results. More research is needed in the transportation and land use interaction but second to segmenting into socioeconomic demographic groups. Lastly, the field may be interested in identifying the underlying pricing, quality of life factors, and the perspective of the reliability of transportation system from the viewpoint of demographic groups.

3 METHOD

The study method includes three parts: MXD identification, derivation of urban form variables, and geocoding of trip records in GIS.

3.1 MXD Identification

The selection of the research sample of MXD's took a 'bottom up' approach based upon local knowledge of city officials, professional planners, CAMPO staff and academic experts. The sampling process involved three working steps. First, a list of 49 communities in the region was created and the contact information of representative planners or public officials collected (Table 3-1). The research team then interviewed by phone the planners or officials, asking them to identify MXD's based on their professional and personal knowledge of their own communities. The interviewee was first given a definition of MXD: "A mixed-use development or district consists of two or more land uses between which trips can be made using local streets, without having to use major streets. The uses may include residential, retail, office, and/or entertainment. There may be walk trips between the uses." If the planner required further clarification, an additional set of characteristics of mixed-use districts, as defined by the ULI (Witherspoon, Abbett, Gladstone 1976) was provided along with known examples, for instance, the Triangle area in Austin.

Mixed-use was a generally recognized concept by the majority of those planners interviewed. However it was sometimes difficult for the planners to unambiguously delineate MXD boundaries. The MXD definition given in this study was relatively expansive and inclusive in order to garner a significant number and variety of samples for statistical analysis. The study did not establish criteria for minimum size, density, or number of land uses for a MXD. A general reference is the area reachable by walking. For example, a circle of ¼~ ½ -mile in radius has an area of approximately 125~502 acres. Downtown districts, with the exception of downtown Austin, and traditional neighborhoods were the primary areas cited by local planners. Some of the candidate MXDs cited were in early stages of development or not fully developed at the time of the CAMPO travel survey in 2005. There were excluded from the sample for this study.

Table 3-1. Results of MXD Identification

		Contact	Title	Date	# of MXD's
Bastrop	Bastrop	Stacy Snell	Director	02/24/09	1
	Elgin	Gary Locke	Planner	02/24/09	1
	Smithville	Tex Middlebrook	City Manager	03/02/09	0
Caldwell	Uhland	Karen	City Secretary	02/27/09	0
	Lockhart	Dan Gibson	Planner	02/27/09	1
	Martinville	Rose Gonsalez	City Secretary	02/27/09	0
	Luling	Misty Pendley	Director	02/27/09	1
Hays	Bear Creek	Kathryn Rosenblueth	City Secretary	02/27/09	0
	Buda	Sam Fees	Coordinator	03/02/09	1
	Dripping Springs	Jon Thompson	Development Coodinator	03/11/09	1
	Hays	(Unlisted)			0
	Kyle	Debbie Guerra		02/24/09	1
	Mountain City	Jeff Radke	City Manager	03/11/09	0
	Niederwald	Richard Crandal	City Administrator	03/11/09	0
	San Marcos	John Foreman	Planner	03/06/09	1
	Wimberly	Abby Gillfillan	Planning Technician	03/03/09	0
	Woodcreek	(Unlisted)			0
Travis	Austin	Rachel May	Senior Planner	12/11/08	3
	Bee Cave	Travis Askey	Asst City Administrator	02/27/09	1
	Briarcliff	Aaron Johnson	City Manager	03/03/09	0
	Creedmoor	(Unlisted)			0
	Jonestown	Dan Dodson	Administrator	03/06/09	0
	Lago Vista	Frank Robbins	Asst City Manager	03/03/09	0

	Lakeway	Kristina Dorrheim		03/06/09	0
	Manor	Tom Bolt	Director	03/03/09	0
	Mustang Ridge	Sheri Mack	City Secretary	03/03/09	0
	Pflugerville	Autumn Speer	Planning Director	03/06/09	1
	Point Venture	Chance Chatham	Village Secretary	03/07/09	0
	Rollingwood	Vicky Rudy	City Administrator	03/03/09	0
	San Leanna	(Unlisted)			0
	Sunset Valley	Carla Jenkins	Chairperson	03/06/09	0
	The Hills	Chris Redd		03/06/09	0
	Volente	Jennifer Zufelt	City Secretary	03/03/09	0
	Webberville	(Unlisted)			0
	West Lake Hills	Mark Littrell	-	03/03/09	0
Williamson	Bartlett	Diane Evans	City Secretary	03/03/09	0
	Cedar Park	Emily Barron	Senior Planner	03/06/09	1
	Florence	Amy Crane	City Secretary	03/03/09	0
	Georgetown	Jordan Maddox	Planner	03/03/09	1
	Granger	Margaret Doss	City Secretary	03/03/09	0
	Hutto	Will Guerin	Planner	03/09/09	0
	Jarrell	Mel Yantis	City Manager	03/10/09	0
	Leander	Robin Stover	Planning	03/03/09	0
	Liberty Hill	Rachel Austin	Deputy City Clerk	03/03/09	0
	Round Rock	Lee Heckman	Principal Planner	03/06/09	2
	Taylor	John Elsden	Planner	12/02/08	1
	Thrall	Troy Marx	Mayor	03/03/09	0
	Weir	Julia Navarrette	City Secretary	03/11/09	0

The second step includes two work sessions with experts from CAMPO and from UT Austin. The experts were presented with maps of land use and street network for the study area and asked to draw on the maps the MXD-like developments. CAMPO staff reviewed the preliminary set of MXDs and offered their own identification of MXD samples. UT planning faculty members, Dr. Robert Paterson and Dr. Kent Butler, who have decades of working knowledge on land use and community development in Central Texas were invited to provide their expert knowledge of Central Texas geography and urban planning. The work session led to identification of additional MXD's.

Finally, the research team using land use GIS and Google aerial photos refined the MXDs identified from previous steps and finalized the boundaries of the MXD's to complete the sample set. The final sample set contains 42 MXD's. Information on their sources and areas is provided in Table 3-2. Figure 3-1 shows the spatial distribution of the MXDs in the region. Maps and aerial photographs of each of the MXD's can be found in Appendix 2.

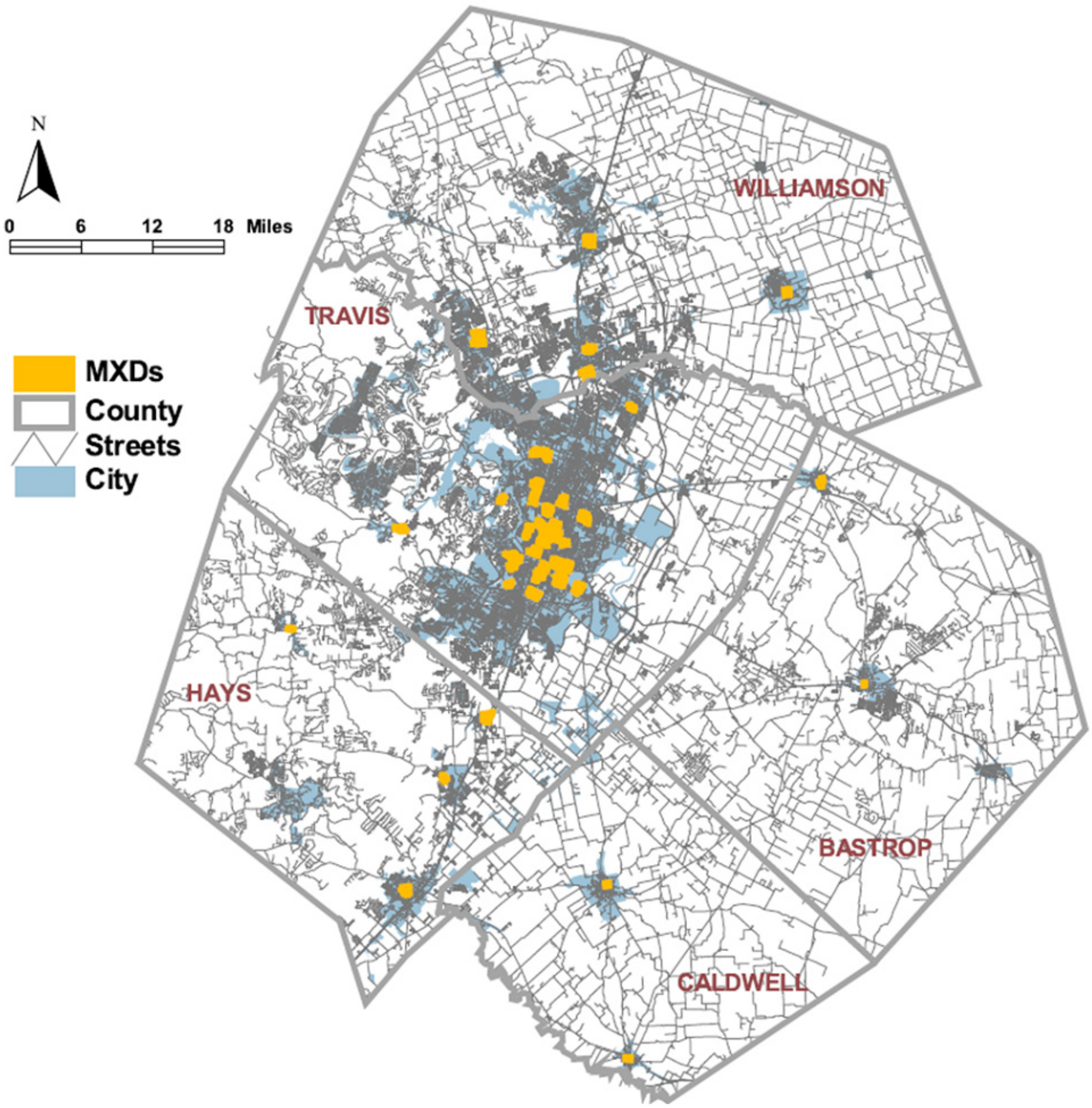


Figure 3-1 MXD Distribution in the Austin, TX Region

Table 3-2. MXD Inventory							
ID	MXD	SOURCE	ACRE	ID	MXD	SOURCE	ACRE
1	Round Rock	Survey	162	22	Rollingwood	CRP	293
2	La Frontera	Survey	243	23	Manor Road	CRP	108
3	San Marcos	Survey	220	24	Windsor Village	CRP	260
4	Pflugerville	Survey	111	25	Burnet at North Loop	CRP	233
5	Cedar Park	Survey	506	26	Exposition	CRP	170
6	Buda	Survey	310	27	East Sixth	CRP	254
7	Bee Cave	Survey	168	28	Montopolis	CRP	276
8	Lockhart	Survey	62	29	Far West	CRP	286
9	Kyle	Survey	104	30	Brodie Oaks	CRP	84
10	Luling	Survey	67	31	Balcones North Loop	CRP	200
11	Bastrop	Survey	25	32	Penn Field	CRP	287
12	Elgin	Survey	104	33	Barton Oaks	CRP	212
13	Georgetown	Survey	316	34	Davenport Village	CRP	110
14	Taylor	Survey	135	35	Hyde Park	Survey	282
15	Dripping Springs	Survey	52	36	North Campus	CRP	550
16	Holly Cesar Chavez	Survey	392	37	West Campus	CRP	371
17	Crestview	CAMPO	211	38	Parker Burton	CRP	96
18	Old West Austin	CAMPO	215	39	East Riverside	CRP	208
19	35th at Jefferson	CRP	120	40	River City North	CAMPO	159
20	Gateway	CRP	225	41	South Congress	CAMPO	107
21	Arboretum	CRP	205	42	South First Street	CAMPO	145

3.2 Derivation of Urban Form Variables

Table 3-3 list the main urban form variables derived for the study at the levels of Traffic Series Zone (TAZ) and MXD. Not all of the variables are available for the five-county region. For instance, data on sidewalk exist at time of study for City of Austin only. Accordingly, sidewalk-related variables are derived only for the area within City of Austin. Table 3-4 reports summary statistics of the variables for MXDs. Specific GIS procedures to derive the variables are presented in Appendix 1.

Table 3-3. Urban Form Variable Definition

Variables	**Definition**
INTERNAL, TAZINTERNAL	Dummy variable indicating that a trip remains internal to the MXD and the TAZ, respectively
CHOSEN	Mode choice variable taking discrete values: 1 Driving Alone, 2 Car Pool, 3 Walking, 4 Biking, 5 Taxi, and 6: Bus
TDIST	Network trip distance between origin and destination locations in miles
VEHPC	Number of motorized vehicles per person in the household
POP	Resident population within the MXD;, data at the TAZ level were prorated.
EMP	Employment within the MXD; Weighted sum of the employment within the MXD for all SIC industries. For Portland, employment estimates were based on the average number of employees in each size category, summed across employer size categories. For other regions, data at the TAZ level were prorated.
ACTIVITY	Resident population plus employment within the MXD
ACTDEN	Activity density per acre within MXD/TAZ. Sum of population and employment within the MXD/TAZ, divided by gross land area
DEVLAND	Proportion of developed land within the MXD
JOBPOP	Index that measures balance between employment and resident population within MXD/TAZ. Index ranges from 0, where only jobs or residents are present in an MXD/TAZ, not both, to 1 where the ratio of jobs to residents is optimal from the standpoint of trip generation. JOBPOP = 1 – [ABS (employment – 0.2*population)/(employment + 0.2*population)]
STRDEN	Centerline miles of all streets per acre land area
INTDEN	Number of intersections per acre
PCT1WAY	% 1-way (i.e., cul-de-sac) intersections in MXD/TAZ
PCT4WAY	% 4-way intersections in MXD/TAZ
STOPDEN	Number of bus stops within the MXD/TAZ per acre land area
SIDEWKDEN	Sidewalk density (ft per acre)
BLKAVG	Average block size in acres in MXD/TAZ

Table 3-4 MXD Descriptive Statistics				
	Minimum	Maximum	Mean	St. Dev.
Area (acre)	25.1	549.5	205.89	113.09
Population	14.0	9975.0	1555.86	1893.83
Households	5.0	4044.0	665.79	859.13
Employment	6.0	7583.0	1319.50	1585.46
Activity (Pop. + Emp.)	20	14805	2875.35	3122.29
Job-Pop Ratio	0.03	5.41	1.20	1.33
Population Density (Persons/Acre)	0.3	26.9	6.71	5.75
Employment Density (Jobs/Acre)	0.1	28.4	5.92	5.87
Bus Stops	0.0	53.0	11.67	14.01
Average Block Size (acre)	1.9	84.2	10.42	13.94
% Cul-de-sac	0.0	0.4	0.09	0.09
% 4-Way Intersection	0.1	1.0	0.44	0.23
Developed Land (%)	0.6	1.0	0.89	0.09
% 4-Way Intersection	0.1	1.0	0.44	0.23
Land Use Mix	0.30	0.82	0.55	0.12
Street Density	7.70	46.23	28.51	9.72
Intersection Density	22.80	403.33	212.45	88.84
Cul-de-sac Density	0.00	58.26	11.02	10.99
4-Way Intersection Density	0.00	305.38	94.96	80.60
Sidewalk Coverage	0.00	1.22	0.46	0.42

3.3 Geocoding of Trip Records in GIS

The main data source for this study comes from the 2005 Austin Activity Travel Survey. The survey records geographic coordinates of activity locations and trip ends (origins and destinations) of the surveyed travelers. For travel analysis, these trip ends are geocoded in TransCAD GIS (Figure 3-2 Top). Network distance is estimated based on the assumption that the traveler took the shortest path in length between trip origin and destination (Figure 3-2 bottom). Figure 3-3 illustrates the geocoded trip ends.

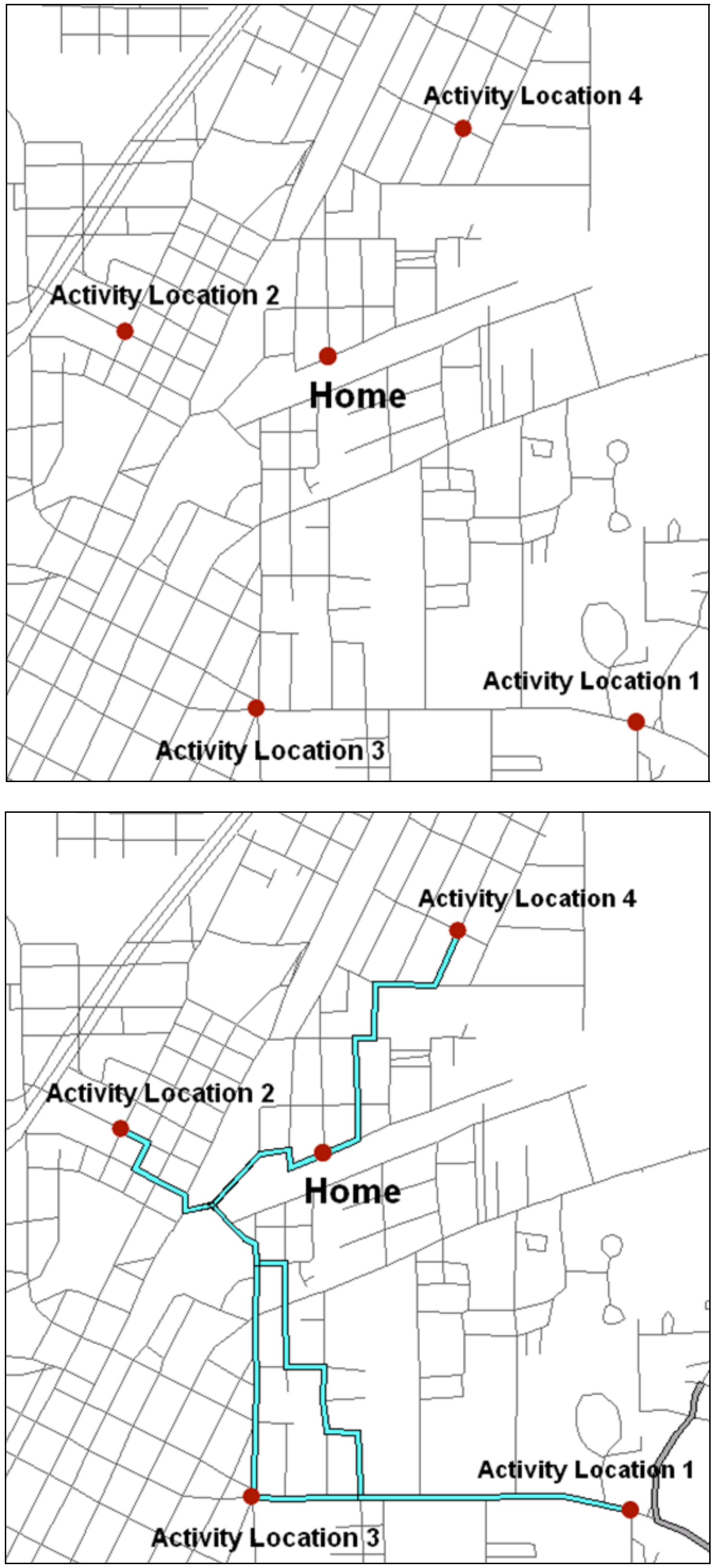


Figure 3-2 Geocoding of Trip Ends and Trip Distance Estimate

Figure 3-3 Distribution of Trip Ends in the 2005 Austin Activity Travel Survey

Table 3-5 reports descriptive statistics of the households located inside and outside MXDs. Notably, households outside MXDs having an average number of 2.82 persons per household are larger than those inside MXDs (2.29 persons per household). The statistical test of difference in sample means suggests that the difference in average household size is significant. This difference exists mainly due to a larger number of non-working dependents in non-MXD households than MXD households because statistically the MXD and non-MXD households appear to have the same average number of workers. On the per capita basis, however, the average MXD household exhibits similar characteristics to the average non-MXD household in terms of income, vehicle ownership, and tenure. The descriptive statistics shown in Table 3-5 suggest to a certain extent the representativeness of the sampled MXD households for the 2005 surveyed households except for household size.

Table 3-5 Sample Household Characteristics									
	HH Inside MXDs (n=65)				HH Outside MXDs (n=1,354)				
Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	t-test
# Persons in HH	2.29	1.20	1.00	5.00	2.82	1.54	1.00	13.00	-2.75
# Workers in HH	1.08	0.83	0.00	2.00	1.12	0.80	0.00	2.00	-0.44
HH Income (2005 $1000's)	45.35	36.30	5.00	150.00	54.38	38.33	5.00	150.00	-1.86
Income/Person (2005 $1000s)	22.21	17.19	2.50	87.50	22.92	18.47	0.83	150.00	-0.30
Vehicles in HH	1.80	0.96	0.00	4.00	1.91	0.91	0.00	7.00	-0.93
Vehicles/Person	0.87	0.46	0.00	3.00	0.79	0.41	0.00	5.00	1.59
Vehicles/Worker	1.24	0.46	0.00	2.00	1.41	0.71	0.00	5.00	-1.54
Bikes in HH	0.85	1.39	0.00	7.00	1.67	7.20	0.00	99.00	-0.92
Years in Residence	3.80	1.73	0.00	5.00	3.98	1.58	0.00	5.00	-0.89

4 CASE STUDY: ANALYSIS OF MXD TRAVEL CHARACTERISTICS

This section reports individual and household travel characteristics from analyzing the 2005 Austin Activity Travel Survey. The main interests are in the differences in travel behavior between those who are associated (living in, traveling from or to) with the MXDs and those who are not. Seven aspects of travel behavior analyzed include:

- Trip length distribution
- Trip generation rates and internal rate of capture
- Person miles of travel (PMT)
- Vehicle ownership
- Departure time
- Travel mode choice

4.1 Trip Length Analyses

4.1.1. Average Trip Time and Distance

Table 4-1 shown below compare average trip length (times and distances) between MXD and Non-MXD trips for four trip purposes. MXD trips refer to those with trip ends, either origins or destinations, falling within MXDs. Trip times are derived from travel logs of departures and arrivals reported by the surveyed individuals in the 2005 Austin Activity-Travel Survey. A number of records show exceptionally long trip times. The analyses for this study exclude the records with one-way trip time longer than 180 minutes. The last column of each table shows statistical test of the difference in average trip length between MXD and non-MXD trips.

Table 4-1 Average Trip Time and Distance for Home-Based Work Trips

	MXD Trips				Non-MXD Trips				t-test
Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	
Time (minutes)	22.92	17.30	2.00	165.00	23.82	16.27	1.00	175.00	-0.93
Distance (miles)	8.87	8.33	0.12	41.96	10.75	9.16	0.01	49.30	-3.90
	n=393				n=1530				

On average MXD trips are 0.9 minute shorter than non-MXD HBW trips. However, test of the difference in sample means suggests that the difference in average trip times between MXD and non-MXD trips is attributable to sampling errors. For HBW travel purpose, average MXD trip distance (8.87 miles) is statistically significantly shorter than non-MXD trips (10.75 miles), indicating a higher average travel speed for non-MXD trips than for MXD trips.

For HBNW trips, MXD travelers travel longer in both time and distance than non-MXD travelers. The differences in average trip length cannot be attributed to sampling errors (Table 4-2).

Table 4-2 Average Trip Time and Distance for Home-Based Non-Work Trips									
	MXD				Non-MXD				t-test
Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	
Time (minutes)	15.47	10.94	1.00	90.00	14.56	11.90	1.00	180.00	2.50
Distance (miles)	6.07	6.44	0.01	45.82	5.41	6.40	0.01	65.87	3.13
	n=1104				n=6245				

Table 4-3 shows that, for NHBW trips, MXD travelers travel shorter in both time and distance than non-MXD travelers. The differences in average trip length are statistically significant. For non-home based other trips, there are no statistically significant differences in average trip time and distance between MXD and non-MXD trips (Table 4-4).

Table 4-3 Average Trip Time and Distance for Non-Home-Based Work Trips									
	MXD				Non-MXD				t-test
Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	
Time (minutes)	13.12	10.08	1.00	75.00	16.09	13.98	1.00	120.00	-3.80
Distance (miles)	5.39	6.25	0.10	43.66	6.59	7.22	0.03	43.03	-2.69
	n=310				n=694				

Table 4-4 Average Trip Time and Distance for Non-Home-Based Other Trips									
	MXD				Non-MXD				t-test
Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	
Time (minutes)	13.11	11.79	1.00	120.00	13.25	11.40	1.00	75.00	-0.25
Distance (miles)	4.68	5.68	0.01	35.50	4.86	6.26	0.01	40.01	-0.66
	n=571				n=1641				

4.1.2. Trip Length Distribution (TLD)

This section presents TLD estimates for four trip purposes for MXD and non-MXD trips. TLD is assumed to take a Gamma function and estimation was done in Matlab. Estimated friction function parameters and average trip time are reported following each TLD graph.

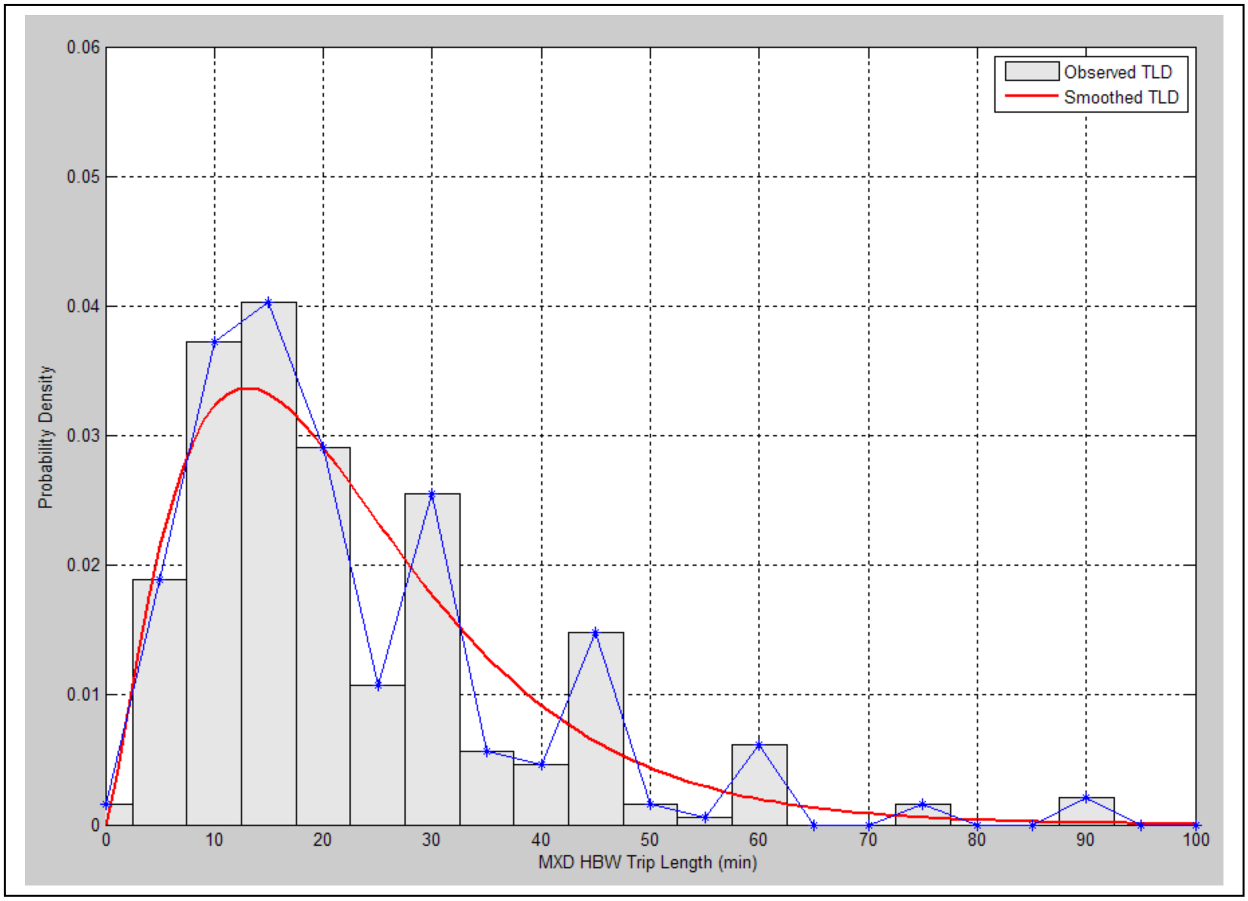


Figure 4-1 TLD for MXD HBW Trips

Estimated Friction Function Parameters:
A = 0.0040; B = 1.3560; C = -0.1044

Estimated Average Trip Time: 22.56 minutes

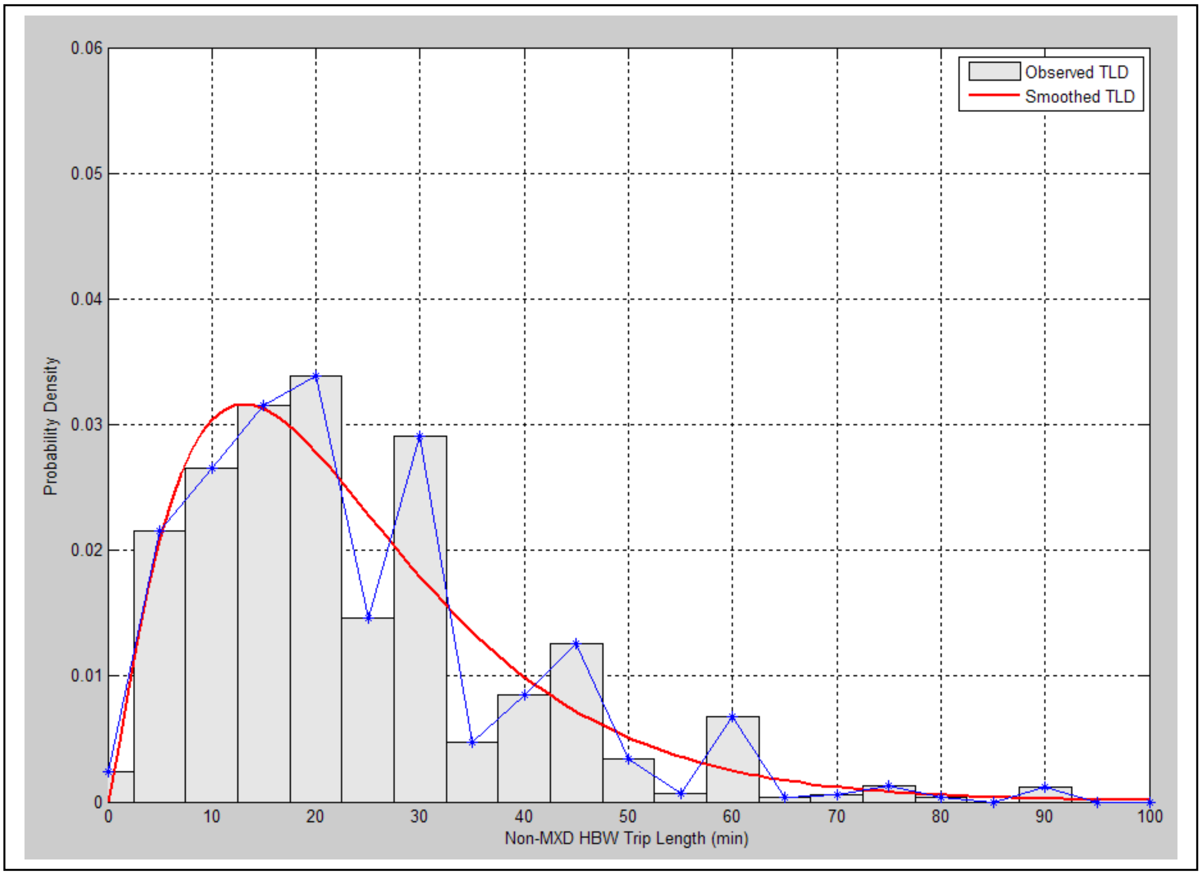


Figure 4-2 TLD for Non-MXD HBW Trips

Estimated Friction Function Parameters:
A = 0.0046; B = 1.2302; C = -0.0940

Estimated Average Trip Time: 23.72 minutes

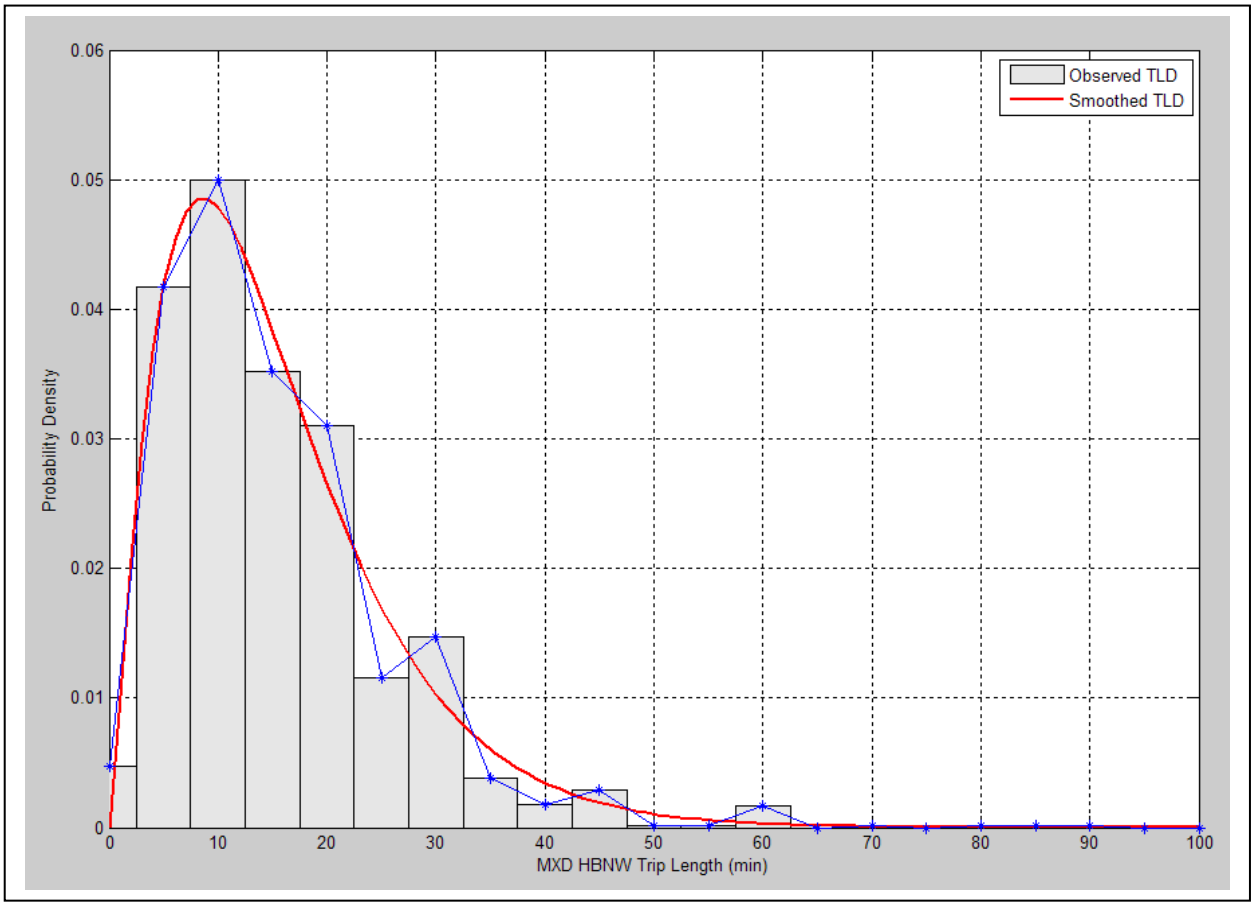


Figure 4-3 TLD for MXD HBNW Trips

Estimated Friction Function Parameters:
A = 0.0116; B = 1.2471; C = -0.1453

Estimated Average Trip Time: 15.47 minutes

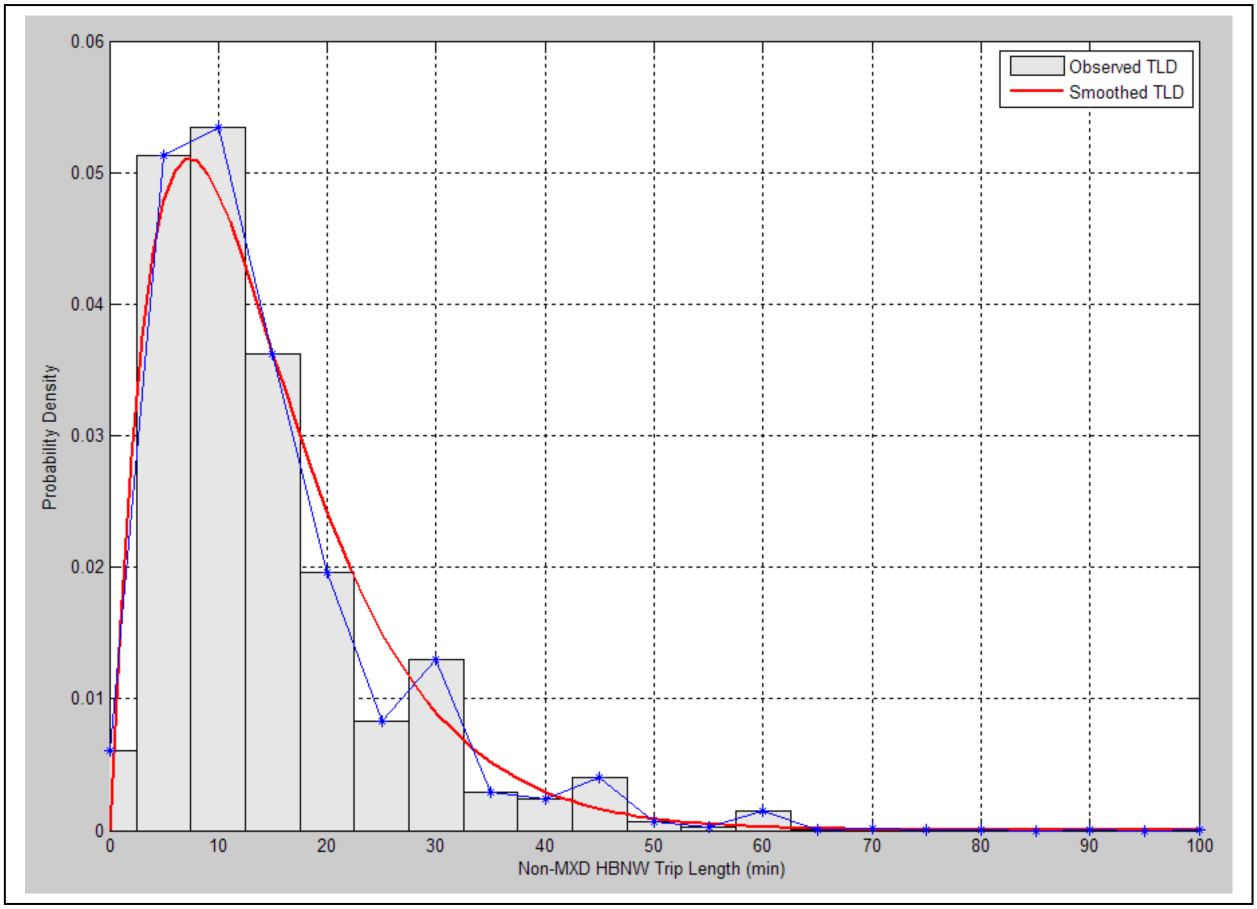


Figure 4-4 TLD for Non-MXD HBNW Trips

Estimated Friction Function Parameters:
A = 0.0182; B = 1.0361; C = -0.1410

Estimated Average Trip Time: 14.44 minutes

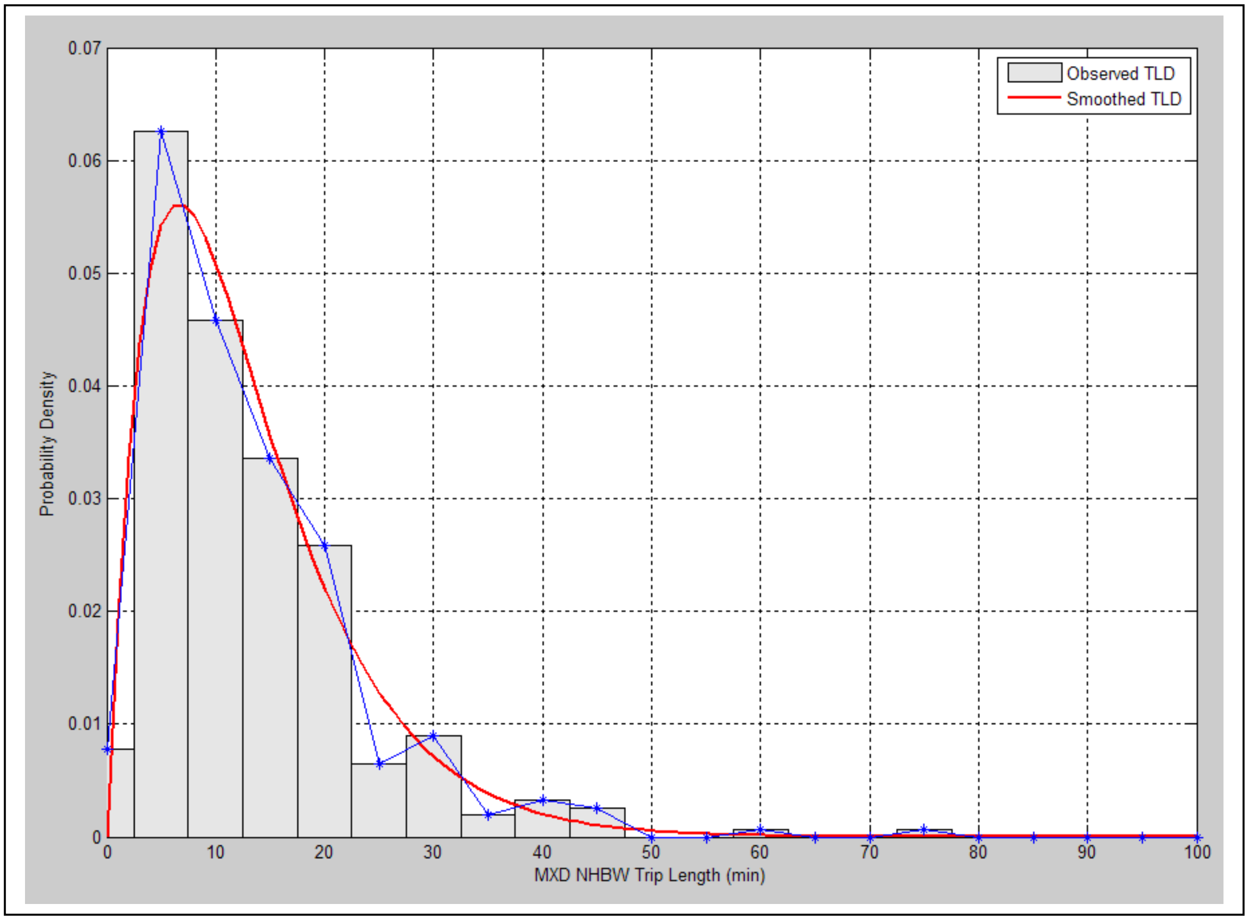


Figure 4-5 TLD for MXD NHBW Trips

Estimated Friction Function Parameters:
A = 0.0224; B = 1.0277; C = -0.1545

Estimated Average Trip Time: 13.12 minutes

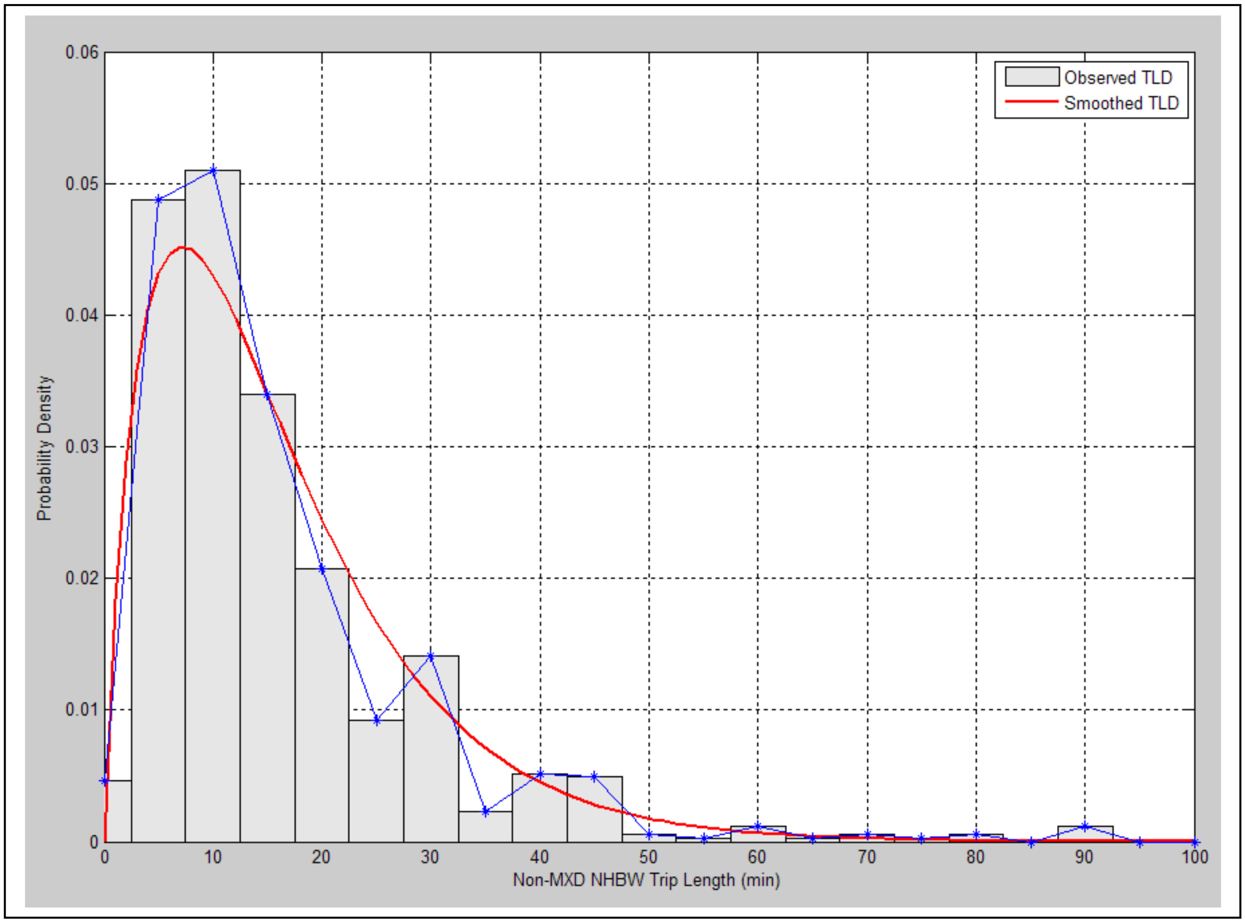


Figure 4-6 TLD for Non-MXD NHBW Trips

Estimated Friction Function Parameters:
A = 0.0205; B = 0.8105; C = -0.1126

Estimated Average Trip Time: 16.09 minutes

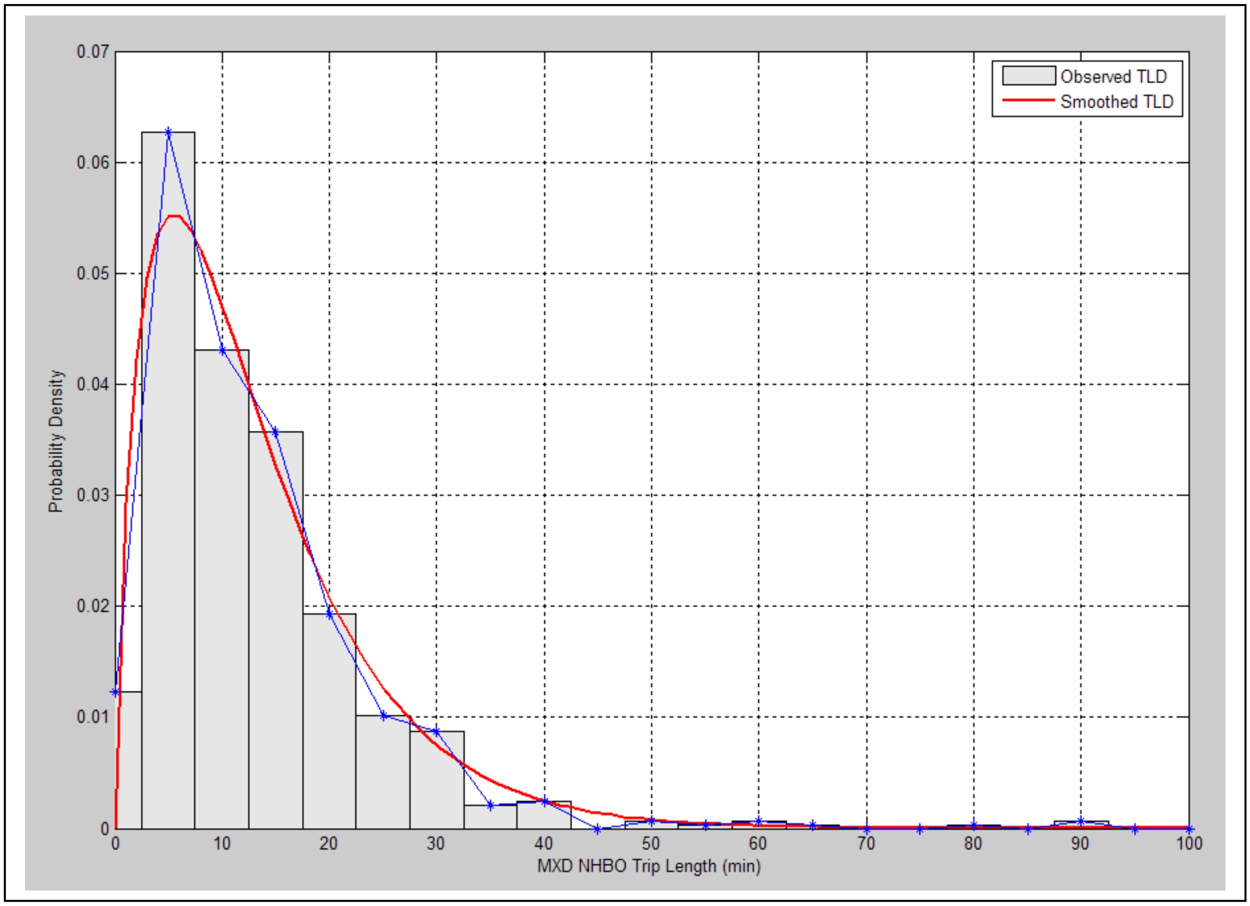


Figure 4-7 TLD for MXD NHBO Trips

Estimated Friction Function Parameters:
A = 0.0332; B = 0.7224; C = -0.1314

Estimated Average Trip Time: 13.11 minutes

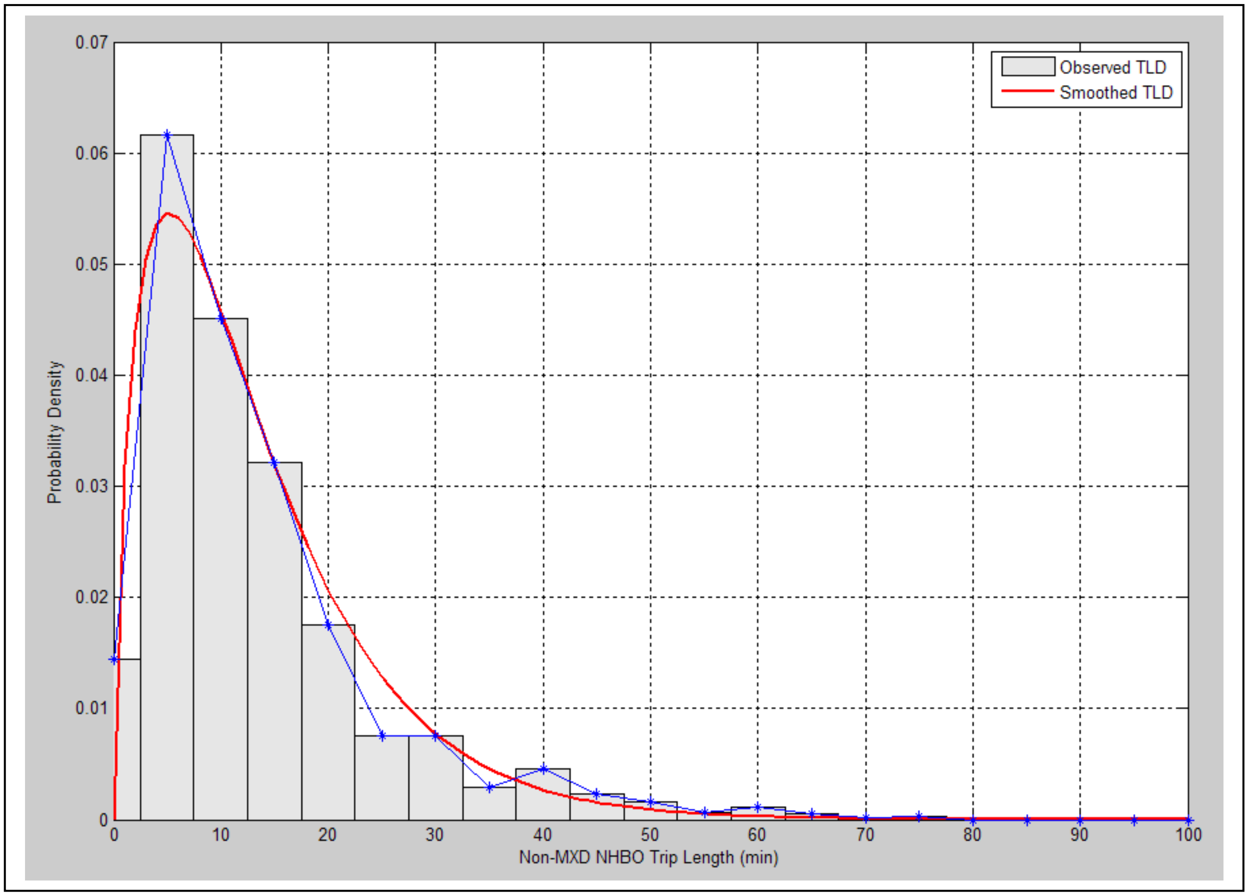


Figure 4-8 TLD for Non-MXD NHBO Trips

Estimated Friction Function Parameters:
A = 0.0359; B = 0.6452; C = -0.1242

Estimated Average Trip Time: 13.25 minutes

4.2 Trip Generation Rates and Internal Rate of Capture

4.2.1 Trip Rates of MXDs and Non-MXDs

Table 4-5 presents a summary of trip generation for MXD and non-MXD homes for four trip purposes and for total trips as well. On average, individuals living inside MXDs make statistically no different number of daily trips as those living outside MXDs. Nevertheless, those living in MXDs make more frequent HBW trips. Intuitively, jobs and homes in MXDs are relatively close. The close proximity may encourage workers to go home, for example, during lunch breaks, and then go back to the workplace. An ordered logit model of HBW trip rate confirms the expectation (Table 4-6).

Table 4-5 Trip Rates by Purposes

	Home Inside MXDs (n=123)				Home Outside MXDs (n=3,264)				
Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	t-test
Total Trips	3.8	2.3	1.0	15.0	3.7	2.3	1.0	27.0	0.36
By Purpose									
HBW	0.8	1.2	0.0	7.0	0.6	0.9	0.0	6.0	3.15
HBNW	2.2	1.8	0.0	10.0	2.2	1.6	0.0	12.0	0.10
NHBW	0.3	0.9	0.0	5.0	0.3	1.0	0.0	25.0	0.50
NHBO	0.4	0.9	0.0	5.0	0.7	1.2	0.0	11.0	-2.23

Table 4-6 Ordered Logit of HBW Trip Rate

	Coef.	Std. Err.	t-Stat.	
Age (years)	-0.012	0.002	-4.88	**
Gender (1: Female; 0: Male)	-0.590	0.079	-7.43	**
Student (1: Yes; 0: No)	-3.161	0.182	-17.34	**
Household Size (Persons)	0.166	0.070	2.36	**
Income Per Capita (2005 $)	0.005	0.003	1.93	*
Vehicles Per Capita	0.408	0.123	3.31	**
Years in Residence	0.009	0.026	0.35	
Distance to Downtown (Miles)	0.000	0.004	0.02	**
Population Density (Persons/Acre)	0.022	0.014	1.56	
Job Density (Jobs/Acre)	0.022	0.013	1.69	*
% Cul de sac Intersections	-0.550	0.402	-1.37	
Street Density (Feet/Acre)	-0.001	0.001	-0.85	
Number of obs: 3,369				
Pseudo R-squared: 0.1194				
Note: * Significant at 0.01 level; ** Significant at 0.05 level.				

4.2.2 Three-Way Tabulation of Household Trip Rates

Tables 4-7 ~ 4-9 report person trip production rates for the full sample, the sub-sample outside MXDs, and the sub-sample inside MXDs, respectively. Rates for four trip purposes are reported: home-based work, home-based nonwork, non-home-based work, and non-home-based others. Reports are disaggregated in three ways: income, number of workers in households, and household size. Income grouping uses household income in 2005 dollars: 1: Less than $9,999; 2: $10,000 to $19,000; 3: $20,000 to $34,999; 4: $35,000 to $49,999; 5: $50,000 to $99,999; 6: $100,000 or more.

These tabulations may be used to develop look-up tables for estimating MXD-related trip productions for CAMPO planning models.

Table 4-7 Average Trips per Household by # of Workers, Income and Household Size (All Households)

Income Group	Workers	HH Size	Home-Based Work Trips	Home-Based Non-Work Trips	Non-Home-Based Work Trips	Non-Home-Based Other Trips
1	0	1	0.00	2.56	0.00	0.81
1	0	2	0.00	4.35	0.00	0.35
1	0	3	0.00	8.00	0.00	3.00
1	0	4	0.00	8.00	0.00	8.00
1	0	5	0.00	9.80	0.00	4.40
2	0	1	0.00	2.82	0.00	1.21
2	0	2	0.00	5.00	0.00	1.29
2	0	3	0.00	9.75	0.00	4.00
2	0	5	0.00	14.50	0.00	2.50
3	0	1	0.00	2.37	0.00	1.29
3	0	2	0.00	5.11	0.00	1.57
3	0	3	0.00	8.00	0.00	1.50
3	0	4	0.00	2.00	0.00	0.00
4	0	1	0.00	2.68	0.00	1.23
4	0	2	0.00	4.63	0.00	1.63
4	0	3	0.00	6.00	0.00	3.00
4	0	4	0.00	10.00	0.00	0.00
5	0	1	0.00	3.00	0.00	1.22
5	0	2	0.00	5.49	0.00	1.84
5	0	3	0.00	6.50	0.00	1.75
6	0	1	0.00	3.00	0.00	1.50
6	0	2	0.00	5.57	0.00	1.93
6	0	3	0.00	6.00	0.00	3.50

6	0	4	0.00	8.00	0.00	5.00
1	1	1	1.00	1.57	0.14	0.29
1	1	2	1.33	5.67	0.00	0.33
1	1	3	1.50	4.83	0.50	2.33
1	1	4	1.00	9.00	3.00	8.00
1	1	5	1.00	10.00	1.00	0.50
2	1	1	1.29	1.50	0.43	1.43
2	1	2	1.45	3.80	0.55	1.90
2	1	3	1.00	7.44	0.33	2.11
2	1	4	1.40	9.40	0.60	1.60
2	1	5	1.31	10.81	0.56	2.19
3	1	1	1.52	1.26	0.93	0.22
3	1	2	1.81	2.25	0.69	0.81
3	1	3	1.63	5.73	0.67	1.47
3	1	4	1.50	7.38	0.25	0.81
3	1	5	1.42	11.92	0.50	2.42
4	1	1	1.41	1.59	0.71	0.62
4	1	2	1.38	3.31	0.55	0.72
4	1	3	1.94	4.47	0.06	0.53
4	1	4	1.32	7.63	0.58	2.00
4	1	5	1.60	17.40	0.40	7.40
5	1	1	1.32	1.32	0.95	0.82
5	1	2	1.34	2.92	0.37	1.05
5	1	3	1.61	5.50	0.83	2.44
5	1	4	1.24	10.00	0.95	3.19
5	1	5	1.42	14.84	2.74	5.16
6	1	1	0.71	2.00	1.71	0.29
6	1	2	1.82	3.09	1.18	2.36
6	1	3	1.53	6.05	0.79	2.11
6	1	4	1.24	11.84	0.80	3.64
6	1	5	1.22	16.00	1.44	3.11
1	2	2	0.00	7.00	0.00	1.00
1	2	4	3.00	5.00	2.00	2.50
2	2	2	1.71	3.43	0.57	0.43
2	2	3	2.50	3.17	1.17	0.50
2	2	4	2.75	6.25	1.25	0.25
2	2	5	2.60	11.20	0.40	3.40
3	2	2	2.96	2.63	1.75	1.38
3	2	3	3.62	2.33	0.57	0.33
3	2	4	2.79	7.25	0.96	1.67

3	2	5	3.10	11.35	1.00	2.10
4	2	2	2.97	2.06	1.68	0.91
4	2	3	2.68	4.71	1.36	1.25
4	2	4	3.06	7.50	1.84	1.38
4	2	5	3.21	10.64	1.11	2.82
5	2	2	3.00	2.14	1.63	1.21
5	2	3	2.87	4.94	2.21	1.09
5	2	4	2.38	8.15	1.73	2.04
5	2	5	2.62	11.29	1.79	4.24
6	2	2	3.16	2.06	1.52	0.68
6	2	3	2.63	5.03	2.09	1.44
6	2	4	1.86	8.62	2.48	3.41
6	2	5	2.50	12.36	2.09	6.05

Table 4-8 Average Trips per Household by # of Workers, Income and Household Size (Households Outside of MXDs)

Income Group	Workers	HH Size	Home-Based Work Trips	Home-Based Non-Work Trips	Non-Home-Based Work Trips	Non-Home-Based Other Trips
1	0	1	0.00	2.44	0.00	0.88
1	0	2	0.00	4.13	0.00	0.38
1	0	3	0.00	8.00	0.00	3.00
1	0	4	0.00	8.00	0.00	8.00
1	0	5	0.00	9.80	0.00	4.40
2	0	1	0.00	2.63	0.00	1.22
2	0	2	0.00	4.96	0.00	1.26
2	0	3	0.00	9.75	0.00	4.00
2	0	5	0.00	12.00	0.00	3.00
3	0	1	0.00	2.38	0.00	1.41
3	0	2	0.00	5.09	0.00	1.57
3	0	3	0.00	8.00	0.00	1.50
3	0	4	0.00	2.00	0.00	0.00
4	0	1	0.00	2.71	0.00	1.24
4	0	2	0.00	4.72	0.00	1.69
4	0	3	0.00	6.00	0.00	3.00
4	0	4	0.00	10.00	0.00	0.00
5	0	1	0.00	3.00	0.00	1.14
5	0	2	0.00	5.52	0.00	1.88

5	0	3	0.00	6.50	0.00	1.75
6	0	1	0.00	3.00	0.00	1.50
6	0	2	0.00	5.57	0.00	1.93
6	0	3	0.00	5.33	0.00	4.67
6	0	4	0.00	8.00	0.00	5.00
1	1	1	0.83	1.83	0.17	0.33
1	1	2	1.33	5.67	0.00	0.33
1	1	3	1.50	4.83	0.50	2.33
1	1	4	1.00	9.00	3.00	8.00
1	1	5	1.00	10.00	1.00	0.50
2	1	1	1.29	1.50	0.43	1.43
2	1	2	1.45	3.80	0.55	1.90
2	1	3	1.00	7.00	0.14	2.71
2	1	4	1.40	9.40	0.60	1.60
2	1	5	1.31	10.81	0.56	2.19
3	1	1	1.43	1.39	0.83	0.22
3	1	2	1.80	2.27	0.67	0.83
3	1	3	1.59	5.85	0.67	1.56
3	1	4	1.50	7.38	0.25	0.81
3	1	5	1.42	11.92	0.50	2.42
4	1	1	1.44	1.63	0.72	0.59
4	1	2	1.37	3.41	0.56	0.78
4	1	3	1.94	4.47	0.06	0.53
4	1	4	1.28	7.17	0.61	1.72
4	1	5	1.60	17.40	0.40	7.40
5	1	1	1.38	1.29	1.00	0.81
5	1	2	1.34	2.92	0.37	1.05
5	1	3	1.61	5.50	0.83	2.44
5	1	4	1.24	10.00	0.95	3.19
5	1	5	1.39	15.00	2.89	5.44
6	1	1	0.71	2.00	1.71	0.29
6	1	2	1.82	3.09	1.18	2.36
6	1	3	1.53	6.05	0.79	2.11
6	1	4	1.24	11.84	0.80	3.64
6	1	5	1.25	14.88	1.25	3.00
1	2	2	0.00	7.00	0.00	1.00
1	2	4	3.00	5.00	2.00	2.50
2	2	2	1.71	3.43	0.57	0.43
2	2	3	2.60	3.80	1.40	0.60
2	2	4	2.75	6.25	1.25	0.25

2	2	5	2.60	11.20	0.40	3.40
3	2	2	2.55	2.73	1.59	1.50
3	2	3	3.62	2.33	0.57	0.33
3	2	4	2.77	7.55	0.77	1.82
3	2	5	3.16	11.42	0.84	2.21
4	2	2	3.03	1.97	1.70	0.94
4	2	3	2.69	4.96	1.42	1.35
4	2	4	3.06	7.50	1.84	1.38
4	2	5	3.19	10.74	1.15	2.78
5	2	2	3.10	1.90	1.75	1.13
5	2	3	2.71	4.71	2.27	1.04
5	2	4	2.34	8.19	1.72	2.09
5	2	5	2.62	11.29	1.79	4.24
6	2	2	3.13	2.00	1.50	0.70
6	2	3	2.67	5.10	1.97	1.43
6	2	4	1.86	8.62	2.48	3.41
6	2	5	2.50	12.36	2.09	6.05

Table 4-9 Average Trips per Household by # of Workers, Income and Household Size (Households inside of MXDs)

Income Group	Workers	HH Size	Home-Based Work Trips	Home-Based Non-Work Trips	Non-Home-Based Work Trips	Non-Home-Based Other Trips
1	0	1	0	3.5	0	0.25
1	0	2	0	8	0	0
2	0	1	0	8	0	1
2	0	2	0	6	0	2
2	0	5	0	22	0	1
3	0	1	0	2.33	0	0
3	0	2	0	6	0	2
4	0	1	0	2	0	1
4	0	2	0	2	0	0
5	0	1	0	3	0	1.5
5	0	2	0	4	0	0
6	0	3	0	8	0	0
1	1	1	2	0	0	0
2	1	3	1	9	1	0
3	1	1	2	0.5	1.5	0.25
3	1	2	2	2	1	0.5

3	1	3	2	4.67	0.67	0.67
4	1	1	1	1	0.5	1
4	1	2	1.5	2	0.5	0
4	1	4	2	16	0	7
5	1	1	0	2	0	1
5	1	5	2	12	0	0
6	1	5	1	25	3	4
2	2	3	2	0	0	0
3	2	2	7.5	1.5	3.5	0
3	2	4	3	4	3	0
3	2	5	2	10	4	0
4	2	2	1	5	1	0
4	2	3	2.5	1.5	0.5	0
4	2	5	4	8	0	4
5	2	2	2	4.6	0.4	2
5	2	3	4.4	7.2	1.6	1.6
5	2	4	4	6	2	0
6	2	2	4	4	2	0
6	2	3	2	4	4	1.5

4.2.3 Internal Rate of Capture

Table 4-10 reports internal rates of capture for each of the 42 MXDs in the study area. On average, 7.4% of MXD trips are internal, with both trip origins and destinations falling within the MXD boundaries. The highest rate of internal capture is nearly 35%. Table 4-11 compares internal trip rates of MXDs with TAZs in comparable size.

Table 4-10 - Internal Rate of Capture by MXD's

MXD	Total Trip Ends	Internal Trips	% of Trips
1	18	0	0.00
2	44	3	6.82
3	77	23	29.87
4	10	0	0.00
5	37	1	2.70
6	3	0	0.00
7	14	0	0.00
8	22	0	0.00
9	8	0	0.00
10	4	0	0.00

11	13	1	7.69
12	17	1	5.88
13	44	3	6.82
14	28	2	7.14
15	7	0	0.00
16	63	0	0.00
17	79	18	22.78
18	52	2	3.85
19	51	13	25.49
20	36	5	13.89
21	36	2	5.56
22	36	2	5.56
23	9	2	22.22
24	44	4	9.09
25	32	1	3.13
26	25	0	0.00
27	46	6	13.04
28	31	1	3.23
29	84	10	11.90
30	12	0	0.00
31	18	0	0.00
32	19	1	5.26
33	9	0	0.00
34	11	2	18.18
35	56	0	0.00
36	101	6	5.94
37	62	11	17.74
38	37	1	2.70
39	23	8	34.78
40	53	2	3.77
41	14	2	14.29
42	12	0	0.00

Table 4-11 Internal Trip Rates in MXDs vs. in TAZs								
	MXD (n=42)				TAZ* (n=450)			
Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max
% Internal	7.64	9.28	0.00	34.78	4.57	9.37	0.00	50.00
Internal Trips	3.14	4.98	0.00	23.00	1.06	2.36	0.00	15.00
Total Trips	31.67	21.90	3.00	90.00	14.54	14.25	0.00	115.00
Area (acre)	205.89	113.09	25.10	549.50	253.27	143.04	25.44	547.97
*Note: Only include those TAZs comparable in size to MXDs.								

4.3 Analysis of Person-Miles of Travel (PMT)

On average, a person living in MXDs travels 17 miles daily, about six miles less than those living outside MXDs. The difference can be attributed mainly to shorter travel for HBNW and NHBO purposes (Table 4-12).

Table 4-12 Average Person-Miles of Travel by Households In- and Out-of-MXDs									
	Home Inside MXDs (n=123)				Home Outside MXDs (n=3,264)				
Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	t-test
PMT/Day	17.0	16.5	0.3	84.0	23.2	22.6	0.0	276.0	-3.00
By Purpose									
HBW	5.8	11.5	0.0	71.7	5.9	13.1	0.0	100.7	-0.14
HBNW	8.3	10.2	0.0	61.9	12.2	15.3	0.0	120.7	-2.81
NHBW	1.3	4.9	0.0	33.2	1.9	7.5	0.0	214.9	-0.77
NHBO	1.7	5.1	0.0	36.2	3.2	8.9	0.0	92.4	-1.94
By Travel Mode									
Walk/Bike	0.4	1.8	0.0	16.4	0.7	3.2	0.0	56.3	-1.21
Drive Alone	10.1	14.5	0.0	67.0	11.8	18.4	0.0	143.0	-1.02
Carpool	6.4	10.5	0.0	71.7	10.4	16.8	0.0	123.0	-2.63
Transit	0.1	0.9	0.0	9.7	0.2	5.1	0.0	276.0	-0.17
Other	0.0	0.2	0.0	1.8	0.1	1.2	0.0	50.9	-0.27

To understand factors explaining shorter PMT of MXD travelers, a regression model was estimated (Table 4-13). Notably, aside from individual and household socioeconomic factors, urban form variables, i.e., regional location (distance to downtown), population and job density, network connectivity, and street density contribute additional explanatory power to distance variance.

Table 4-13 Regression Analysis of Average Miles of Travel Per Person				
	Coef.	Std. Err.	t-Stat.	
Age (years)	-0.0002	0.0230	-0.01	
Gender (1: Female; 0: Male)	-0.6765	0.7108	-0.95	
Employed (1: Yes; 0: No)	6.0265	0.8217	7.33	**
Student (1: Yes; 0: No)	-6.9607	1.1743	-5.93	**
Household Size (Persons)	0.8362	0.5645	1.48	
Income Per Capita (2005 $)	0.0731	0.0256	2.85	**
Vehicles Per Capita	3.3712	1.1585	2.91	**
Years in Residence	-0.1140	0.2274	-0.50	
Distance to Downtown (Miles)	0.1665	0.0395	4.21	**
Population Density (Persons/Acre)	-0.4797	0.1279	-3.75	**
Job Density (Jobs/Acre)	-0.3802	0.1260	-3.02	**
% Cul de sac Intersections	6.9733	3.5944	1.94	*
Street Density (Feet/Acre)	-0.0551	0.0110	-5.02	**
Constant	21.9138	2.7991	7.83	**
Number of obs: 3,369				
R-squared: 0.169				
Adj R-squared: 0.166				
Note: * Significant at 0.01 level; ** Significant at 0.05 level.				

4.4 Vehicle Ownership Analysis

Table 4-14 tabulates households by the number of vehicles owned. It shows that there is higher percentage of zero- and one-vehicle households in MXDs than in non-MXDs. Table 4-15 provides descriptive statistics of household vehicle ownership. Table 4-16 reports preliminary regression analysis of vehicle ownership as functions of income, household size, and MXD attributes.

Table 4-14 Household by # of Vehicles Owned

If Outside MXDs:			If Inside MXDs:		
# of Vehicles	Households	%	# of Vehicles	Households	%
0	46	3.40%	0	3	4.62%
1	373	27.55%	1	24	36.92%
2	683	50.44%	2	25	38.46%
3	188	13.88%	3	9	13.85%
4	48	3.55%	4	4	6.15%
5	9	0.66%	5	0	0%
6	6	0.44%	6	0	0%
7	1	0.07%	7	0	0%
Total	1,354	100.00%	Total	65	100.00%

Table 4-15 Descriptive Statistics of Household Vehicle Ownership

If Outside MXDs:					
Variable	N	Mean	Std. Dev.	Min.	Max.
Vehicles / HH	1354	1.91	.9123	0	7
Vehicles /	998	1.41	.7137	0	5
If Inside MXDs:					
Variable	N	Mean	Std. Dev.	Min.	Max.
Vehicles / HH	65	1.80	.9552	0	4
Vehicles /	45	1.24	.4641	0	2

Table 4-16 Regression Models of Household Vehicle Ownership

	In MXDs				Outside MXDs			
Variable	Coeff.	Std. Err.	t-stat.		Coeff.	Std. Err.	t-stat.	
Income (1000's$)	0.0123	0.0027	4.63	**	0.0066	0.0006	11.41	**
HH Size	0.3112	0.0762	4.08	**	0.1855	0.0143	13.01	**
Average Blok Size (acre)	-0.0248	0.0187	-1.32		0.0005	0.0003	2.13	**
Bus Stop Density	-0.6469	1.9715	-0.33		-2.5562	0.9032	-2.83	**
% 4-way Intersection	-1.0379	0.5963	-1.74	*	-0.2956	0.1871	-1.58	
Constant	1.1641	0.4480	2.60	**	1.1127	0.0627	17.75	**
Number of Observations			65				1419	
R-Squared			.2560				.2392	
Adjusted R-Squared			.2188				.2365	

4.5 Departure Time Analysis

Travelers living in MXDs leave home in the morning approximately 11 minutes later those living in non-MXDs. Departure time analysis provides information for calibrating time-of-day distribution and for better understanding peaking effects of traffic (Table 4-17).

Table 4-17 Departure Time for Morning Trips

	Trip Ends in MXDs					Trip Ends outside MXDs				
Variable	N	Mean	Std. Dev	Min	Max	N	Mean	Std. Dev	Min	Max
All Trips	204	544.9	123.8	0	710	1,028	533.6	110.9	0	715
HBW	33	568.3	167.4	0	708	121	557.5	177.5	0	715
HBNW	170	539.9	113.8	0	710	904	530.2	98.4	45	715
Note: Times measured as minutes from midnight.										

4.6 Mode Choice Analysis

4.6.1 Sample Modal Splits

Mode choice analysis utilizes two sources of data: the 2005 Austin Activity Travel Survey and the 2005 Transit On-Board Survey conducted by CapMetro. The 2005 Activity survey includes 13 types of travel modes (Table 4-18).

Table 4-18 Modal Split of Non-MXD Trips		
Mode	Frequency	%
Walk	510	3.81
Auto/Van/Truck Driver	8,489	63.34
Auto/Van/Truck Passenger	3,648	27.22
Carpool Driver	15	0.11
Carpool Passenger	41	0.31
Vanpool Passenger	5	0.04
Commercial Vehicle Driver	59	0.44
Comm. Vehicle Passenger	21	0.16
Bus	20	0.15
Taxi/Paid Limo	99	0.74
Bicycle	414	3.09
Motorcycle/Moped	10	0.07
Other	51	0.38
Don't Know	8	0.06
Refused	12	0.09
Total Valid Records	13,402	100

For references, Tables 4-19 and 4-20 show the modal splits of MXD trips and non-MXD internal trips, respectively. On average, the MXD internal travel has a walking-share (16%) four times of that for non-MXD travel.

Table 4-19 Modal Split of MXD Internal Trips		
Mode	Trips	%
Walk	21	15.79
Auto/Van/Truck Driver	75	56.39
Auto/Van/Truck Passenger	30	22.56
Other	7	5.26
Total	133	100

Table 4-20 TAZ Average Trip Rates and Shares by Travel Modes								
	Drive Alone	Carpool	Walk	Bike	Taxi	Bus	Other	Total Trips
Average Trips	5.86	6.61	0.53	0.44	0.08	0.02	0.15	13.71
Average Share	51.51%	40.14%	2.88%	3.40%	0.62%	0.22%	1.23%	100%
Note: This table is generated at the request of TTI researchers who are studying pedestrian network and travel in Austin for CAMPO.								

For the bus mode, there are only 20 out of 18,545 trips in the original dataset from the 2005 survey, under-representing the use of public transportation in the region. To correct the sample bias, trip records from the 2005 Transit survey from CapMetro were added for the analysis. The raw dataset of the Transit survey contains 20,449 observations. Including the full sample of transit survey for mode choice analysis will introduce new bias. Because there was no information on transit share for 2005, the analysis made an assumption that the bus share for 2005 retained at the minimum the level in 1997, which reported a bus share of 2.31% in the 1997 Austin Activity Travel Survey. This gives 428 (2.31% of 18,545) bus trips expected in 2005. A subset of the Transit survey was then drawn randomly to produce 428 valid observations for the mode choice analysis. This gives a total of 448 bus trips, of which 435 records are valid with complete information for the study.

Trips made by commercial vehicle drivers and passengers were excluded from the analysis because the mode choice behavior is expected to be deterministic--they drove for work. For this analysis, the remaining 11 trip modes were aggregated into six: drive alone (DA), car pool (CA, including van pool), walk, bike, bus, and taxi. Table 4-21 reports sample distribution by modes in the final dataset for mode choice analysis.

Table 4-21 Sample Distribution by Travel Modes with Combined Datasets		
Mode	Times Chosen	Share
Drive Alone	5,823	42.7%
Car Pool	6,340	46.5%
Taxi	99	0.7%
Bus	435	3.2%
Walk	518	3.8%
Bike	411	3.0%
Total	13,626	100.0%

4.6.2 Logit Modeling of Travel Mode Choice

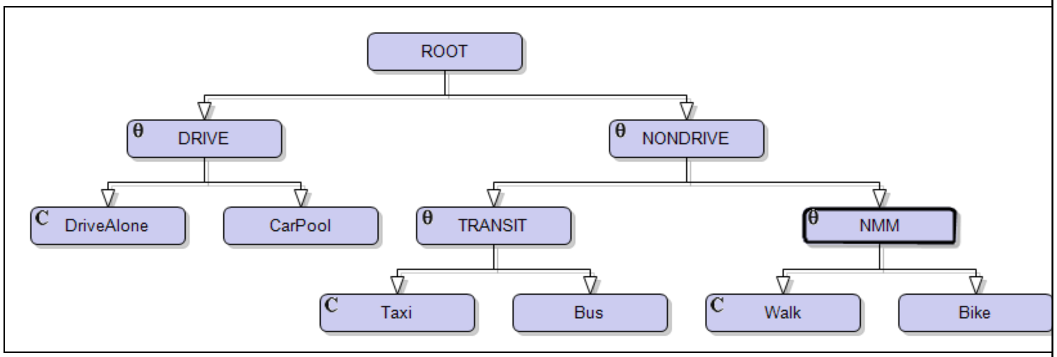
The choice modeling began with specifications of nested logit (NL) structures. Figure 4-9 show examples of NL models explored in the analysis based on different assumptions on the unobserved attributes of the travel modes. Selection of the final models for reporting purposes in this volume considers three aspects of model performance: 1) the sign of coefficients for system and socio-demographic variables; 2) the theta coefficient of Inclusive Value (IV) or the logsum; and 3) the estimate of value of time (VOT). The coefficients for system and socio-demographic variables are assessed based on travel behavior theories and/or common knowledge. For instance, the coefficients for time and monetary cost variables are expected to have negative signs. The theta coefficient is expected to have a value falling between 0 and 1 (Ben-Akiva and Lerman 1985). If the theta coefficient estimate is rejected statistically, the NL model collapses to the conventional joint multinomial logit (MNL) structure. Estimating VOT provides a quantitative assessment of model performance. It is expected that a reasonable VOT for commuting trips ranges from 30% to 50% of wage rate.

Searching for global optimum solution to estimate theta turns out to be a tedious process as the estimate is sensitive to the starting value of theta. In practical applications exhaustive searches for consistent estimate of theta can be done by following a batch approach suggested by Balakrishna and Sundaram (2009).

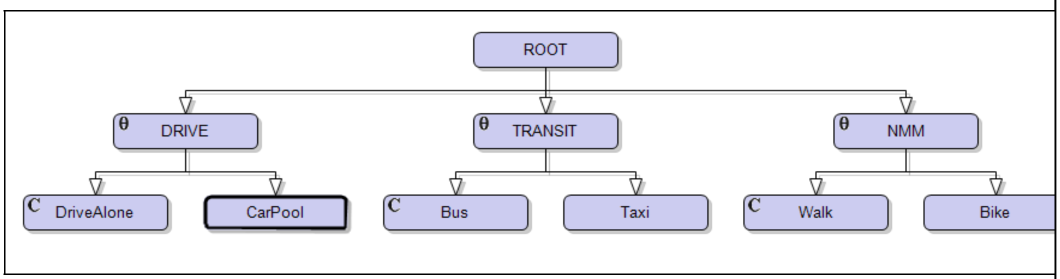
This analysis carried out approximately 80 model runs. Current results suggest that joint MNL specifications outperformed NL specifications. In the MNL and NL models, the coefficient estimates for system and socio-demographic variables have expected signs. The theta estimates in NL models are between 0 and 1 as expected and statistically significant. However, VOT estimates with the NL models appear unreasonably large. Table 4-22 reports VOT estimates for HBW trips. It shows a VOT at $43.75 per hour for a commuter with an annual income of $45,000. The VOT estimates with MNL models are acceptable at $9.05/hour for the region and $13.85/hour for City of Austin. Accordingly, for the final models the analysis specifies no theta coefficient, essentially estimating MNL joint models. Tables 4-24 ~ 4-27 report the final results of MNL modeling. For reference purpose, one NL model is presented in Table 4-23.

Data values for travelers' socioeconomic and demographic characteristics are taken from the 2005 Survey. The skim tables of driving and bus times come from CAMPO. Cost and time values for other modes are estimated base on input from CAMPO. Specifically:

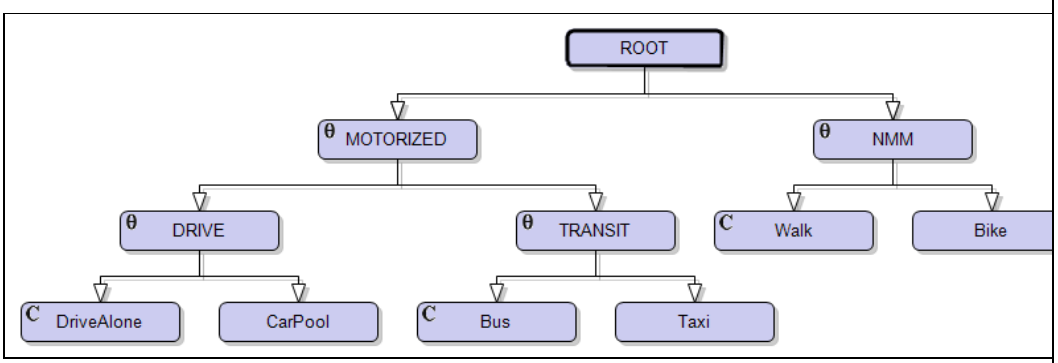
- Driving cost: 12.92 cents/mile (provided by CAMPO);
- Carpool cost: Driving cost/Persons in Vehicle;
- Bus cost: 75 cents if trip distance <10 miles; 150 cents if >10 miles;
- Taxi cost: (2.05+ ((trip distance *11)-2)*0.2)*1.1 (derived from City of Austin taxi fare rules plus 10% tips);
- Zero cost for walking and biking;
- Carpool time: DrivingTime* (1+ 0.2*(sqrt(popinveh)))
- Taxi time: Driving time + 10 minutes wait time;
- Walking time: 3 miles/hour if age 13-60; 2 miles/hour otherwise; and
- Bike time: 15 miles/hour if age 13-60; 10 miles/hour otherwise.



NL Model Structure A



NL Model Structure B



NL Model Structure C

Figure 4-9 Examples of Alternative NL Model Structures

Table 4-22 Value of Time Estimates by Travel Modes			
Mode	NL Region Model	MNL Region	MNL City of Austin
Drive Alone	$43.75	$9.05	$13.85
Carpool	$27.04	$2.81	$3.70
Taxi	$393.22	$49.55	$37.62
Bus	$93.93	$7.78	$7.90
Note: Value of time=(Time_Coeff/Cost_Coef)*Income; where Time_Coef and Cost_Coef are obtained from mode choice models presented later and cost is measured as bus fare or driving cost divided by income. See Ben-Akiva and Lerman (1985) for further reference. The values shown in this table are for a person with an household income of $45,000.			

Table 4-24 shows a base model and an expanded model of travel mode choice for HBW trips in the Austin region. The base model specifies variables representing travel costs (time and monetary) and traveler socio-demographic characteristics, whereas the expanded model adds in variables of MXD features. Mode initials in parentheses indicate the modes to which variables are specified.

Results from the expanded model for HBW trips suggest that higher population densities at trip origins are associated with higher probabilities of choosing non-driving modes for work commute. Increasing population densities at destinations encourage car pooling and riding buses. Concentration of jobs at higher densities supports more bus uses. Street connectivity matters: cul-de-sac intersections (% 1-way) discourage walking.

Table 4-25 shows models of mode choice for HBNW trips. Coefficients for all cost variables have expected negative signs. Except for taxi cost, all coefficients are significant at 95% or above level. For HBNW trips, population and job densities at designations matter to mode choice decisions. The coefficient for % 1-way (i.e., cul-de-sac) intersections has a positive sign, seemingly counter intuitive. Future studies should explore the issue by estimating separate models for various non-work purposes, for example, shopping, leisure, school, and personal business.

Data on sidewalk provision is available for areas within City of Austin. To utilize the data, MNL models HBW and HBNW trips are re-estimated with observations falling within City of Austin. The results (Tables 4-26 ~ 4-27) confirm that, aside from population and job densities, sidewalk provision at trip origins significantly influence mode choice for walking to work. No statistically significant effects are observed for non-work travel.

Table 4-23 Nested Logit Model of Travel Mode Choice for HBW Trips				
Variable	Coef.	Std. Err.	t-Stat.	
Time (DA)	-0.146	0.009	-15.96	**
Cost (DA)	-8.988	0.550	-16.34	**
Time (CP)	-0.119	0.007	-15.95	**
Cost (CP)	-11.884	0.551	-21.56	**
Time (Taxi)	-0.254	0.062	-4.09	**
Cost (Taxi)	-1.745	0.028	-63.37	**
Time (Bus)	-0.195	0.029	-6.79	**
Cost (Bus)	-5.596	0.224	-25.03	**
Vehpc (DA, CP)	6.105	0.325	18.78	**
HHSize (CP)	0.010	0.007	1.46	
Female (CP)	0.011	0.008	1.32	
Age2035 (WK)	-0.378	0.872	-0.43	
Age3550 (WK)	0.644	0.754	0.85	
Age5065 (WK)	0.695	0.832	0.84	
Theta (DRIVE)	**0.021**	**0.005**	**-184.35**	**
Constant (DA)	0.025	0.022	1.15	
Constant (Taxi)	3.089	1.085	2.85	**
Constant (WK)	3.174	0.773	4.11	**
Log-Likelihood at Zero			-3483.20	
Log-Likelihood at Start			-139820.38	
Log-Likelihood at End			-780.64	
-2 (LL(Zero) - LL(End))			5405.13	
-2 (LL(Start) - LL(End))			278079.49	
Asymptotic rho squared			0.7759	
Adjusted rho squared			0.7707	

Table 4-24 Logit Model of Travel Mode Choice for HBW Trips

	Base Model				Expanded Model			
Variable	Coef.	Std. Err.	t-Stat.		Coef.	Std. Err.	t-Stat.	
Time (DA)	-0.095	0.009	-10.09	**	-0.093	0.010	-9.31	**
Cost (DA)	-27.196	2.066	-13.17	**	-27.717	2.110	-13.14	**
Time (CP)	-0.056	0.011	-4.95	**	-0.048	0.012	-3.84	**
Cost (CP)	-45.149	3.925	-11.50	**	-45.782	4.000	-11.44	**
Time (Taxi)	-0.069	0.066	-1.04		-0.061	0.064	-0.95	
Cost (Taxi)	-3.288	0.862	-3.81	**	-3.333	0.871	-3.82	**
Time (Bus)	-0.135	0.041	-3.33	**	-0.146	0.042	-3.44	**
Cost (Bus)	-50.143	4.187	-11.98	**	-50.614	4.254	-11.90	**
Vehpc (DA, CP)	3.184	0.388	8.22	**	3.336	0.412	8.10	**
HHSize (CP)	0.200	0.077	2.59	**	0.186	0.075	2.49	**
Female (CP)	0.474	0.151	3.15	**	0.439	0.156	2.82	**
Age2035 (WK)	-2.637	0.868	-3.04	**	-2.808	0.931	-3.02	**
Age3550 (WK)	-0.408	0.656	-0.62		-0.427	0.708	-0.60	
Age5065 (WK)	-0.251	0.739	-0.34		-0.554	0.818	-0.68	
PopDen at Origin (Non-DR)					0.027	0.014	1.92	*
PopDen at Destination (CP, BU)					0.040	0.014	2.93	**
JobDen at Destination (BU)					0.009	0.003	3.10	**
PCT1Way at Origin (WK)					-10.732	2.875	-3.73	**
Block Size at Origin (WK)					-0.001	0.044	-0.01	
Constant (DRIVE)	120.887	0.668	181.05	**	120.326	0.689	174.67	**
Constant (DA)	2.647	0.255	10.36	**	3.060	0.280	10.93	**
Constant (TRANSIT)	124.311	0.660	188.44	**	123.716	0.688	179.84	**
Constant (Taxi)	-1.736	1.071	-1.62		-1.301	1.057	-1.23	
Constant (WK)	125.138	0.737	169.75	**	126.296	0.814	155.09	**
Log-Likelihood at Zero		-3483.20				-3483.20		
Log-Likelihood at Start		-2687.25				-4404.23		
Log-Likelihood at End		-845.51				-826.80		
-2 (LL(Zero) - LL(End))		5275.38				5312.81		
-2 (LL(Start) - LL(End))		3683.47				7154.86		
Asymptotic rho squared		0.7573				0.7626		
Adjusted rho squared		0.7518				0.7557		

Table 4-25 Logit Model of Travel Mode Choice for HBNW Trips								
	Base Model				Expanded Model			
Variable	Coef.	Std. Err.	t-Stat.		Coef.	Std. Err.	t-Stat.	
Time (DA, CP)	-0.042	0.002	-19.09	**	-0.043	0.002	-18.44	**
Cost (DA)	-9.262	0.437	-21.20	**	-9.336	0.441	-21.18	**
Cost (CP)	-15.256	0.661	-23.09	**	-15.209	0.667	-22.80	**
Time (Taxi)	-0.193	0.039	-4.98	**	-0.197	0.040	-4.96	**
Cost (Taxi)	-0.077	0.048	-1.61		-0.076	0.047	-1.62	
Time (Bus)	-0.180	0.031	-5.86	**	-0.175	0.032	-5.43	**
Cost (Bus)	-6.659	0.852	-7.82	**	-6.708	0.914	-7.34	**
Vehpc (DA, CP)	2.254	0.163	13.80	**	2.299	0.166	13.82	**
HHSize (CP)	0.063	0.043	1.47		0.084	0.044	1.92	*
Female (CP)	0.339	0.050	6.78	**	0.341	0.050	6.77	**
Ageto20 (WK, BK)	-0.482	0.178	-2.71	**	-0.432	0.174	-2.49	**
Age3550 (WK, BK)	-0.734	0.146	-5.04	**	-0.748	0.148	-5.04	**
Age65up (WK, BK)	-0.757	0.262	-2.89	**	-0.747	0.253	-2.95	**
PopDen at Origin (Non-DR)					0.007	0.006	1.21	
PopDen at Destination (CP, BU)					0.020	0.006	3.44	**
JobDen at Destination (BU)					0.031	0.003	9.01	**
PCT1Way at Origin (WK)					0.932	0.522	1.79	*
Block Size at Origin (WK)					0.001	0.002	0.51	
Constant (DRIVE)	1.377	0.157	8.78	**	1.142	0.174	6.57	**
Constant (DA)	0.123	0.123	1.01		0.322	0.132	2.45	*
Constant (TRANSIT)	1.272	0.234	5.44	**	0.695	0.254	2.74	**
Constant (Taxi)	-0.872	0.604	-1.44		-0.258	0.620	-0.42	
Constant (WK)	2.389	0.102	23.49	**	2.213	0.155	14.24	**
Log-Likelihood at Zero		-12001.90				-12001.90		
Log-Likelihood at Start		-9608.34				-9964.74		
Log-Likelihood at End		-6025.05				-5980.74		
-2 (LL(Zero) - LL(End))		11953.70				12042.32		
-2 (LL(Start) - LL(End))		7166.58				7968.01		
Asymptotic rho squared		0.4980				0.5017		
Adjusted rho squared		0.4965				0.4998		

Table 4-26 Logit Model of Travel Mode Choice for HBW Trips by Travelers Living in City of Austin

	Base Model				Expanded Model			
Variable	Coef.	Std. Err.	t-Stat.		Coef.	Std. Err.	t-Stat.	
Time (DA, CP)	-0.077	0.011	-6.97	**	-0.080	0.011	-7.47	**
Cost (DA)	-14.922	2.145	-6.96	**	-15.334	2.065	-7.43	**
Cost (CP)	-0.041	0.018	-2.35	**	-0.033	0.018	-1.84	*
Time (Taxi)	-30.174	4.234	-7.13	**	-30.690	4.076	-7.53	**
Cost (Taxi)	-0.036	0.075	-0.48		-0.030	0.075	-0.40	
Time (Bus)	-2.610	0.880	-2.96	**	-2.676	0.880	-3.04	**
Cost (Bus)	-0.086	0.039	-2.23	**	-0.094	0.040	-2.35	**
Vehpc (DA, CP)	-29.461	3.977	-7.41	**	-30.149	3.820	-7.89	**
HHSize (CP)	3.293	0.401	8.21	**	3.456	0.410	8.42	**
Female (CP)	0.627	0.138	4.55	**	0.578	0.136	4.25	**
Ageto20 (WK, BK)	0.568	0.192	2.96	**	0.536	0.198	2.71	**
Age3550 (WK, BK)	-1.974	0.845	-2.34	**	-2.165	0.884	-2.45	**
Age65up (WK, BK)	-0.270	0.653	-0.41		-0.357	0.711	-0.50	
PopDen at Origin (Non-DR)					0.031	0.016	1.96	**
PopDen at Destination (CP, BU)					0.045	0.015	3.05	**
JobDen at Destination (BU)					0.008	0.003	2.64	**
Sidewalk/Acre at Origin					0.005	0.002	2.05	**
Sidewalk/Acre at Destination					0.001	0.002	0.56	
Constant (DRIVE)	120.103	0.711	168.87	**	120.095	0.717	167.44	**
Constant (DA)	3.910	0.452	8.64	**	4.419	0.473	9.35	**
Constant (TRANSIT)	124.425	0.678	183.55	**	124.371	0.695	178.85	**
Constant (Taxi)	-1.443	1.175	-1.23	**	-0.904	1.189	-0.76	
Constant (WK)	125.808	0.759	165.76	**	125.870	0.797	157.90	**
Log-Likelihood at Zero		-2145.53				-2145.53		
Log-Likelihood at Start		-1671.44				-2267.67		
Log-Likelihood at End		-629.83				-617.74		
-2 (LL(Zero) - LL(End))		3031.40				3055.59		
-2 (LL(Start) - LL(End))		2083.22				3299.87		
Asymptotic rho squared		0.7064				0.7121		
Adjusted rho squared		0.6976				0.7009		

Table 4-27 Logit Model of Travel Mode Choice for HBNW Trips by Travelers Living in City of Austin								
	Base Model				Expanded Model			
Variable	Coef.	Std. Err.	t-Stat.		Coef.	Std. Err.	t-Stat.	
Time (DA, CP)	-0.053	0.003	-15.42	**	-0.054	0.004	-15.05	**
Cost (DA)	-14.484	0.853	-16.97	**	-14.651	0.879	-16.66	**
Cost (CP)	-23.062	1.200	-19.22	**	-23.302	1.245	-18.72	**
Time (Taxi)	-0.207	0.049	-4.24	**	-0.215	0.049	-4.35	**
Cost (Taxi)	-0.189	0.082	-2.31	**	-0.185	0.084	-2.19	**
Time (Bus)	-0.190	0.031	-6.11	**	-0.186	0.033	-5.61	**
Cost (Bus)	-9.320	1.032	-9.03	**	-9.550	1.081	-8.83	**
Vehpc (DA, CP)	2.955	0.228	12.97	**	3.045	0.236	12.92	**
HHSize (CP)	0.120	0.055	2.18	**	0.133	0.056	2.37	**
Female (CP)	0.384	0.067	5.75	**	0.390	0.067	5.82	**
Ageto20 (WK, BK)	-0.399	0.203	-1.96	**	-0.330	0.196	-1.68	*
Age3550 (WK, BK)	-0.517	0.189	-2.73	**	-0.534	0.183	-2.92	**
Age65up (WK, BK)	-0.591	0.259	-2.28	**	-0.627	0.308	-2.03	**
PopDen at Origin (Non-DR)					0.010	0.007	1.34	
PopDen at Destination (CP, BU)					0.023	0.007	3.22	**
JobDen at Destination (BU)					0.032	0.004	9.05	**
Sidewalk/Acre at Origin					-0.001	0.001	-0.51	
Sidewalk/Acre at Destination					-0.001	0.001	-1.08	
Constant (DRIVE)	1.435	0.216	6.63	**	1.127	0.232	4.85	**
Constant (DA)	0.344	0.153	2.25	**	0.591	0.169	3.50	*
Constant (TRANSIT)	1.729	0.258	6.70	**	1.084	0.285	3.80	**
Constant (Taxi)	-0.215	0.724	-0.30		0.514	0.742	0.69	
Constant (WK)	2.917	0.158	18.42	**	3.141	0.186	16.89	**
Log-Likelihood at Zero		-7373.55				-7373.55		
Log-Likelihood at Start		-7876.23				-8631.93		
Log-Likelihood at End		-3619.13				-3575.51		
-2 (LL(Zero) - LL(End))		7508.83				7596.08		
-2 (LL(Start) - LL(End))		8514.19				10112.85		
Asymptotic rho squared		0.5092				0.5151		
Adjusted rho squared		0.5067				0.5120		

Mode choice analyses for the Austin area presented above report findings that are consistent with the literature on the role of urban form in influencing travel. After the effects of system performance and traveler socio-demographic characteristics are controlled, MXD features such as high population and job densities, network connectivity, and sidewalk provision exhibit additional influence on mode choice decisions. These features matter at both trip origins and destinations. CAMPO can refine its mode choice models by including the urban form variables to capture the potential effects of the Activity Centers on regional travel demand.

5 SUMMARY AND APPLICATIONS OF THE STUDY RESULTS

The study identified 42 MXD sites in the Austin, TX area and analyzed travel characteristics associated with MXD with the 2005 Austin Activity Travel Survey. Main results are summarized below:

- On trip length (distance & time), MXD trips are 1.9 miles shorter for HBW trips, 0.65 mile / 0.9 minute longer for HBNW trips, and 1.2 miles/3 minutes shorter for NHBW trips;
- On trip generation, MXDs show 40% higher internal rate of capture than TAZs (non-MXDs). People living in MXDs make 0.2 more daily trips /person for HBW and 0.3 fewer daily trips/person for NHBO purposes;
- MXDs have more zero- or one-car households;
- Travelers from MXD households leave homes ~10 minutes later than others in the morning;
- Daily PMT is ~6 miles less for MXD households than otherwise;
- On the role of urban form attributes, population and job densities at origins and destinations influence travel mode choice independent from the effects of system performance and socio-demographic factors. Network connectivity and sidewalk provision also matter

The results suggest areas in which CAMPO models can be modified or refined to capture the potential effects of the Activity Centers growth strategy on regional travel, for instance:

- Re-calibrating friction functions for trip distribution analysis;
- Revising trip rates for trip production calculation;
- Improving estimation of internal trip making;
- Re-estimating vehicle ownership models, which in turn affect trip generation and parking demand;
- Fine-tuning time-of-day distribution; and
- Re-fining travel mode choice models by including urban form indicators.

The study contributes to transportation planning and policy making in Central Texas by providing local empirical evidence on urban form-travel connection. Yet the study's method and process should be of interest to a broad audience in academia and practice. Fully incorporating the results in CAMPO planning process still requires additional efforts. It is non-trivial task to accomplish what are suggested above in the four-step models. To this end, the study presented in this report serves mainly for illustrative purposes to CAMPO.

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APPENDIX

1. GIS Methodology

Data Preparation

The first step was to prepare the data from its original source format to how it would be used for the GIS analysis.

Travel Survey

The 2005 CAMPO Travel Survey was originally in text format. The data had to be first patterned in Excel. Then, the file was geocoded by the X,Y coordinates in TransCAD to create points for each travel survey entry. Last, the TransCAD file was exported to a SHP file for use in ArcMap.

Roads and Parcels

The roads and parcels files, from TNRIS and CAPCOG, respectively, were originally in individual county shapefiles. The shapefiles for all five counties were then merged into a single five-county shapefile for both the roads and parcels.

Intersections

There at first no multi-point file of intersections, it needed to be created from the polyline road centerline file. The roads file was opened in TransCAD and a multi-point file was created by extracting the nodes from the intersection of two or more road centerline segemnts. The resulting nodes were exported into a SHP file for ArcMap.

To determine the type of intersection, the node SHP file was opened in SPSS. For each node there were one or more road centerline segments that were associated with it, creating a number of samples that all corresponded to the same node. The 'Frequency' function was used to sum up the number of different road centerline segments, with different ID numbers, that intersected at the node. All the 'false' nodes that were just the point of two segments of the same road were elimated, if the ID number of roads associated with it were the same one. The sum of segments determined if the intersection was a cul-de-sac, a 3-way, or 4-way or greater intersection.

Overlays

In order to analyze the spatial data of the land use, transportation, and travel survey in terms of their relations to other geometry, it was necessarily to overlay that data onto the geometry of another file. Three different scales of geography polygons were overlayed with other data sets that were polyline, multi-point, and polygon files.

In ArcMap, the 'Spatial Join' tool was used to perform overlays for joining the values of the three geometries to the polygons of the three geographies, TAZ's, the grid, and MXD's.

Below is a list of the settings used in the ‘Spatial Join’ too for future replication of these data sets or other of similar shape:

Multi-Points onto Polygons

‘Target Feature’ - TAZ/Grid/MXD

‘Join Feature’ - Mult-Point file

i.e. Travel Survey, Bus Stops

‘Join Operation’ - One-to-One/Many

One-to-One - for every instance of a point contained within a polygon

One-to-Many - for sum of points within a polygon

‘Match Option’ - ‘Contains’

Polylines onto Polygons

‘Target Feature’ - TAZ/Grid/MXD

‘Join Feature’ - Polyline file

i.e. Roads, Sidewalks

‘Join Operation’ - One-to-One

‘Field Map of Join Features’

Select field that refers to the length of the segment

‘Merge Rule’

Select ‘Sum’ - This will add together the sum of the length of all the segments that are overlayed in each polygon feature.

‘Match Option’ - ‘Intersects’

Polygons onto Polygons

‘Target Feature’ - TAZ/Grid/MXD

‘Join Feature’ - Polygon file

i.e. Parcels, TAZ

‘Join Operation’ - One-to-One/Many

One-to-One - for every instance of a polygon intersecting with a polygon (i.e. Parcels)

One-to-Many - for sum of features within a polygon (i.e. TAZ’s)

‘Match Option’ - ‘Intersects’

Calculation of Variables

Parcel-based Variables

DEVLAND, LANDMIX, POPDEN, and EMPDEN

ArcMap Steps:

Clip Parcels by TAZ/Grid/MXD

‘Calculate Geometry’ of clipped Parcels layer

Overlay clipped Parcels layer with TAZ/Grid/MXD

‘One-to-Many’ will keep values unaggregated. The areas for each land use in each TAZ/Grid/MXD will be summed together and organized in a Pivot Table in Excel.

Excel Steps:

‘Data’>’Pivot Table Report’

H

‘Range’ - Select Land Use Code, Area, and TAZ/MXD/Grid columns INCLUDING headers

Click ‘No’ - ‘Keep Values Separate’

Click ‘Layout - Drag field buttons to proper grid location

‘Column’ - Land Use Code

‘Data’ - Area

‘ROW’ - TAZ/Grid/MXD

Sum together various land use codes for different combinations of residential, commercial, etc.

Use total land use areas combined from multiple land use codes to calculate:

LANDMIX

DEVLAND

POPDEN

EMPDEN

TAZ-based Variables

POP, EMP, ACTIVITY, POPDEN, EMPDEN, ACTDEN, JOBPOP

Overlay Roads with TAZ’s/Grid/MXD’s

Clip Grid/MXD’s by TAZ’s

Overlay Roads with TAZ-clipped Grid/MXD’s

Join total road length field to TAZ-clipped Grid/MXDs with overlayed roads

‘Field Calculator’ - Divide the value of the sum of the overlayed road segment length of TAZ-clipped Grid/MXD by the sum of the overlayed road segment length of the unclipped TAZ file.

Multiply that percentage by the total population and employment of the TAZ to calculate prorated figures for the portion that is overlayed in the Grid/MXD.

Pro-rating is based upon the percentage of road centerlines in the overlayed Grid/MXD, not the total area.

2. Maps of MXDs in the Austin, TX Area

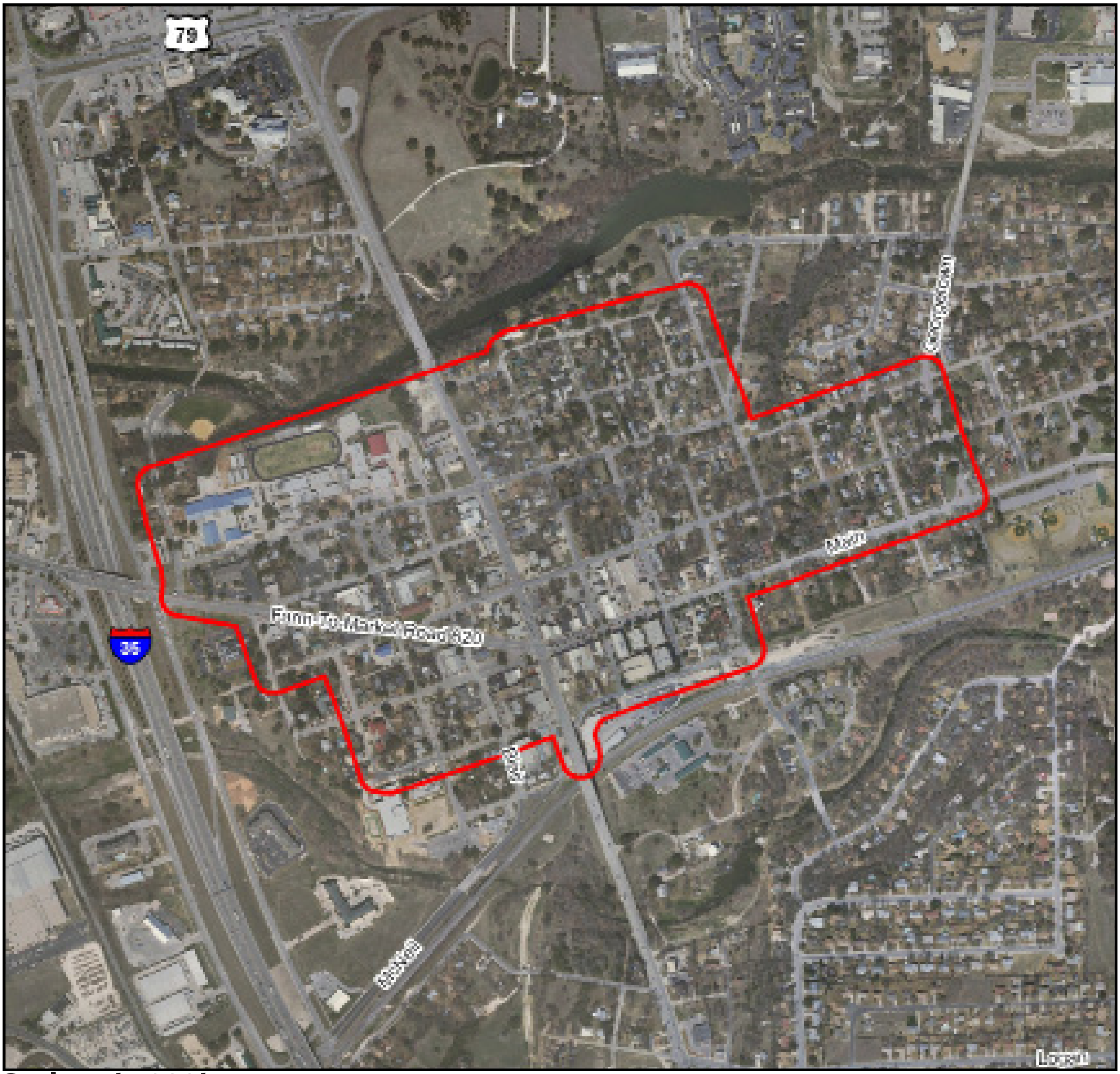
ID	***MXD Name***
1	Round Rock
2	La Frontera
3	San Marcos
4	Pflugerville
5	Cedar Park
6	Buda
7	Bee Cave
8	Lockhart
9	Kyle
10	Luling
11	Bastrop
12	Elgin
13	Georgetown
14	Taylor
15	Dripping Springs
16	Holly Cesar Chavez
17	Crestview
18	Old West Austin
19	35th at Jefferson
20	Gateway
21	Arboretum
22	Rollingwood
23	Manor Road
24	Windsor Village
25	Burnet at North Loop
26	Exposition
27	East Sixth
28	Montopolis
29	Far West
30	Brodie Oaks
31	Balcones North Loop
32	Penn Field
33	Barton Oaks
34	Davenport Village
35	Hyde Park
36	North Campus
37	West Campus
38	Parker Burton
39	East Riverside
40	River City North
41	South Congress
42	South First Street

‘Round Rock’ #1

Round Rock, TX

Williamson County

Source: Survey



Scale - 1’:1000’

‘La Frontera’

#2

Round Rock, TX

Williamson County

Source: Survey

Scale - 1’:1000’

‘San Marcos’

#3

San Marcos, TX

Hays County

Source: Survey

Scale - 1’:1000’

‘Pflugerville’ #4

Pflugerville, TX

Williamson County

Source: Survey

Scale - 1’:1000’

‘Cedar Park’ #5

Cedar Park, TX

Williamson County

Source: Survey

Scale - 1’:1500’

'Buda' #6

Buda, TX

Hays County

Source: Survey

Scale - 1':1000'

‘Bee Cave’ #7

Bee Cave, TX

Travis County

Source: Survey

Scale - 1’:1000’

‘Lockhart’ #8

Lockhart, TX

Caldwell County

Source: Survey

Scale - 1’:1000’

‘Kyle’ #9

Kyle, TX

Hays County

Source: Survey

Scale - 1’:1000’

'Luling' #10

Luling, TX

Caldwell County

Source: Survey

Scale - 1':1000'

'Bastrop' #11

Bastrop, TX

Bastrop County

Source: Survey

Scale - 1':1000'

'Elgin' #12

Elgin, TX

Bastrop County

Source: Survey

Scale - 1':1000'

‘Georgetown’ #13

Georgetown, TX

Williamson County

Source: Survey

Scale - 1’:1000’

‘Taylor’ #14

Taylor, TX

Williamson County

Source: Survey

Scale - 1’:1000’

‘Dripping Springs’ #15

Dripping Springs, TX

Hays County

Source: Survey

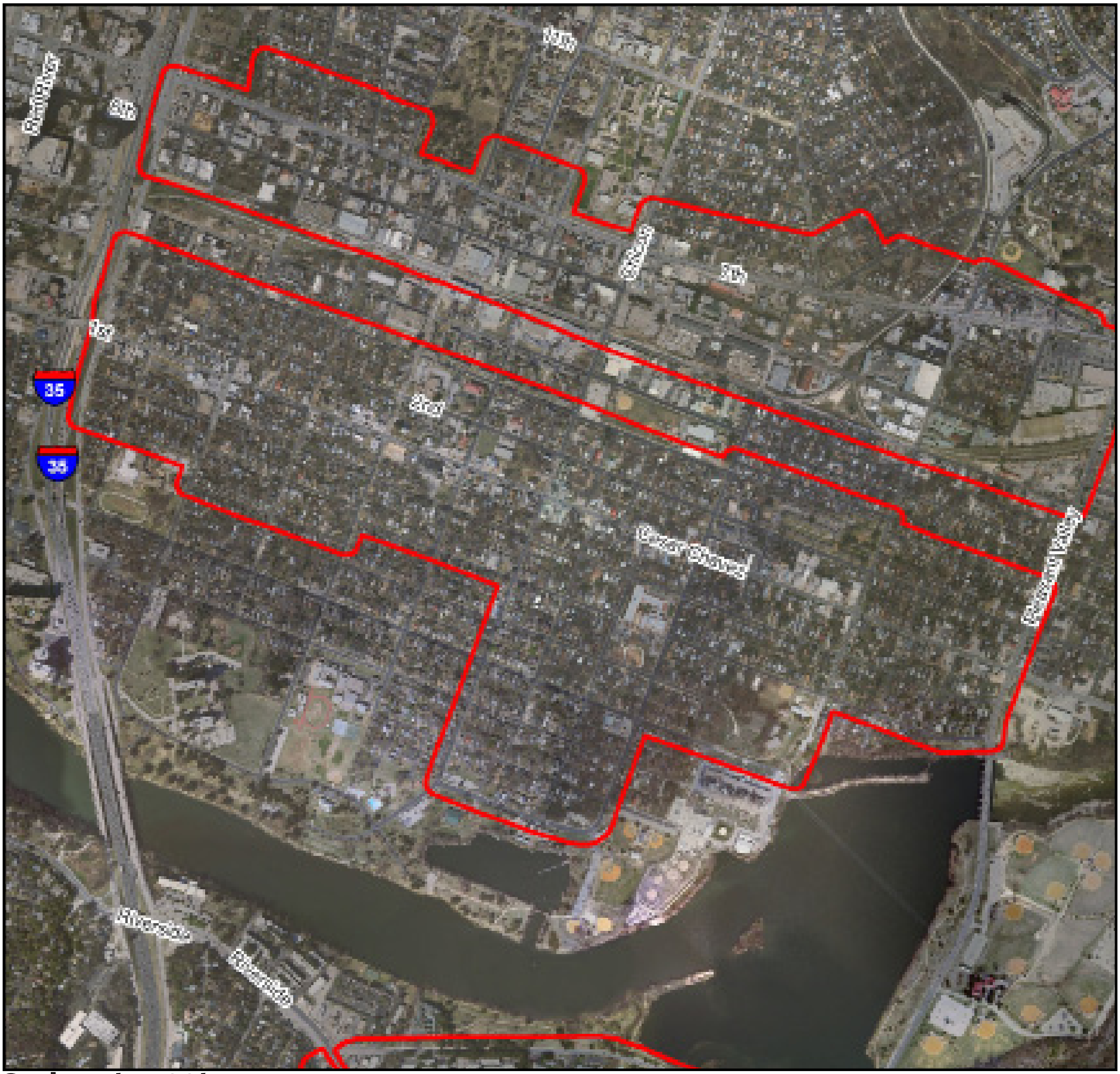
Scale - 1’:1000’

‘Holly Cesar Chavez’ #16

Austin, TX

Travis County

Source: Survey



Scale - 1’:1500’

‘Crestview’

#17

Austin, TX

Travis County

Source: CAMPO

Scale - 1’:1000’

‘Old West Austin’ #18

Austin, TX

Travis County

Source: CAMPO

Scale - 1’:1000’

‘35th at Jefferson’ #19

Austin, TX

Travis County

Source: CRP

Scale - 1’:1000’

‘Gateway’ #20

Austin, TX

Travis County

Source: CRP

Scale - 1’:1000’

‘Arboretum’ #21

Austin, TX

Travis County

Source: CRP

Scale - 1’:1000’

‘Rollingwood’ #22

Rollingwood, TX

Travos County Source: CRP

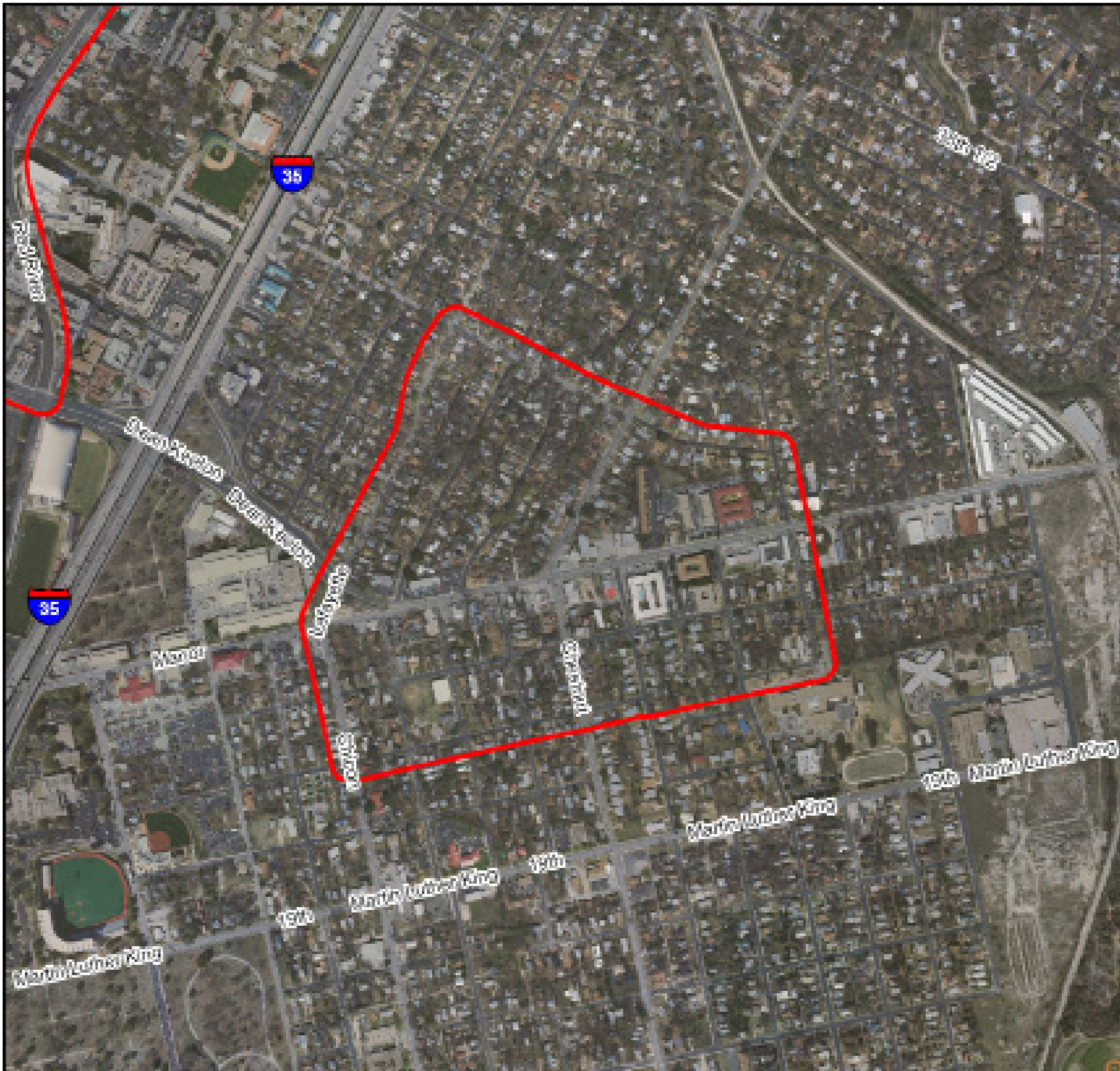
Scale - 1’:1250’

'Manor Road' #23

Austin, TX

Travis County

Source: CRP



Scale - 1':1000'

‘Windsor Village’ #24

Austin, TX

Travis County

Source: CRP

Scale - 1’:1000’

‘Burnet at North Loop’ #25

Austin, TX

Travis County

Source: CRP

Scale - 1’:1000’

‘Exposition’ #26

Austin, TX

Travis County

Source: CRP

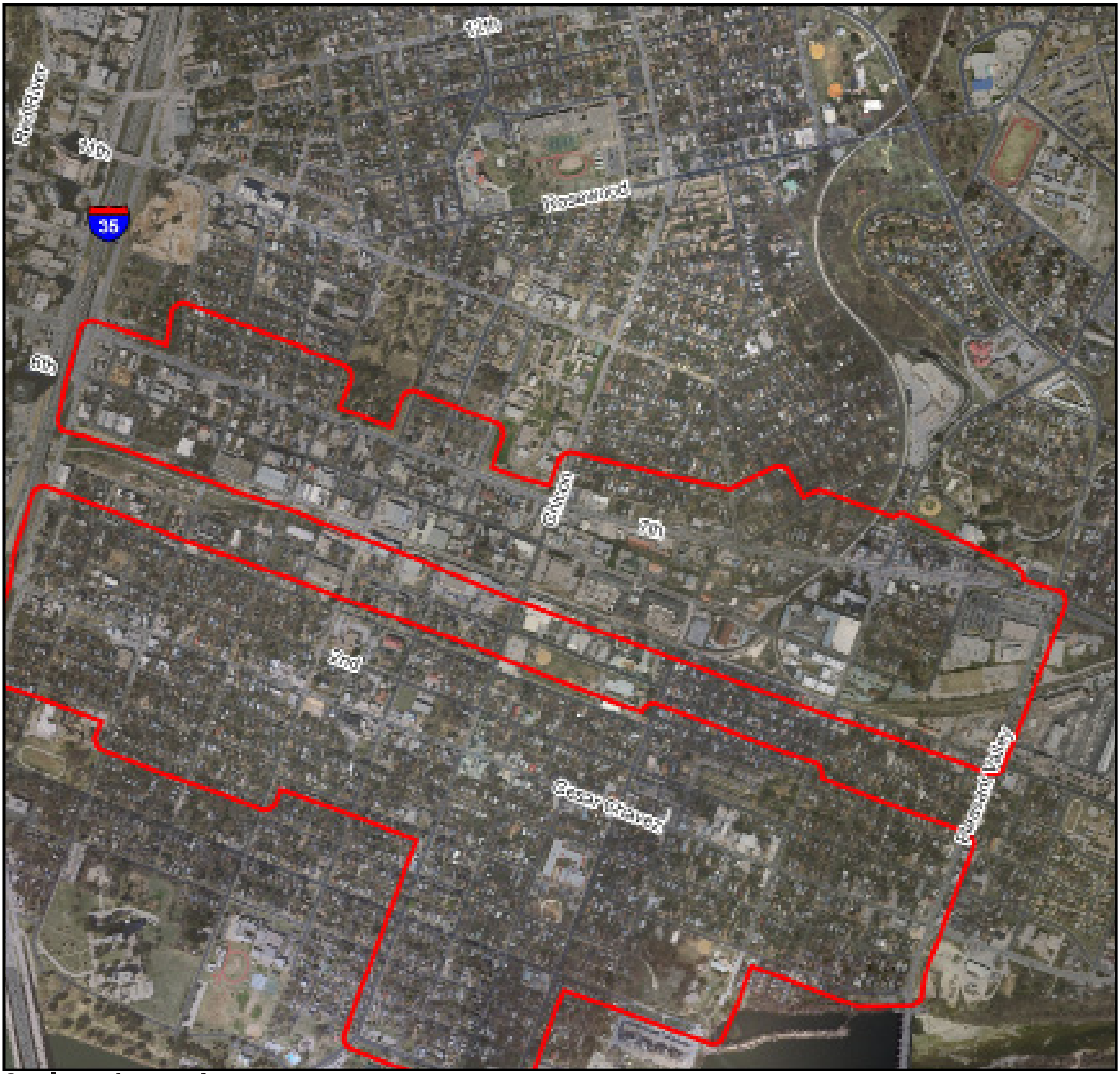
Scale - 1’:1000’

‘East Sixth’ #27

Austin, TX

Travis County

Source: CRP



Scale - 1’:1500’

‘Montopolis’ #28

Austin, TX

Travis County

Source: CRP

Scale - 1’:1000’

‘Far West’ #29

Austin, TX

Travis County

Source: CRP

Scale - 1’:1000’

'Brodie Oaks' #30

Austin, TX

Travis County

Source: CRP

Scale - 1':1000'

‘Balcones North Loop’

#31

Austin, TX

Travis County

Source: CRP

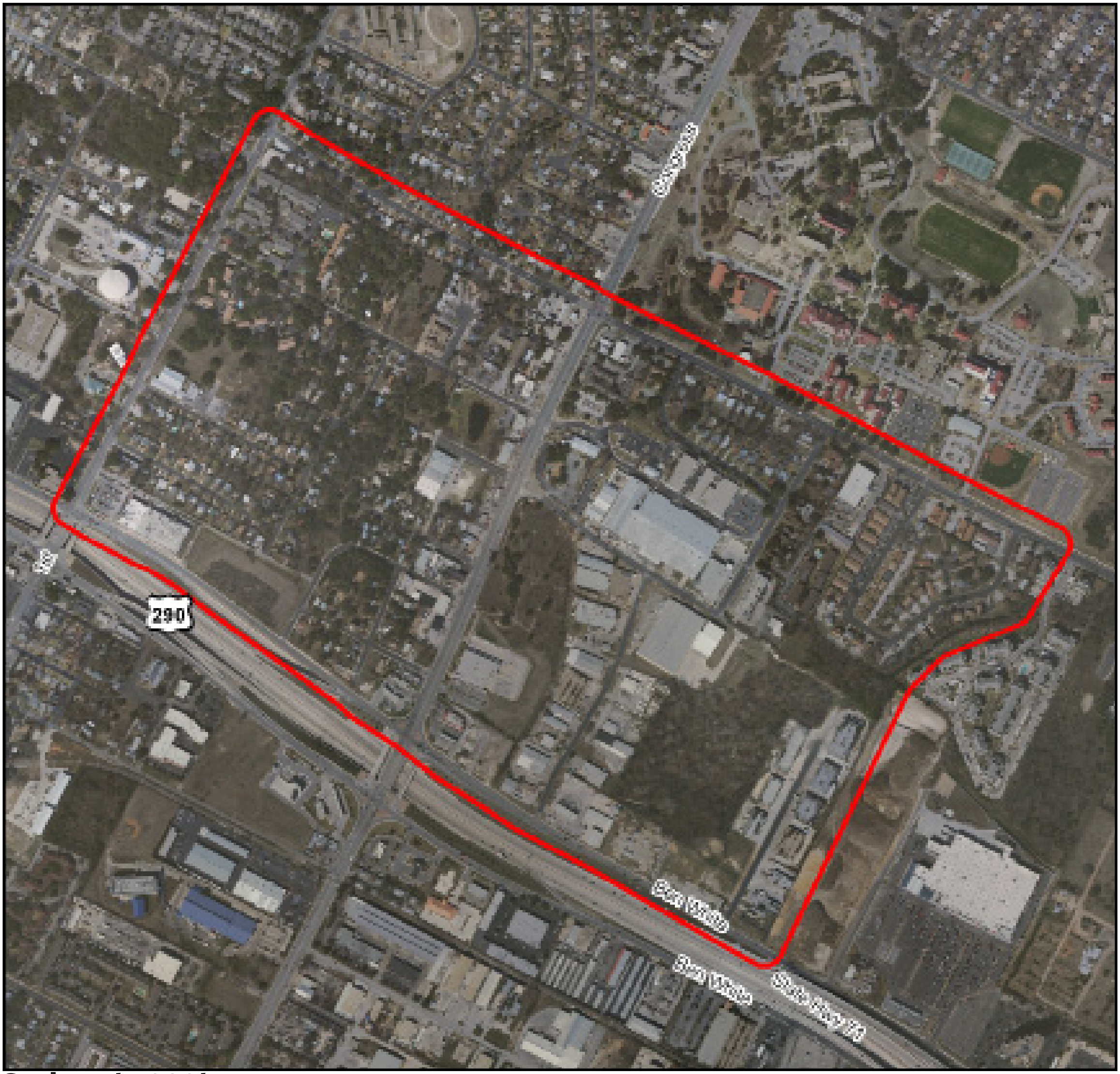
Scale - 1’:1000’

‘Penn Field’ #32

Austin, TX

Travis County

Source: CRP



Scale - 1’:1000’

‘Barton Oaks’ #33

Austin, TX

Travis County

Source: CRP

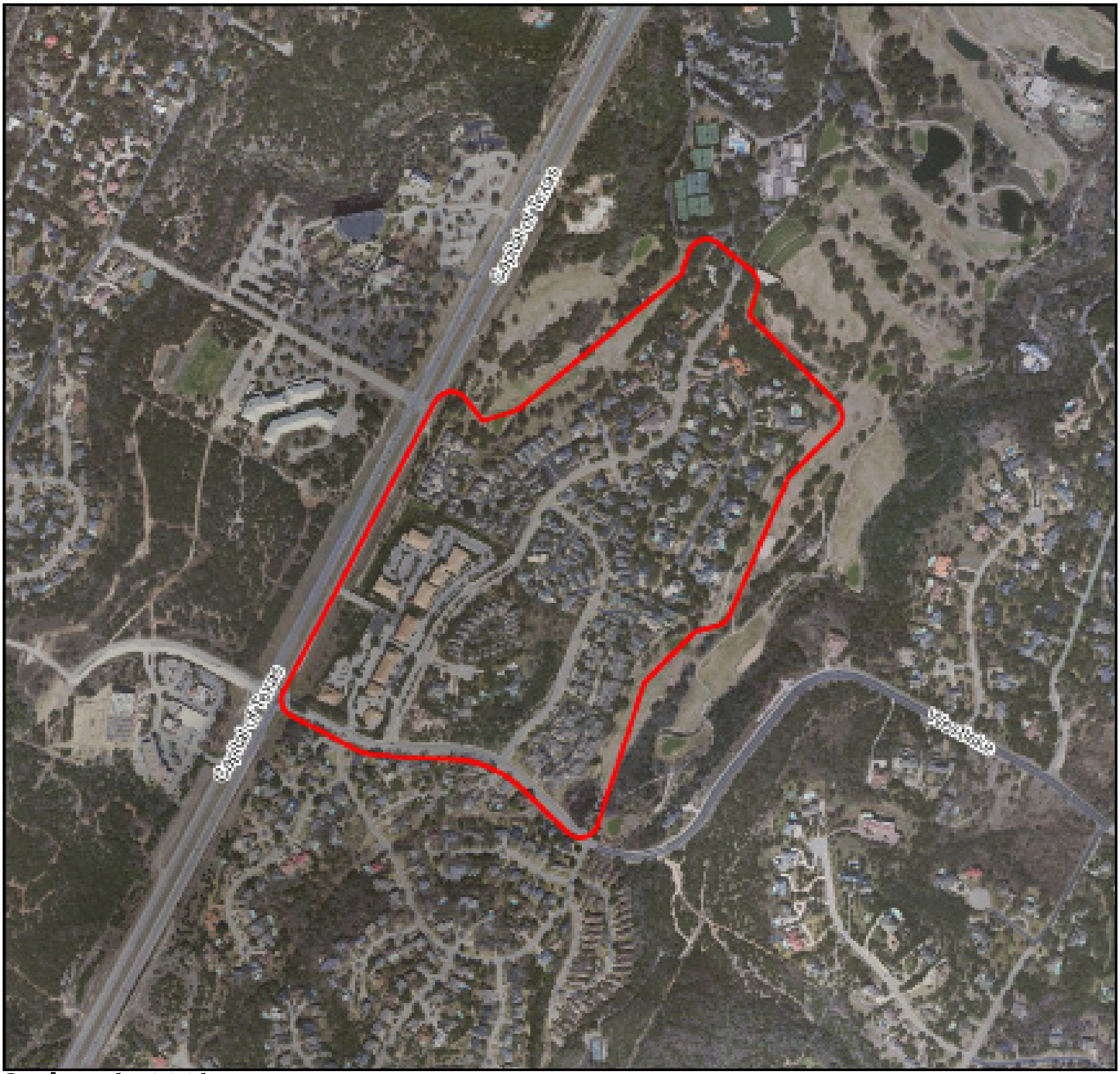
Scale - 1’:1000’

‘Davenport Village’ #34

Austin, TX

Travis County

Source: CRP



Scale - 1’:1000’

‘Hyde Park’ #35

Austin, TX

Travis County

Source: Survey

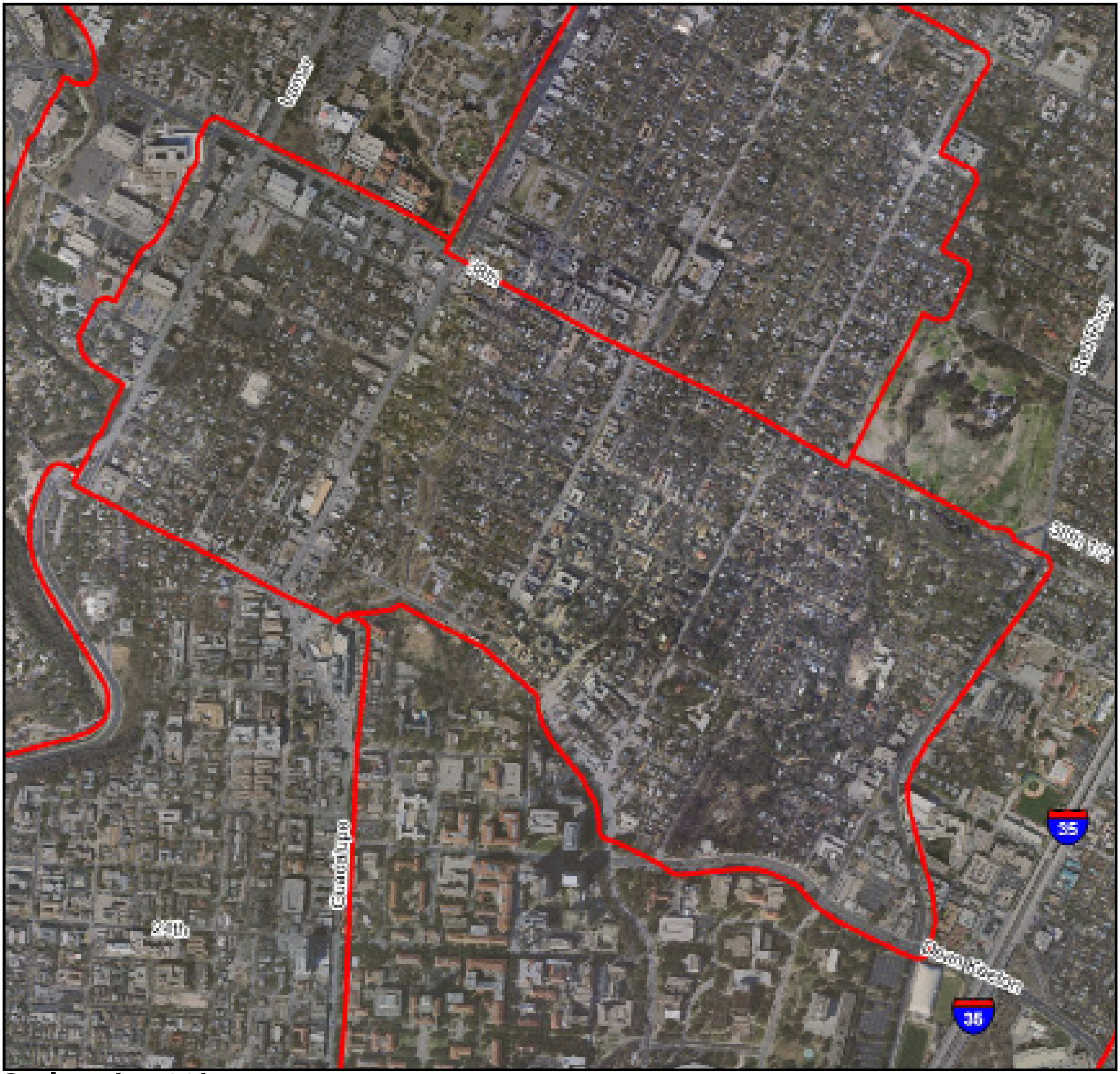
Scale - 1’:1000’

‘North Campus’ #36

Austin, TX

Travis County

Source: CRP



Scale - 1’:1500’

‘West Campus’ #37

Austin, TX

Travis County

Source: Survey

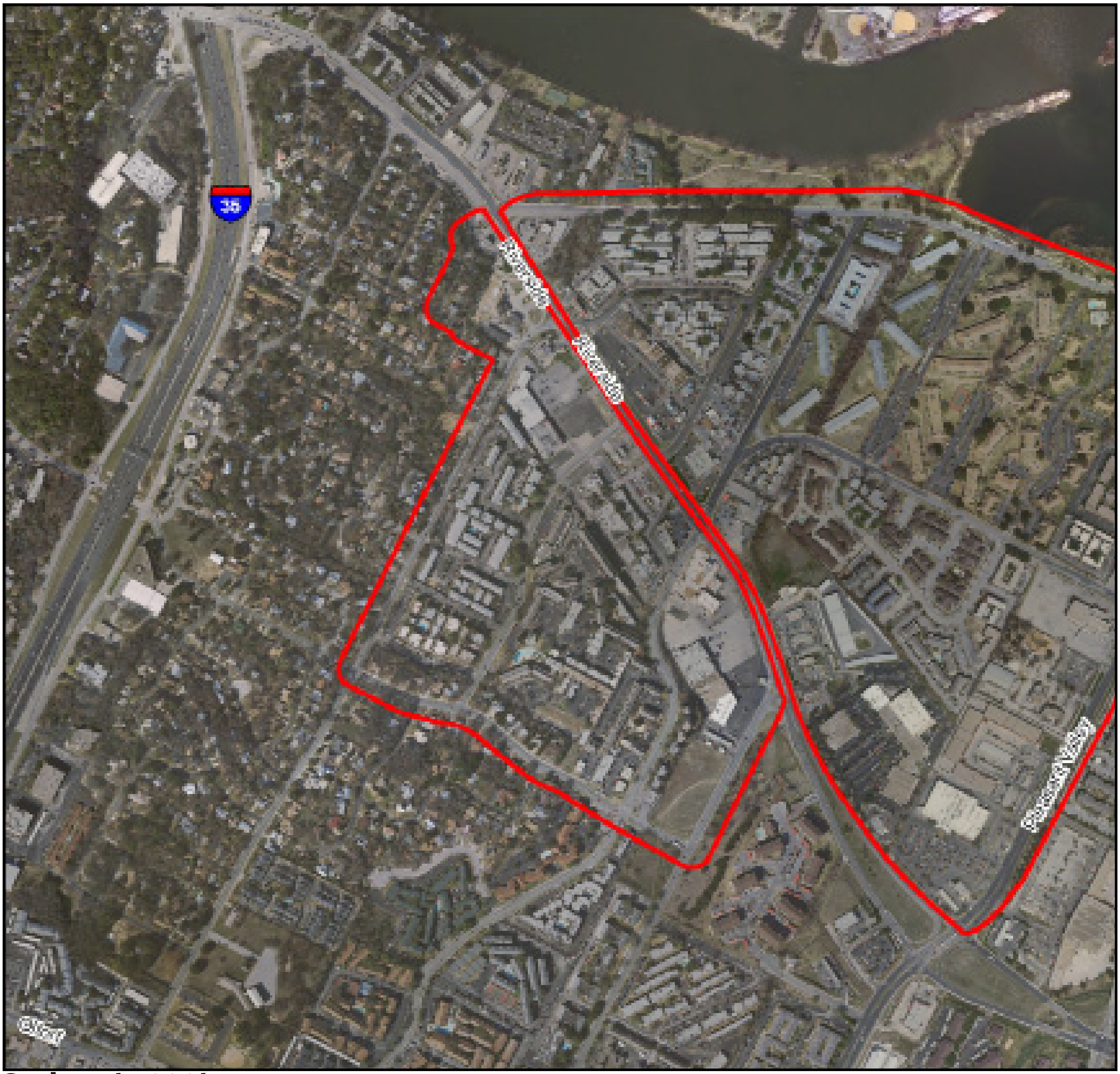
Scale - 1’:1500’

‘Parker Burton’ #38

Austin, TX

Travis County

Source: CRP



Scale - 1’:1000’

‘East Riverside’ #39

Austin, TX

Travis County

Source: CRP

Scale - 1’:1000’

'River City North'

#40

Austin, TX

Travis County

Source: CAMPO

Scale - 1':1000'

‘South Congress’ #41

Austin, TX

Travis County

Source: CAMPO

Scale - 1’:1000’

‘South First Street’ #42

Austin, TX

Travis County

Source: CAMPO

Scale - 1’:1000’