Travel Behavior and Built Environment: Exploring the Importance of Urban Design at the Non-Residential End of the Trip

J. Richard Kuzmyak, Jerry Walters, Hsi-hwa Hu, Jason Espie, and Dohyung Kim

Lincoln Institute of Land Policy
Working Paper

Lincoln Institute Product Code: WP12RK1

Abstract

This working paper presents results of an analysis of how land use characteristics may affect travel behavior decisions when considered in the context of non-residential trip destinations. Interest in the relationship between land use and travel behavior is central to planning and policy discussions addressing concerns such as mobility, congestion, energy dependency and climate change. There is considerable evidence that conventional dispersed, auto-centric development patterns (aka "sprawl") are inefficient, wasteful of land and natural resources, and difficult to sustain. In contrast, community designs that emphasize higher-density/more compact forms, a diverse mix of land uses, thoughtful design that makes uses more attractive and accessible to pedestrians, a traditional street grid, and good transit access have been shown to reduce auto reliance, cut average trip lengths, and reduce vehicle miles of travel. While much good research has been done to help quantify those characteristics of the built environment that influence travel decisionmaking using the "Ds" of density, diversity, design and destinations, the focus of this existing body of research has been almost exclusively on the residential production end of the trip. This leaves a major gap in accounting for how conditions at the non-residential end of the trip also factor into how a person chooses to travel to a given destination, or more fundamentally, how they choose what destination to travel to. This research study, enabled by a Lincoln Institute grant, processed travel survey and underlying land use data from Southern California to begin to address how the characteristics of the built environment at non-residential trip destinations—such as commercial or employment centers—influence travel patterns to those destinations. While much additional research remains to be done with the unique database assembled, the initial findings are highly encouraging in beginning to quantify the importance of the built environment at non-residential trip ends. This is an important step toward completing the behavioral construct which is needed to fully account for the benefits of compact, mixed, transit served land use on travel behavior.

About the Authors

Rich Kuzmyak is a principal with the Renaissance Planning Group in Arlington, VA. Rich has been a transportation planner and travel behavior analyst for over 30 years, primarily as a consultant to federal, state, and local planning and transportation agencies, as well as non-profit research organizations like the Transportation Research Board of the National Academy of Sciences. His strong interest in quantifying the connection between land use and travel behavior began when he served in key advisory roles within Maryland state government to help implement the state's innovative Smart Growth and Livable Communities Act. In working with the Maryland Department of Planning, the Department of Transportation, and eventually the Governor's Office, he realized the difficulty in gaining support for new approaches like Smart Growth without compelling evidence. He subsequently performed national research on land use relationships for the Transit Cooperative Research Program (*TCRP Report 95: Chapter 15—Land Use and Site Design*, 2003), and developed models linking travel behavior and land use characteristics for the Baltimore Metropolitan Council, the Southern California Association of Governments (SCAG), and the Arizona Department of Transportation, which were used for leading planning and policy studies. With Fehr & Peers, he led development of a local sustainability planning tool for use in addressing SB 375 requirements in Southern California for SCAG. He is currently leading NCHRP project 8-78 which is developing methods for estimating bicycle and pedestrian demand for planning and project development; the methods are mapping new ground in attempting to account for non-motorized modes in the transportation and land use planning process.

Renaissance Planning Group
1901 North Moore Street, Suite 1204
Arlington, VA 22209, USA
703.776.9922 ext 501
rkuzmyak@citiesthatwork.com

Jerry Walters leads sustainability practices for Fehr & Peers, transportation consultants. His experience includes transportation policy planning related to State and national sustainable communities legislation. Jerry has co-authored such studies as: *Growing Cooler—the Evidence on Urban Development and Climate Change* for the Urban Land Institute, *Mixed-use Development and Vehicle Trips: Improving the Standard Estimation Methodology* for US EPA, *Smart Mobility Call to Action* for California Department of Transportation, *Measuring the Benefits of Compact Development on Vehicle Miles and Climate Change* for National Association of Environmental Professionals, *The Effect of Housing near Transit Stations on Vehicle Trip Rates and Transit Trip Generation* for California Department of Housing and Community Development , and *Quantifying the GHG Benefits of Transportation Mitigation* Strategies for the California Air Pollution Control Officers Association.

Fehr & Peers
One Walnut Creek Center
100 Pringle, Suite 600
Walnut Creek, CA 94596
925-930-7100
j.walters@fehrandpeers.com

Jason Espie, AICP, is a project manager with Renaissance specializing in integrated land use and transportation planning. He has developed tools and led analyses stressing land use and transportation interaction in the context of regional long range plans, scenario planning processes, comprehensive plans, multimodal corridor studies, and transit oriented development plans. Jason has considerable experience with GIS tools and methods; these skills have been used build and operating GIS-based planning tools such as Renaissance's CorPlan and CorMap models, CommunityViz, and other similarly structured tools. His applications experience with these tools includes land suitability assessment, build out analysis, population and employment demographics and projections, trend analysis, connectivity and mobility assessment, and developing socioeconomic inputs for travel demand models and traffic forecasting. Jason has a Masters Degree in Urban and Environmental Planning from the University of Virginia School of Architecture. Prior to joining Renaissance he worked for more than twelve years in the non-profit sector doing community development, communications, and environmental policy work.

Renaissance Planning Group
455 Second Street SE, Suite 300
Charlottesville, Virginia 22902
434.296.2554 Ext 303
jespie@citiesthatwork.com

Dr. Hsi-hwa Hu is a modeling analyst with the Southern California Association of Governments (SCAG). He has been extensively involved in SCAG's efforts to improve the sensitivity of its transportation planning models to land use and related policy issues. This work began with quantifying the effects of the Compass Blueprint Vision, a sweeping transit-oriented land use concept that defined SCAG's 2008 regional transportation plan update. Passage of California's state climate change law SB 375 in 2008 greatly increased the need to be able to account for land use impacts on VMT and greenhouse emissions. In response to the SB 375 requirements, Dr. Hu has been involved in development of a local Sustainability Planning Tool for regional outreach, has been leading staff and consultant efforts in development of a new activity-based travel model, and has performed research to validate the accuracy of changes to SCAG's existing trip-based model to forecast realistic travel response to SB 375 inspired land use changes. Trained as a transportation planner and engineer, and obtained his Ph.D. degree in Planning from University of Southern California.

Southern California Association of Governments
818 West 7th Street, 12th floor
Los Angeles, CA 90017
213-236-1834
hu@scag.ca.gov

Dr. Dohyung Kim is an instructor in GIS and Transportation Planning at California Polytechnic State University in Pomona, CA. Dr. Kim's experience in both academia and industry has involved crash mapping, multi-modal transportation planning, community walkability analysis, scenario planning, and land development projects. He has received numerous awards for his work, which he has presented at national and international conferences, and is a workshop instructor at the international URISA conference. Dr. Kim's current research focuses on GIS application to transportation safety, land use scenario planning, urban growth potential simulation, 3D visualization and simulation in urban design. He earned his M.A. in Urban and Regional Planning from the University of Wisconsin-Madison, and his Ph.D. in Urban and Regional Planning from the University of Florida.

Department of Urban and Regional Planning
California State Polytechnic University
Pomona College of Environmental Design
3801 West Temple Avenue, Building 7-224
Pomona, California 91768
(909) 869-2688
dohyungkim@csupomona.edu

Table of Contents

List of Figures

List of Tables

Appendix A: List of Tables

Travel Behavior and Built Environment

Summary

This Lincoln-assisted research study has attempted to extend knowledge on how the built environment impacts travel behavior, specifically in the context of land use characteristics at the trip destination. How design of the man-made environment influences travel behavior has been one of the more compelling and debated planning issues for at least two decades. If compact, mixed-use and transit served community designs are to be given serious consideration as an alternative to sprawl—and as a potential strategy against global warming—demonstration of their benefits in reducing auto dependency and vehicle miles of travel must be unequivocal. For this to happen, it is important that we extend the traditional focus of such research the home production end of a trip and attempt to better understand how conditions at the attraction end also factor into travel decision-making. It would be expected that the combined influence of land use at both ends of a trip would not only influence the mode of travel for a given trip, but also greatly influence the choice of the destination where travel needs are satisfied.

This important investigation has been enabled by a Planning and Urban Form Research Fellowship grant from the Lincoln Institute for Land Policy. The study focused on use of a new 2009 regional household travel survey performed in the Los Angeles region under sponsorship of the California Department of Transportation. The survey data were processed and conveyed by the Southern California Association of Governments (SCAG), which has supported the work in numerous ways including sharing of key supporting data, development of various measures using the regional travel model, and assistance with the analysis. SCAG has been in all ways a partner in the research, including financial support through a parallel contract aimed at strengthening its existing modeling tools for the purposes of more completely addressing the requirements of the California climate change law, SB 375.

To pursue its research objectives, the research team worked extensively with the daily trip portion of the SCAG travel survey, which contains approximately 54,000 trip records from 6,600 households residing in the 6-county SCAG region. Using GIS methods, team members developed a comprehensive set of built environment variables for each trip end in the survey database, including measures of development density, land use mix and diversity, urban design, transit access and regional accessibility. The initial analysis which is presented in this paper has focused on the extent to which combinations of measures from these different groups are effective in explaining tendencies in travel behavior, principally choice of travel mode for a range of common trip purposes. Future analyses with the rich dataset developed are planned, including models of destination choice for different trip purposes where destination has not predetermined (e.g., travel to work or school).

While the initial results are far from conclusive and further, more in-depth analyses are planned, the findings are nevertheless quite encouraging. After controlling for a wide range of sociodemographic characteristics of the traveler and their household, the length of the trip, and the number of persons making the trip, we have been able to demonstrate with statistical

confidence that key measures of the built environment do in fact influence travel mode choice, and to a lesser extent, auto trip length (a basic determinant of VMT).

We have found the following measures of to be effective in explaining modal choice:

- Employment and population density: higher levels produce more trips by transit and walking, fewer by auto driver and auto passenger. Interestingly, bicycle travel appears to benefit more from levels of density that are more like those for auto travel.

- Mix of uses: as measured through jobs/population balance, higher rates of mix increase walking and discourage driving; effects on transit and bicycle were not found to be significant with our data.

- Design: a higher density of four-way intersections is associated with higher rates of walking and bicycling, and lower rates of auto travel.

- Transit availability: a higher density of both rail stations and bus stops is very directly associated with higher rates of transit use, and reduced rates of auto driver trips. The effect on auto passenger, walking or bicycling was not found to be significant.

- Regional accessibility: the number of people that can reach the destination by transit within 45 minutes of travel time is a strong positive factor in determining rates of transit and walking trips, and is negatively associated with auto driver trips. An equivalent measure of accessibility using highway instead of transit travel time had a strong positive effect on bicycle travel, presumably because bicycle travel requires good roadway access.

Many other measures of these same general commodities also showed relevance, though when considered simultaneously did not exhibit relationships as strong or consistent as those listed above. In particular, an extensive set of complex entropy and mix indices which showed importance in modeling residential production travel behavior proved to be disappointingly ineffective when applied at the attraction end. A particular surprise was the inability to incorporate measures of retail and service activity into the equations, where previous research focused on the residential end has shown such activity to be an important part factor in household vehicle ownership, mode choice and VMT.

The above results describe findings in relation to total travel, without regard to trip purpose. Individual trip purpose models were also estimated for each mode, covering home-based work, home-based other, home-based shopping, home-based social/ recreational, and non-home based travel. A number of these individual purpose models were statistically stronger than the model for all purposes combined, and favored some of the built environment (and socio-economic) variables over others. Additional research that focuses more deeply on the ideal combination of measures for each mode and purpose may reveal more context-appropriate relationships, and perhaps bring different variables into play. A goal of this research was to try to find a primary set of "best" measures and then retain that framework across all modes and purposes to illustrate their relative importance in this first wave of experimentation and reporting. Additional research is planned for this database at SCAG in the coming months, in support of ongoing model enhancement and SB 375 compliance efforts. Using more advanced statistical approaches and model frameworks, a richer set of findings is anticipated.

Background and Purpose

While there has been extensive research on the link between the built environment—commonly referred to as "land use"—and travel, virtually all of that research has focused on conditions at the trip origin, and particularly with conditions surrounding the residential trip origin[i]. This research, which has employed the framework of the "Ds"—short for the attributes of density, diversity, design, destinations and distance to transit—has furnished important understanding as to how the shape of one's home environment influences travel decision-making. Transportation and urban planners now have a stronger sense of how such characteristics as compact/higher density development, a diverse and complementary mix of uses, a street grid and design features that encourage pedestrian access and circulation, and high levels of accessibility to regional opportunities via mass transit result in lower rates of auto ownership and use, shorter trip lengths—meaning fewer vehicle miles of travel (VMT)—and more trips made by transit or non-motorized modes. These are important relationships to access when addressing concerns like traffic congestion, transportation funding shortfalls, and goals related to climate change and sustainability in regional planning, policy and project prioritization.

Regrettably, existing research explains only part of the overall paradigm of how land use and travel behavior are interrelated. Thanks to several decades of creative and diligent research by the profession, we now have a fairly solid understanding about how land use impacts household travel behavior decisions at the home end of a trip; however, we then run out of evidence to help explain what happens from there. A travel decision obviously involves several dimensions, not the least of which is the choice of *where* to travel to accomplish a particular purpose, closely accompanied by choice of *how* to travel there, i.e., by what mode. These decisions are heavily intertwined. While the selection of travel mode depends strongly on the decision of "where" the person chooses to travel, conversely the decision of where to travel often depends on how easy it is to get there by a given mode. In many cases, people decide where to travel having already decided by what mode they will travel; in much of post-war America, that mode is the private automobile because it is the only practical choice in a landscape comprised of low-density residential subdivisions, shopping centers and office parks.

A key policy question that is not easily answered with conventional transportation planning tools concerns the extent to which this "expected" behavior might change if the environment in which the decision was made were fundamentally different. "What if" more households had access to a richer array of employment, retail, service and entertainment opportunities nearer to home, and could conveniently access those opportunities within a five minute walk from home vs. driving 15 minutes on congested roads to accomplish the same purpose? Unfortunately, we cannot project the full impact of alternative land use designs that would offer these opportunities, because we do not have the appropriate model structures to fully capture how these choices are being affected by conditions at both ends of a potential trip.

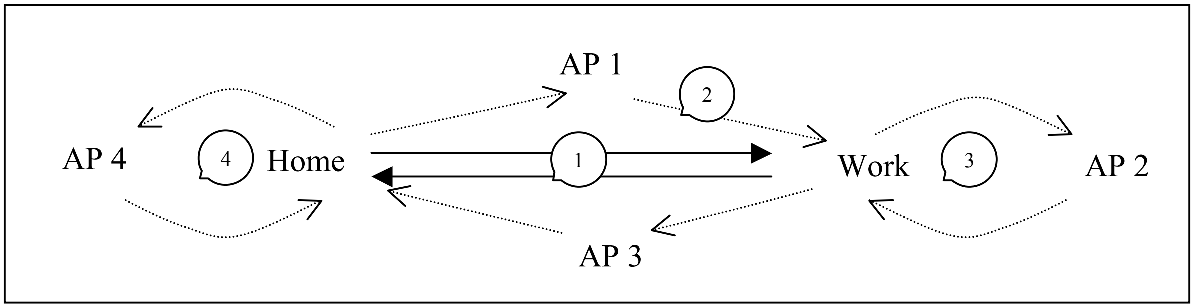
In transportation planning parlance, households and individuals generate trip "productions" to accomplish daily activity needs, while a wide variety of employment, commercial and social opportunities constitute the "attractions" through which those trip demands can be satisfied. In conventional planning models, productions and attractions are estimated at the level of traffic analysis zones (TAZs) for an array of different trip purposes (work, school, shop), and then a mathematical procedure known as "trip distribution" does the job of matching up these demand and supply potentials and creating trip movements. This apportioning is done using a gravity-type relationship, where the demand/supply potential between any pair of zones is inversely proportional to the difficulty (impedance) of traveling between those two zones. This process is repeated for individual trip purposes, and results in a trip table showing trip flows between each origin and destination zone. The forecasting model then estimates the modes that will be taken for each of these movements, and subsequently assigns the (private vehicle) trips to a computerized representation of the regional highway network, resulting in volumes, flows and travel speeds on specific transportation facilities.

While this process works reasonably well for auto and transit travel—for which it was designed—it has critical shortcomings in addressing the behavioral questions associated with compact, mixed land use and travel by non-motorized modes. Because these models are limited to analyzing tripmaking between zones, what occurs *within* a TAZ is effectively lost to the analysis. Since TAZs are roughly the geographic equivalent of a census tract, most if not all of the critical detail of compact mixed-use community designs is lost within the geographic aggregation of a zone. It also means that non-motorized modes are not part of the equation, since many would be made within a TAZ rather than between TAZs, as well as short auto trips.

In order for transportation planners and decision-makers to be confident of the extent to which the built environment truly impacted travel behavior, they would have to be shown how such designs comprehensively influenced the pattern of choices that households respond to. With a larger number of attractive opportunities closer to home—or work, or other opportunities—which could be reached or connected by walking, transportation demand theory would predict that households and individuals would adjust their patterns to accomplish more activities with less expenditure of travel budget (time and cost). Trips are seldom made as simple one-stop home-based journeys, but commonly incorporate multiple purposes and stops which are organized into "tours". Empirical studies reveal that households in compact mixed use urban settings tend to make a larger number of simple home-based one-stop tours, mainly because the convenience of the setting allows it[ii]. In contrast, suburban households who rely on driving for their travel needs are more likely to make multi-stop tours for efficiency in reducing travel time and mileage[iii].

The conundrum in the number of ways that compact mixed land use designs could affect travel decision-making can be illustrated with the following example in figure 1.

Figure 1: Typical Trip Tours Showing Alternative Activity Pattern Possibilities



This example is fundamentally about making a home-based work trip, although there are many different ways the trip can be performed. The journey begins at home and the principal purpose is to travel to a work site. However, the tour can obviously take various forms, ranging from (1) the simple home–work–home tour; to (2) one that involves stops for ancillary purposes (APs) like shopping or errands on the way to or from home and work (AP 1 and AP 3); (3) tours which are based from the work location that accomplish these ancillary purposes (AP 2); or (4) trips of the same need and purpose performed from the home base (AP 4) outside of the work tour, per se.

One can envision that the manner in which these trips are staged and which mode or modes are used for the travel has much to do with land use conditions at the attraction (work) end, as well as the production (home) end, and also the quality of the travel alternatives connecting primary production and attraction. If the home environment has a rich array of land uses and opportunities, the traveler (or household) may choose to conduct many of its household-related travel needs at the home end, thus freeing the work traveler to focus on a simple trip to/from work and greater flexibility in the choice of mode (this was well demonstrated in a study of the South Bay Cities in Southern California by Solimar Research[iv]. On the other extreme, the household may reside in a monolithic suburban environment, but the work traveler may have rich opportunities at the work end, thus opening a different set of travel choices for mode used to reach work. In what is probably more the most common case, the traveler does not have ideal opportunities at either the home end or the work end, and so is inclined to perform necessary travel duties on the way to or from work; this situation strongly encourages travel by private vehicle to achieve the necessary flexibility.

What further complicates the above example is the sharing of travel responsibilities among household members. Depending on which situation the work traveler faces, a variety of adaptations can occur through which remaining household travel needs can be accomplished by other household members. The ultimate response of the planning profession to explain this complex set of behavioral relationships is expected to come from the evolving class of tour-based and activity-based micro-simulation models. These models largely do away with zones, and focus instead on connecting individual households and trip itineraries with the best set of opportunities to satisfy their personal and household travel needs. In the near-term, however, there is a need for more insight and confidence in examining new and more widespread occurrences of smart growth type development policies.

In Los Angeles, for example, SCAG has been working diligently to implement the requirements of California Senate Bill 375, calling for reductions in greenhouse gas emissions to be obtained through revised land use and transportation plans that reduce auto dependency and VMT production. The reduction targets are ambitious, particularly in a metropolitan area like Los Angeles that has for so long had its economy and way of life shaped by a vast system of regional freeways and a proclaimed "love affair with the automobile". The last two decades have seen a major shift in ideology in planning in southern California, first motivated by the severe smog conditions in the early 1990s, then by ever-mounting traffic congestion problems, and now the recent actions in response to climate change and global warming. SCAG's most recent Regional Transportation Plan (RTP) was based on a new "Blueprint Vision" for managing future growth through priority investment in regional transit and a desire to focus future growth around transit stations and in compact, mixed-use centers.

SB 375 has ushered in a new sense of importance and specific requirements to achieve the aspirations of the Blueprint Vision. Under SB 375 guidelines, SCAG is in the process of developing a Sustainable Community Strategy (SCS) as the basis for its next RTP, which will demonstrate the fabric of local land use plans and regional transportation investments that will allow Los Angeles to meet the VMT and GHG targets established under SB 375. One of its responsibilities under the act has been to develop a planning tool that can be used by local jurisdictions to help them examine and revise their existing comprehensive plans to reduce VMT and GHG emissions as part of their own SCS development. The authors of this research paper previously served SCAG in developing a Local Sustainability Planning Tool that performs this function and which has been in use in the SCAG region for SB 375 planning. While this tool is seen as a great aid to the local planning process, it does carry a number of limitations, the most prominent of which is that it only addresses the impact of land use on residential production-end travel.

Simultaneously, SCAG has been engaged in other requirements that involve near-term and long-term improvements to the regional transportation planning model. One team of experts has been working on development of a modern activity-based travel model, as required by the act. However, as this process has not yet reached completion, SCAG staff has engaged in a substantial program of improvements to the existing trip-based model to meet current SB 375 compliance needs. These improvements include reduction in the average size of its TAZs, which has led to an increase in the number of TAZs from about 4100 to over 11,000, and also an attempt to improve the overall sensitivity of the model to land use.

Images of Desired Built Environment Characteristics

Before proceeding to the discussion of how the database was compiled, and particularly the task of defining and developing the various built environment measures used in the analysis, it is helpful to take a moment to discuss the characteristics of land use that this research is attempting to study. The framework supplied by the "Ds" is a refreshingly simple way to try to categorize complex phenomena like "built environment" into a set of primary attributes: density, diversity, design and destinations. This framework has been widely used in land use research for almost 20 years as a way of differentiating among different land use concepts through measures other than just density. Some researchers in recent years have been attempting to modify and expand the set of D factors into still other dimensions, including Ds measures for distance to transit, parking, demographics, demand management and development scale[v].

This section uses a collection of images to try to illustrate what is meant by these various terms. As will become apparent, these images are not from Southern California where our research data are from, but from Arlington, Virginia. There are several reasons for this decision, the first being that we did not have immediate access to the types of images that would allow us to illustrate the full range of compact, mixed-use, transit supported development. We not only had ready access to such images for Arlington, but recognized that Arlington has become perhaps the national model for smart growth and transit oriented development.

The history of Arlington's rebirth began in the early 1970s, when the County made a controversial decision to locate the new Metrorail Orange Line right through the heart of inner Arlington, in what is known as the Rosslyn/Ballston corridor. This corridor, which spans about three miles from Rosslyn on the east (nearest the District of Columbia) to Ballston on the west, was something of a victim of inner-ring suburban blight, with an aging housing stock, a commercial landscape dominated by used car lots and marginal retail, and not much in the way of employment. The county's vision of Metrorail as an instrument for revitalization was unique among its sister jurisdictions, most of which chose to minimize disruption by locating the tracks and stations along existing rail or highway rights of way. Critically, the county backed up its decision with supportive land use planning and zoning, and more "urban" street and highway concepts, featuring a highly articulated and well managed local street grid.

In the 30-plus years since it began as a vision, the Rosslyn/Ballston corridor has seen major investment in office and commercial real estate around each of the five station areas, while quaint fringe residential neighborhoods have been maintained, enhanced, and supplemented with new multifamily medium and high-rise apartments and condominiums in the spaces between. Despite its urban character and its location as a gateway to Washington DC, its roads are surprisingly uncongested, and cars, buses, pedestrians and bicyclists can be seen moving about in acceptable harmony. So indeed, there is much to learn from Arlington, and while Los Angeles undeniably has many examples of good development, these images will hopefully make the case very positively.

An effective built environment starts with density. Areas that are compact in design serve to bring people and activities closer together. Densities do not have to be at the level of a regional central business district in order to be effective, but functionally must lead to walkable distances between desired activities—either in getting people to or from public transit, or providing convenient access to a variety of potential attractions and services. Figures 1 and 2 illustrate the type of development density seen in the vicinity of North Lynn and 19th Streets in the heart of Rosslyn, which is the highest density you are likely to see in Arlington. Figure 1 shows North Lynn Street, which is an arterial serving traffic moving to and from DC via Georgetown and the Key Bridge on the north, while figure 2 shows 19th Street which connects with I-66 and the Roosevelt Bridge into Washington on the east. Building heights may reach 20 stories in the area immediately adjacent to Metrorail stations (the Metro station fronts on the parallel street to the right, just to the right of the brown commercial building in the foreground). However, they seldom exceed 10 stories elsewhere and are sufficiently varied and interspersed with parks and retail activity that there is none of the dreaded urban canyon effect. Blocks are short and the sidewalks wide and attractive, so as seen in figures 3 and 4, the pedestrian realm is open, inviting, and well used at all hours.

The next characteristic of a well designed area is having a diverse mix of uses, including employment, varied retail/commercial activity, and residential development of various types and price levels. Arlington obviously has significant employment, particularly government-related and other white collar professional employment, as seen from the many office buildings. However, there is also a great variety of residential development, ranging from medium to high-rise apartments and condominiums as shown in figure 5 to older, rehabbed units as in figures 6 and 8, and modern-made-to-look-embedded styles as in figure 7.

Retail and commercial services are a critical part of the use mix in a well-designed area, to serve both the needs of residents and those of employees and visitors, again to lessen the need for private vehicle travel for this important category of travel needs that comprises 75 percent or more of daily person travel. Figures 9, 10, 11 and 12 only begin to show the degree to which restaurants, banks, retail shops and services that abound in Arlington serve daily needs of employees and visitors, as well as local residents. Much of this commercial/retail activity is in the form of mixed-use development, with either retail or services built into the ground floor of multi-story office or residential buildings. Mixed-use development is an important design strategy for not only providing more opportunity and amenity, but functionally improving access to these activities by walking.

Walkability is its own critical design element, as introduced earlier in this section. In addition to its compactness and mixed-use design, Arlington's exemplary walkability stems from its comprehensive sidewalk networks, short blocks making for minimum-distance paths, frequent marked and signalized crossings, and a street network that encourages efficient driver-pedestrian co-existence. Figures 13 and 14 illustrate this feature at street level along busy Wilson Boulevard, while previous figure 2 illustrates the short block segments and wide sidewalks that also encourage walking. Pedestrians are seldom waiting long for their trip to continue, as lights are well sequenced, and it is often possible to continue to move along on one's journey by crossing the leg of the intersection where traffic is stopped. Rosslyn also features a 1970's era system of sky bridges which connect some of the buildings in the core area with each other at the second story and allow crossing of some of the busier streets; these can be seen in figures 1, 18 and 20, and also pedestrian promenades such as exist in Freedom Park in figure 15. On some streets, traffic is so sparse that pedestrians freely cross where convenient, as seen in figure 16. An "unwritten rule" seems to prevail that allows motorists and pedestrians to peacefully co-exist through mutual regard of each others' presence and right to use the space (in most cases, anyway!).

A final design element is multimodal transportation accessibility. In short, residents and visitors are presented with an array of workable choices, from private auto to Metrorail or bus transit, bicycle or walking. Clearly, even with the dominant role of Metrorail in reshaping the corridor, the County's planners realized that there would still be a need for vehicle travel, and planned accordingly. A system of one-way streets helps make most efficient use of existing road capacity, and a grid offers numerous path opportunities for both motorists and non-motorists. Arlington's primary grid incorporates several arterial streets that are designed to channel through traffic efficiently and separate it from internal travel on local streets. This treatment can be seen in the North Lynn Street image in figure 17. The cross-section here allows for three lanes of through traffic, heading for the Key Bridge crossing, but then also allows for left turning traffic to merge and maneuver in a separate lane to the left of a median, which also facilitates pedestrian crossing at the intersection. Note the bicycle lane on the right side of the roadway, as well as a curb lane for buses and right turning traffic. The effectiveness of the design can be seen in figure 18 in the period approaching evening rush hour. Figure 19 is an example of flow separation along another major arterial, Fort Meyer Drive, which directs southbound traffic along a one-way street that parallels North Lynn Street, which is northbound.

Access to the Metrorail station has been similarly well planned, as shown in figure 20, with only one way traffic permitted, bus boarding bays on the right curb adjacent to the station entrance, and a taxi waiting area along the left curb.

Bike travel is common and growing in Arlington, facilitated by a countywide network of on- and off-street bike facilities, and ample secure bicycle parking at the metro stations and at many other activity nodes (buildings, attractions) in the corridor. The regional Capital Bikeshare program has greatly increased interest in spontaneous bike use, and there are currently 22 Bikeshare stations such as the one pictured in figure 21 located in the county. The Rosslyn/Ballston corridor has 11 of these stations and more are planned.

These images help convey a clearer picture of what we mean when we discuss the built environment, and those characteristics that have been found to be important in affecting travel behavior. Hopefully this discussion will make the discussion of measures and analyses introduced in the coming sections easier to follow and their importance more evident.

Figure 2: Northbound North Lynn Street in Rosslyn

Figure 3: Nineteenth Street at Intersection with North Lynn in Central Rosslyn

Figure 4: Sidewalk Passage along Wilson Boulevard

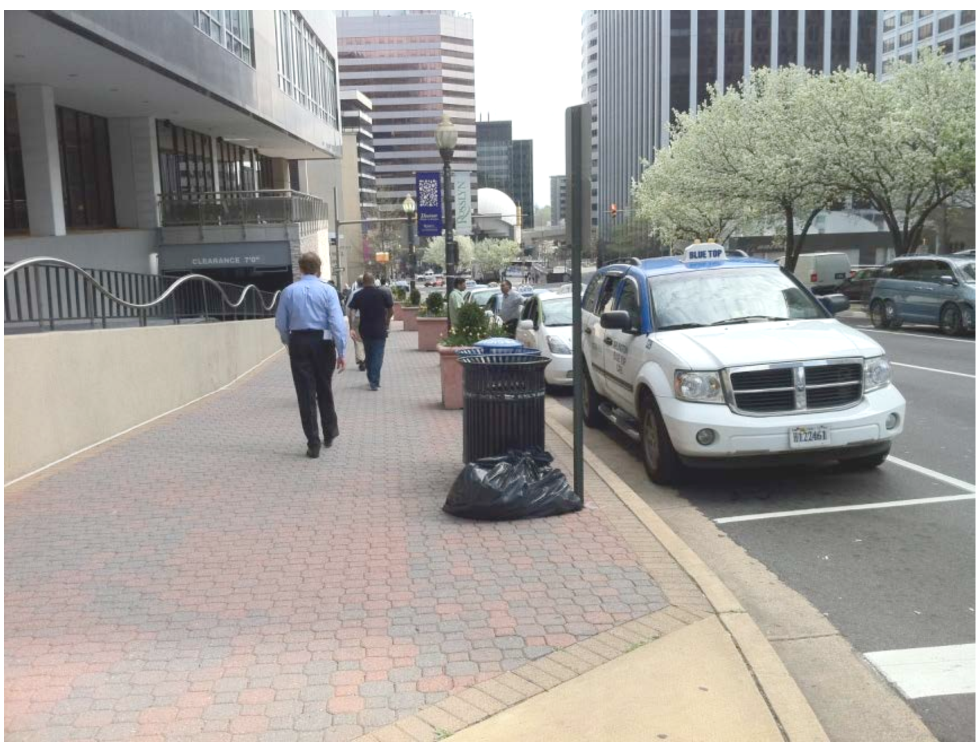


Figure 5: Walkway along Nash Street south of Wilson Boulevard

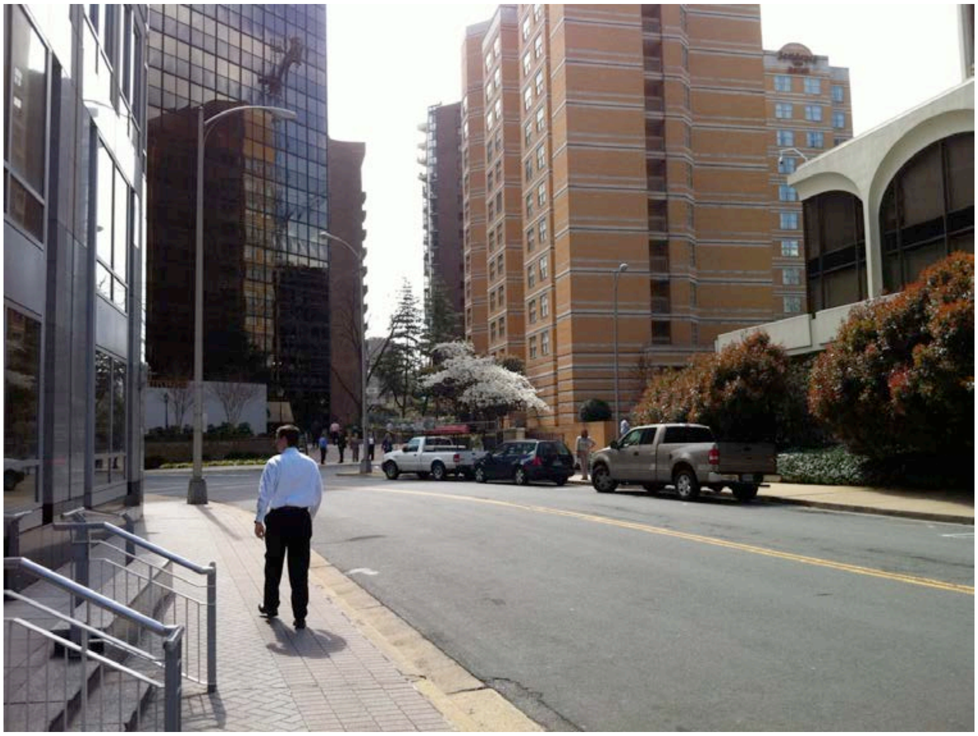


Figure 6: Medium and High-Rise Residential Units along Key Boulevard within Four Blocks of Metro Station

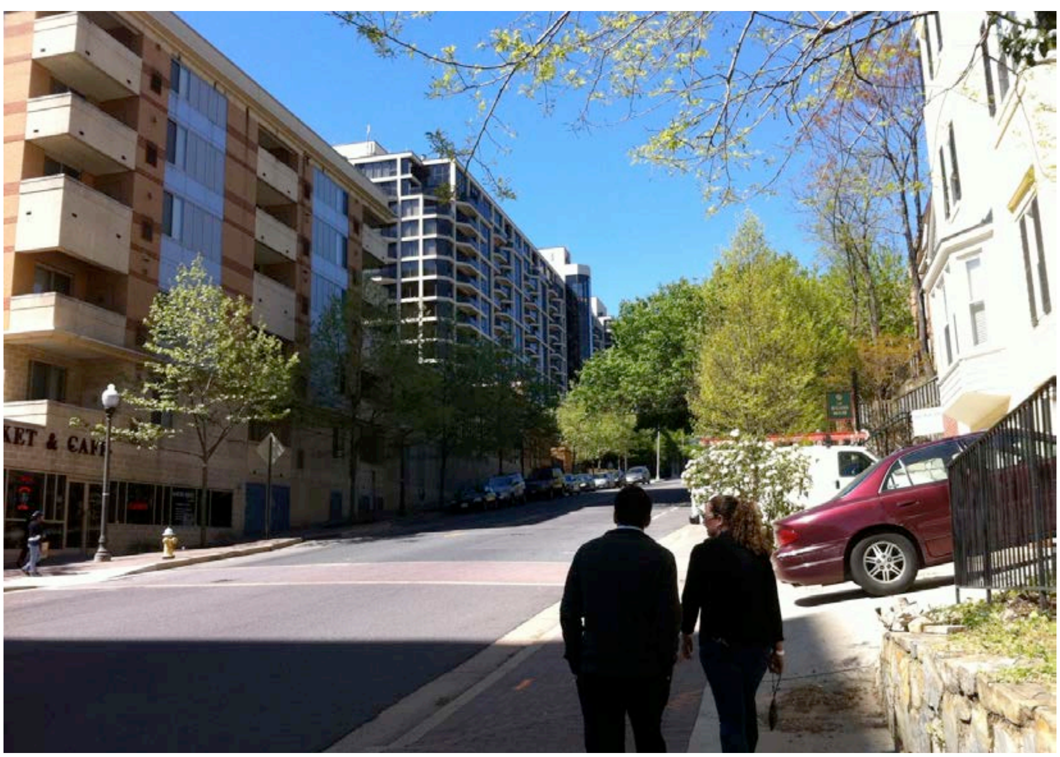


Figure 7: Older Multi-Family Housing within Four Blocks of Metro Station

Figure 8: Newer Multi-Family Housing on North Nash Street at Key Boulevard

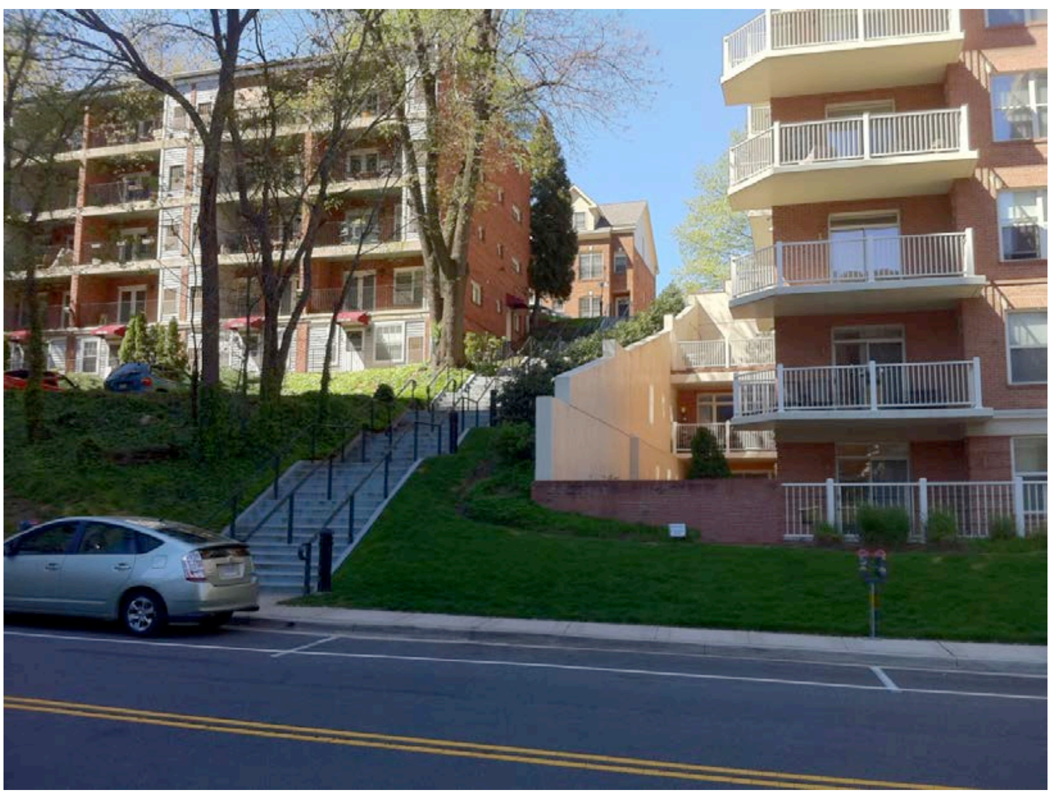


Figure 9: Traditional Multi-Family Housing along Key Boulevard at North Nash Street

Figure 10: One of Many Sidewalk Cafés in Arlington

Figure 11: Restaurants, Shops and Services Lining North Lynn Street, a Major Thoroughfare

Figure 12: Mixed-Use Development in Clarendon

Figure 13: Mixed-Use Development along Clarendon Boulevard

Figure 14: Well Marked Intersection along Wilson Boulevard

Figure 15: Frequent Crossings with Multiple Path Options

Figure 16: Pedestrian Promenade and Overpass at Freedom Plaza

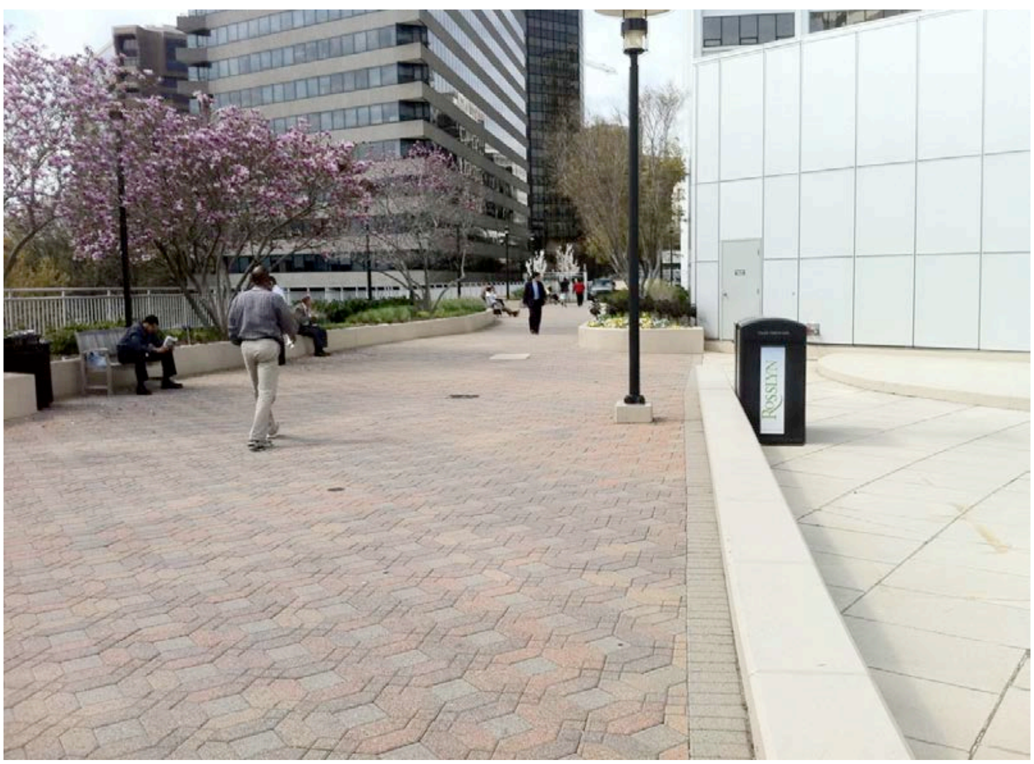


Figure 17: Leisurely Lunch Time Walking on Secondary Streets

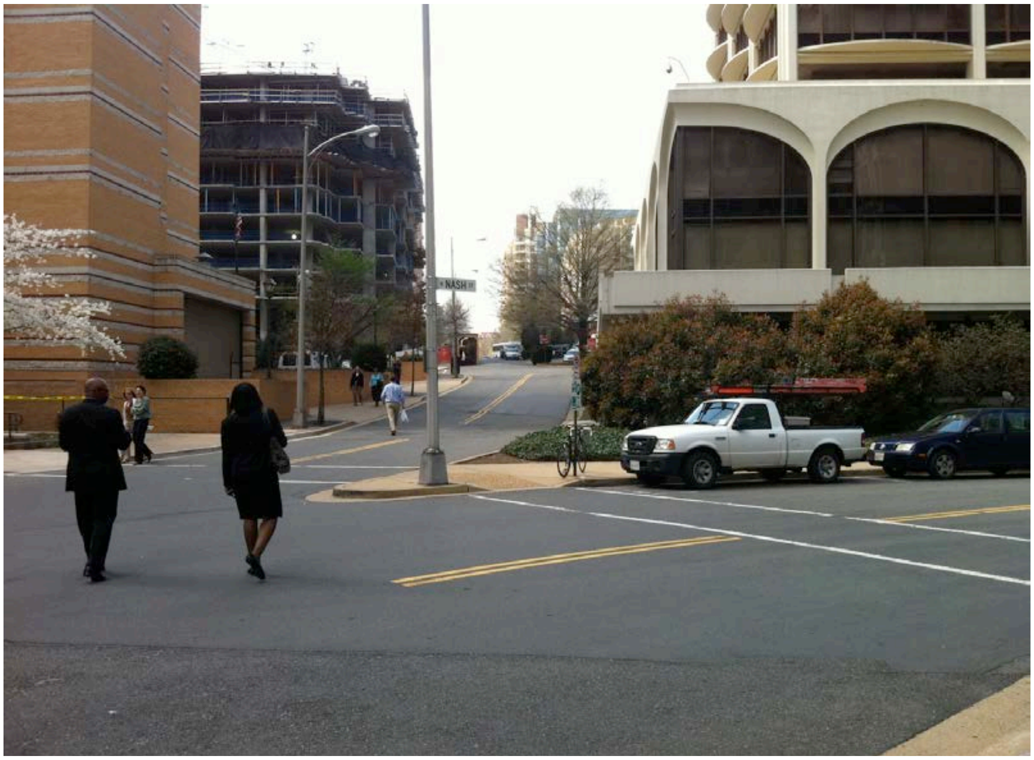


Figure 18: Channelization Design along North Lynn Street in Rosslyn

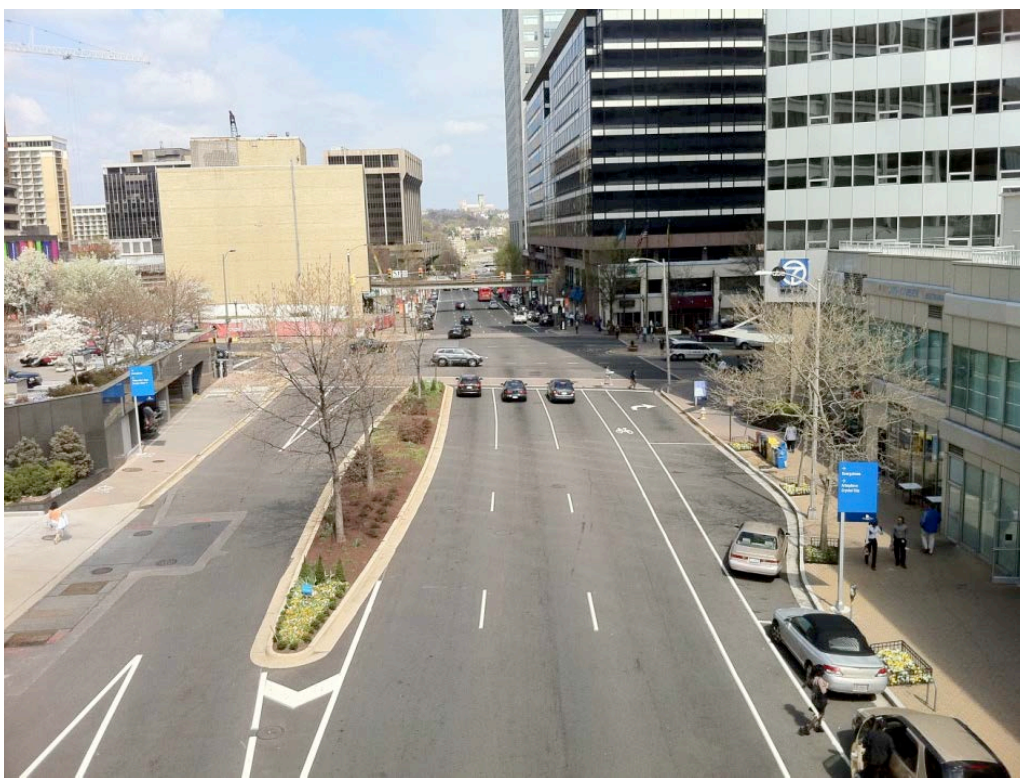


Figure 19: Pedestrian Movement Crossing North Lynn Street in Late Afternoon

Figure 20: Separation of Through and Local Travel along Ft. Meyer Drive

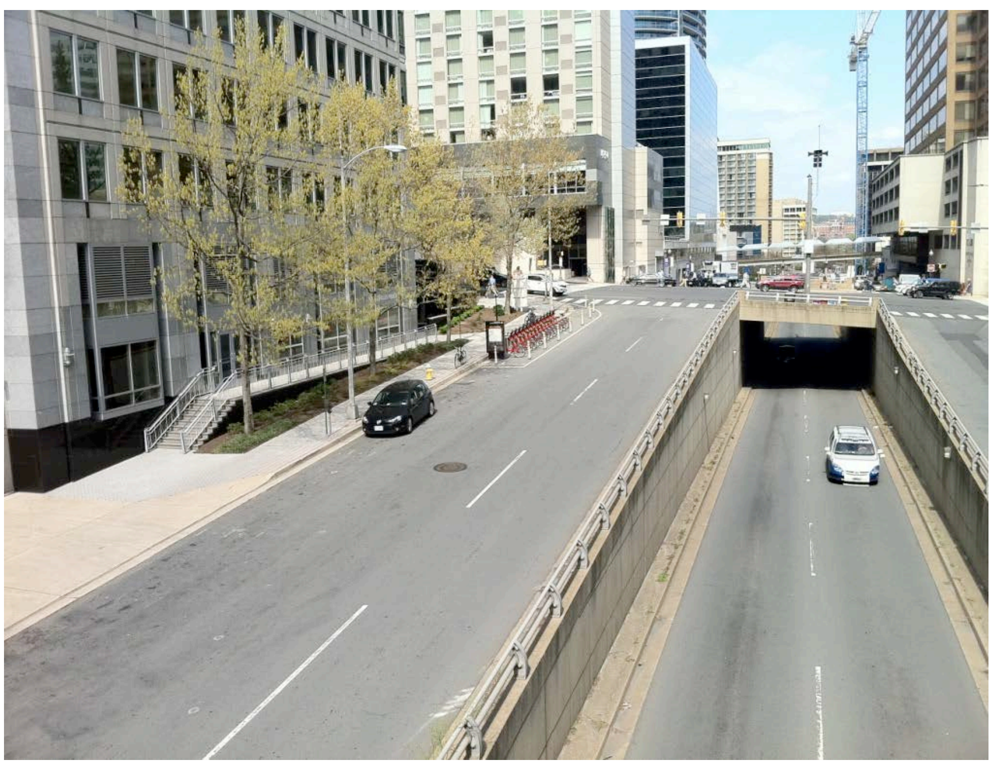


Figure 21: Integration of Metrorail Station with Surface Transportation along North Moore Street

Figure 22: One of 11 Capitol Bikeshare Stations in the Rosslyn/Ballston Corridor

Database Creation

The impetus for this project was the authors' knowledge that previous work in developing the Sustainability Tool for SCAG did not allow ample time to explore a special trip-based dataset that had been created for that project. Most modeling approaches that have attempted to isolate the role of land use factors have focused on the behavior of households, rather than individual travelers and the trips they make. Largely, this is in keeping with the conventions of the standard four-step transportation planning models, which use households as the basis for trip productions to initiate the estimation of trip generation and flows. The other factor is that travel survey data are compiled from households, so households constitute the richest and most concentrated source of travel data. The same is not true for activity at trip attractions, which is more likely to take the form of simple trip generation analyses based on square footage. Focusing travel analysis on households, as opposed to individual travelers or trips, it is also much less complicated, though doing so gives up much important information associated with the traveler (age, gender, work or student status, driver's license) or to the specific trip (purpose, destination, modes available, number of people on the trip, etc.). In point of fact, the role of land use at destinations cannot be examined except at a "trip" level; there simply is not enough information at the household level to attach travel behavior to conditions at the destinations used.

That earlier SCAG study created an opportunity for new research to use the trip based database to investigate the presumed relevance of land use at destinations. The Lincoln Institute and SCAG agreed to support the authors in such in-depth investigation of the travel reducing effects of built environments at trip attractors. SCAG has shared its data resources and supported enhancement of the database and assisted in some of the data analysis. The study makes use of a regional survey was conducted in 2009 as part of the National Household Travel Survey (NHTS). This newer survey was of ample size (6,663 households), and had the advantage of being supported by more complete and up-to-date regional parcel land use data and also the new SCAG regional travel model and its current sociodemographic data. With the permission of Caltrans and SCAG, a decision was made to focus instead on enhancing the new 2009 survey data.

In addition to extensive information on each trip itself, the trip record was also processed to contain detailed information on the household and the individual traveler. The information items listed in figure 23 were extracted from the survey and placed into the individual trip records.

Figure 23: Information Derived from 2009 SCAG Household Travel Survey

Household Information:

- Household size
- Number of adults
- Number of workers
- Life cycle
- Household income
- Number motor vehicles
- Home ownership
- Dwelling type

Individual Traveler Information:

- Gender
- Age
- Work status
- Race
- Driver's license
- Education
- Primary Activity last week
- Distance home to work
- Distance home to school
- Number walk trips past week
- Number bike trips last week

Trip Information:

- Number of trips this respondent/number of this trip
- Day of week
- Start time
- End time
- Time at destination
- Travel time
- Trip distance
- Purpose of this trip (37 categories)
- Purpose of previous trip (37 categories)
- Travel mode
- Driver or passenger
- Household vehicle used
- If transit
  - Mode
  - Access mode
  - Egress mode
  - Parked or dropped off
  - Wait time
  - Access time
  - Egress time
- Number of people on trip
- Number household members on trip

To this base version of the trip database, the research team proceeded to compile and append a comprehensive array of built environment measures to each individual trip end using specific latitude/longitude coordinates. The built environment measures were compiled using a customary "buffering" process in GIS—essentially defining an area of a given radius around each trip end, and then enumerating the characteristics of those areas using an overlay process with other databases. For our purposes we developed both one-fourth and one-half mile buffers around each trip end. The specific measures developed are listed in the following table, summarized categorically in relation to the 5Ds as follows:

- Table 1. Basic Quantities: Simply lists the primary data items and measures used to create the actual built environment variables.

- Table 2. Density: Total developed land area, population, housing units, and employment by gross (total) and net (define by zoning) land area.

- Table 3. Diversity: Mix and balance of land uses, including measures such as entropy and diversity.

- Table 4. Design: Measures of walkability and connectivity corresponding to extent and coverage of the street grid, sidewalks and bike facilities, safety and security.

- Table 5. Distance to Transit: Ease of access to transit service as measured by number of stations or stops within reasonable walking distance.

- Table 6. Destinations: Accessibility by a variety of modes to an array of important attractions, including other households, employment, retail and service, entertainment, etc.

Table 1: Built Environment Variables—Basic Quantities

(Each variable computed for both ¼ and ½ mile radius buffers around each trip end)

Variable Name	Description	Source/Calculation
POP	Resident population in buffer	SCAG 2008 TAZ data
HH	Number of households in buffer	SCAG 2008 TAZ data
SFDU	Number single-family dwelling units	SCAG 2008 TAZ data
MFDU	Number multi-family dwelling units	SCAG 2008 TAZ data
RESI_ACR	Acreage zoned residential	SCAG parcel data
EMP	Total employment in buffer	From InfoUSA—match employer location (x,y coordinates) with buffer
RET_EMP	Total retail employment	From InfoUSA (Retail Trade: NAICS = 44 and 45)
SERV_EMP	Total service employment	From InfoUSA (Service employment: NAICS = 81)
FIRE_EMP	Office employment (Finance, Insurance, Real Estate)	From InfoUSA (Finance, Insurance, RE, Prof Services: NAICS = 52-55)
GOV_EMP	Government and public agency employment	From InfoUSA (Government & public employment: NAICS = 92)
TCPU_EMP	Transportation, communication & public utility employment	From InfoUSA (Transportation, Comm., Utilities, Warehousing, Wholesale Trade: NAICS = 22,23,42, 48-49)
IND_EMP	Industrial and manufacturing employment	From InfoUSA (Industrial employment: NAICS = 31-33, 51)
EDU_EMP	Schools and colleges employment	From InfoUSA (Educational employment: NAICS = 61)
MED_EMP	Medical & health care employment	From InfoUSA (Medical and health care: NAICS = 62)
FOODHOTL	Restaurant & Hotel employment	From InfoUSA (Restaurants and Hospitality services: NAICS = 72)
OTHER_EMP	Residual employment (unnamed)	From InfoUSA (all other NAICS)

Table 1 (continued): Built Environment Variables—Basic Quantities

EMP_ACR	Land area zoned employment	SCAG parcel data
DEVLAND	Acreages of all parcels except vacant, recreational, utilities agricultural, and transportation	SCAG parcel data
RESTR	Count of restaurant establishments	From InfoUSA (NAICS = 722110-722213, 722410)
GROC	Count of grocery and other food-related stores	From InfoUSA (NAICS = 445110 - 445299, 445310)
ACTIVITY	Total jobs + Total population	Sum of basic quantities

Table 2: Built Environment Variables—Density Measures

(Each variable computed for both ¼ and ½ mile radius buffers around each trip end)

Variable Name	Description	Source/Calculation
GRS_POPDEN	Gross population density	Population (method used for basic quantities) divided by total gross acre of buffer.
NET_POPDEN	Net Population density	Resident population divided by land designated as residential (excluding group quarters)
NET_HHDEN	Net household density	Resident household divided by land designated as residential
GREMPDEN	Gross employment density	Employment (method used for basic quantities) divided by total gross acre of buffer.
NTEMPDEN	Net employment density	Employment (method used for basic quantities) divided by parcel acreage defined as employment
GRS_ACTDEN	Gross activity density	ACTIVITY (method used for basic quantities) /Total acres of the buffer
NET_ACTDEN	Net activity density	ACTIVITY (method used for basic quantities) / DEVLAND
NET_FAR	Net Floor Area Ratio	Total sq footage of building divided by total sq footage of developed parcels within the buffer.
RETAIL_FAR	Average retail parcel net FAR	Average FAR for retail parcels in buffer

Table 3: Built Environment Variables—Diversity Measures

(Each variable computed for both ¼ and ½ mile radius buffers around each trip end)

Variable Name	Description	Source/Calculation
JOB_POP_BAL	Jobs/Population Balance = Index that measures balance between employment and resident population within buffer. Index ranges from 0, where only jobs or residents are present in the buffer, not both, to 1 where the ratio if jobs to residents is optimal from the standpoint of trip generation.	JOB_POP_BAL = $1-\frac{ABS(EMP-(0.2\times POP))}{EMP+(0.2\times POP)}$
RET_POP_BAL	Retail Jobs/Population Balance: Same as Jobs/Population Balance but only in relation to retail employment.	RET_POP_BAL = $1-\frac{ABS(RETAIL-(0.05\times POP))}{RETAIL+(0.05\times POP)}$
ENTROPY_13	Entropy with 13 land uses: Index that measures balance among land uses in buffer (SF Resid, MF Resid, Office, Retail Lodging, Gov/Institutional, Indust/TCPU, Agricultural, Medical, Education, Univ, Mixed-Use, and Unbuildable)	$\text{Entropy} = -\sum_j \frac{(P_j \; x \, Ln(P_j))}{Ln\;(J)}$ Where P_j = proportion of land in the J*th* use type Value range = 0 to 1 (1 denotes ideal balance)
ENTROPY_6	Entropy with 6 land uses: FIRE (Office + R&D), Residential (SFR + MFR), Commercial (Retail + Lodging + Commercial MXD), Industrial, Institutional (Govt/Public + Medical + Schools + University), and Unbuildable	As above
LANDMIX	Land Use Mix: An Entropy-like measure based on net acreage in four land use categories likely to exchange trips: residential, commercial, industrial, and public or semi-public	LANDMIX = [SF share*LN (single family share) + MF share*LN (multifamily share)+ Commercial share*LN (comm share)+ Ind share*LN (industrial share)+ public share*LN(public share)]/LN (5)
JOBMIX	Similar to LANDMIX, only it is calculated based on employment rather than land area.	JOBMIX - -[retail share * LN(retail share)+service share * LN (service share)+FIRE share * LN (FIRE share)+TCPU share*LN (TCPU share)]/LN (4)
BUILDMIX	Similar to LANDMIX, only it is calculated based on floor area for the respective land use rather than land area.	

Table 3 (continued): Built Environment Variables—Diversity Measures

(Each variable computed for both ¼ and ½ mile radius buffers around each trip end)

Variable Name	Description	Source/Calculation
DIS_13LU_TYPES	Dissimilarity among 13 land use types: An index that measures the degree that different land uses are mixed and distributed in relation to each other. If location of the uses is highly dispersed/varied, the index value tends toward a value of 1.0.	$\text{Dissimilarity} = \sum_k \frac{1}{K} \sum_1^i \frac{X_{jk}}{J}$ Where: K = total number of developed hectares in buffer X_{ij} = 1 if the central hectare's use differs from its neighbor (X_{ij} = 0 otherwise)
DIS_6LU_TYPES	Dissimilarity for 6 land use types.	As above
NET_DIS_13LU	Net Dissimilarity: Same as (13) above, but eliminate Unbuildable land use from the calculation. This would attempt to account for whether the unbuildable land area is concentrated or scattered.	As above
NET_DIS_6LU	Net Dissimilarity: Same as above, only for 6 land uses.	As above

Table 4: Built Environment Variables—Design Measures

(Each variable computed for both ¼ and ½ mile radius buffers around each trip end)

Variable Name	Description	Source/Calculation
STR_DEN	Street centerline density	Total centerline mileage of streets and roads divided by the respective buffer land area.
INT_DEN	Total intersection density	Total intersections of all types in buffer divided by respective buffer land area.
INTS_4WAY	Percent of intersections that are 4-way (as opposed to 3-way or T intersections) within the buffer.	Street layer from jurisdictions (SCAG model network does not include lower level facilities (local streets, some collectors).
WDT_INTS	Weighted intersections	Same as INT_DEN, except that regular 4-way intersections get full point, 3-ways get 1/2 point, and intersections involving major arterial highways get 1/2 point.

Table 5: Built Environment Variables—Distance to Transit Measures

(Each variable computed for both ¼ and ½ mile radius buffers around each trip end)

Variable Name	Description	Source/Calculation
RAIL_STA	Rail station	Number of metro, commuter rail and light rail transit stations with in the buffer area.
BUS_STOP	Bus stop	Number of unique bus stops within the buffer area; same stop used by different routes counted multiple times.

Table 6: Built Environment Variables—Destination Accessibility Measures

(Each variable computed for both ¼ and ½ mile radius buffers around each trip end)

Variable Name	Description	Source/Calculation
GVWTR30	Regional population transit accessibility: Measures the number of people who live within 30 minutes total transit travel time of the selected trip end. Total travel time includes walk, wait and ride time. WTR signifies "walk" access to transit.	Gravity computational method registers the number of people living in a zone with 30 minutes of transit travel time, divides that number by the actual travel time, and then sums across all eligible TAZs (within 30 mins).
GVWTR30P	Proportion of regional population within 30 minutes by transit, using the gravity formulation.	Same as above, but result expressed as a percentage.
POPWTR30	Total population within 30 minutes of total transit travel time from selected trip end.	Also computed on a TAZ basis, but not discounted by travel time—simply a straight sum.
PTWTR30	Percentage of regional population within 30 minutes, not using gravity formulation.	As above, but result expressed as a percentage.
Each of the above also calculated for 45 minutes of transit travel time		
GVATR30	Same as GVWTR30, only for trips with auto access instead of walk	Same as GVWTR30 but with auto access
GVATR30P	Same as GVWTR30P, only for trips with auto access instead of walk	Same as GVWTR30P but with auto access
POPATR30	Same as POPWTR30, only for trips with auto access instead of walk	Same as POPWTR30 but with auto access

Table 6 (continued): Built Environment Variables—Destination Accessibility Measures

PTATR30	Same as PTWTR30, only for trips with auto access instead of walk	Same as PTWTR30 but with auto access
Each of the above also calculated for 45 minutes of transit travel time		
GVAU30	Same as GVWTR30, only for auto trips	Same as GVWTR30 but for auto trips
GVAU30P	Same as GVWTR30P, only for auto trips	Same as GVWTR30P but for auto trips
POPAU30	Same as POPWTR30, only for auto trips	Same as POPWTR30 but for auto trips
PTAU30	Same as PTWTR30, only for auto trips	Same as PTWTR30 but for auto trips

Analysis

Several types of analyses were attempted with the enhanced SCAG database, in a progressive attempt to ascertain whether the various built environment measures help explain travel decisions, and which have the greatest value in that role.

Pair-wise Analysis

The first approach was simply to better understand the data and examine pair-wise relationships between the potential explanatory variables and measures of travel decision-making. The travel measures selected for this purpose were choice of mode for set of selected trip purposes, which were:

- Go To Work
- Return To Work
- Go To School
- Shopping—from any starting point
- Shopping—beginning from home only
- Medical/dental care
- Food related (not grocery shopping)
- Returning home
- All trips

A total of 54,659 trips were available for analysis from the SCAG travel survey data. Tables 7 and 8 describe the basic characteristics of this sample, indicating the total number of trips for each designated purpose and the distribution by mode, which includes auto driver, auto passenger, transit, walk, bicycle and other. Table 9 illustrates the percentages of each mode/purpose trip that began from home. Examining tables 7 and 8 reveals that 63.8 percent of the trips in the sample are made by auto driver, 19.8 percent by auto passenger, 12.3 percent by walking, and only 1.9 percent by transit, 1.1 percent by bicycle, and 1.1 percent by other mode. Overall, mode could not be determined in 2,941 cases, or about 5.4 percent of the trip sample.

Patterns in mode usage obviously differ by trip purpose. Auto driver is clearly the dominant mode used for travel to work, claiming 88.9 percent of all trips, vs. only 3.5 percent by auto passenger, 3.2 percent by transit, 2.2 percent by walk and 0.8 percent by bicycle. However, for travel to school, auto passenger is the dominant mode at 53.7 percent, while only 21.9 percent drive alone, 17.6 percent walk, 4 percent take transit, and 1.3 percent bicycle (the highest share for bicycling). People making a trip from work are most likely to have traveled as a driver, 70 percent, which is not surprising since 88.9 percent drove to work in the first place. However, a substantial share, 25.4 percent, traveled as a pedestrian, indicating a fair number of occasions where the land use at the work destination permitted mid day travel on foot. While walking accounts for only a small percentage of work trips, 2.2 percent, it does account for 8.6 percent of all home-based shopping trips and 10.2 percent of all food-related trips.

Table 7: Trips by Mode for Select Purposes

	Go To Work	Return To Work	Go To School	Shop, All	Shop, HB only	Medical / Dental	Food Related	Return Home	All Trips
Auto Driver	3048	439	287	6109	3608	652	1959	11601	33017
Auto Passenger	120	14	703	1682	925	211	848	3695	10217
Transit	110	2	52	128	95	55	26	343	990
Walk	75	159	230	652	445	34	327	2395	6367
Bike	26	3	17	46	35	1	17	229	557
Other	50	10	14	53	43	7	28	167	570
All Modes	3429	627	1303	8700	5151	960	3205	18430	51718
Percent by purpose	6.6%	1.2%	2.5%	16.8%	10.0%	1.9%	6.2%	35.6%	100%

(mode unspecified = 2,941 cases)

Table 8: Percent by Mode

	Go To Work	Return To Work	Go To School	Shop, All	Shop, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	88.9%	70.0%	21.9%	70.2%	70.0%	67.9%	61.1%	62.9%	63.8%
Auto Passenger	3.5%	2.2%	53.7%	19.3%	18.0%	22.0%	26.5%	20.0%	19.8%
Transit	3.2%	0.3%	4.0%	1.5%	1.8%	5.7%	0.8%	1.9%	1.9%
Walk	2.2%	25.4%	17.6%	7.5%	8.6%	3.5%	10.2%	13.0%	12.3%
Bike	0.8%	0.5%	1.3%	0.5%	0.7%	0.1%	0.5%	1.2%	1.1%
Other	1.5%	1.6%	1.1%	0.6%	0.8%	0.7%	0.9%	0.9%	1.1%
All Modes	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 9: Percent Starting at Home

	Go To Work	Return To Work	Go To School	Shop, All	Shop, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	78.8%	18.0%	80.1%	43.3%	100.0%	66.0%	41.6%	0.3%	35.3%
Auto Passenger	80.8%	21.4%	87.5%	43.4%	100.0%	69.2%	49.4%	0.5%	36.1%
Transit	85.4%	50.0%	82.7%	57.9%	100.0%	72.7%	30.8%	1.5%	35.1%
Walk	60.0%	0.6%	90.4%	53.5%	100.0%	52.9%	28.4%	0.5%	37.8%
Bike	96.1%	100.0%	100.0%	60.9%	100.0%	100.0%	52.9%	NA	41.3%
Other	74.0%	20.0%	92.9%	57.7%	100.0%	71.4%	28.6%	NA	29.3%
All Modes	78.8%	14.2%	86.4%	44.5%	100.0%	66.7%	42.2%	0.4%	35.7%

Table 9 explores the percentage of trips by each type that begin from home, as opposed to from some other location as part of a tour, which would cause them to be referred to as non home-based trips. The data show that while work and school trips commonly start from home, shopping, medical/dental, and food-related are much less likely to begin from home. Less than half of shopping trips made by auto mode (driver or passenger) begin from home, but more likely are made as part of a continuing chain of trips, or tour, as has been documented in previous studies. A surprisingly small percentage of food-related trips are made from home, suggesting that dining options are not convenient or attractive to many pedestrian travelers, although many of these food related trips may be made from work locations (Return To Work has a high percentage of walk trips), or as a side trip as part of a shopping or other tour for which the primary mode may have been auto or transit. While the sample size is too small for bicycle to draw meaningful conclusions, the data suggest that bicycle trips are far and away the most likely to have begun from home.

Taking away the details of trip purpose, table 10 examines differences seen in socio-demographic characteristics across the different model groups. Generally we see that auto drivers represent households with the fewest members, the highest rates of vehicle ownership, the highest ratio of cars to licensed drivers, the highest incomes, and the most likely to own (vs. rent) their residence. As individuals, auto drivers are the oldest, are evenly male or female, white, have a driver's license, and are employed. Auto passengers are likely to come from the largest households, have very similar income, vehicle ownership and vehicle availability ratios, and are even more likely to live in a single-family detached residence. Their big difference with auto drivers is at the individual level, where they are much younger (32.8 vs. 51.7 years), more likely to be female (65.6%) and white, but much less likely to be employed or to have a driver's license.

Persons making trips as a pedestrian differ from auto drivers in coming from slightly larger households with slightly fewer vehicles, are more likely to be renting and less likely to live in a single family home, and have average incomes that are about 12 percent lower. However, a surprisingly high percentage are drivers (82.7 %). Transit users are perhaps the most different from auto drivers: their incomes are about half those of auto driver households, they are the most likely to be renting, and are the least likely to live in a single family home. They also have the lowest rates of auto ownership, probably for economic reasons, although 78.7 percent have driver's licenses. Cyclists are also a distinct group. First, they are overwhelmingly male (76%), are young, white, and have income, auto availability, and residence characteristics that are slightly higher than pedestrians.

These sociodemographic differences are significant enough that they cannot be ignored in subsequent analyses, particularly as the transit users suggest much different economic circumstances, and both passengers and cyclists appear to be much younger on average.

Table 10: Sociodemographic Differences Across Modes (all trips)

	Auto Driver	Auto Passenger	Transit	Walk	Bike	All Modes
Persons per household	2.99	3.85	3.33	3.18	3.35	3.19
Vehicles per household	2.48	2.46	1.18	2.02	2.09	2.39
Vehicles per driver	1.16	1.11	0.62	1.06	1.05	1.13
Vehicles per worker	1.74	1.76	0.98	1.53	1.47	1.70
Average age	51.7	32.8	42.2	44.4	36.7	46.7
Percent female	50.0%	65.6%	59.1%	54.4%	23.3%	53.4%
Percent white	74.4%	65.4%	45.5%	66.4%	74.0%	71.1%
Average income ($1000)	78.3	76.7	36.8	68.3	69.5	75.9
Percent with driver's license	100.0%	73.0%	78.7%	82.7%	74.9%	93.5%
Own residence	84.5%	79.9%	35.5%	70.0%	73.6%	80.7%
Single family detached house	78.8%	79.8%	38.0%	64.9%	72.2%	76.4%
Worker	63.0%	41.4%	47.0%	51.1%	62.9%	58.5%

Table 11 provides a similar comparison across modes, only this time in relation to characteristics of the trip. Here we also see important differences with regard to travel distance, in which transit is the longest at 9.3 miles, followed by auto passenger at 9.13, auto driver at 8.62, bike at 3.14 miles, and walk at 0.73. These distances vary substantially across different trip purposes, though the relationships across the modes remain relatively the same. The reader is encouraged to examine these differences in the appendix tables. Because walk and bicycle are lower speed modes, the travel times associated with the short distances begin to pull them into comparison with the auto modes, with average walk travel time being slightly lower than auto driver/passenger, and bicycle being slightly greater. At 50.1 minutes, however, transit trips consume the greatest total travel time. This may have some role in explain the category-high value of time spent at the destination, which is much higher for transit than any of the other modes.

Other differences seen in table 11 include:

- Auto passenger trips have the greatest number of other persons on the trip, which would be expected, but transit is second highest, which is perhaps unexpected.

- Auto drivers logged the greatest number of trips per day, while transit users had the least—this is probably because it is more difficult to link transit trips of various purposes and destinations than it is with driving or the other modes.

Table 11: Differences in Trip Characteristics across Modes (all trips)

	Auto Driver	Auto Passenger	Transit	Walk	Bike	All Modes
Number people on trip	1.54	3.05	1.79	1.09	1.02	1.78
Number HH members on trip	1.38	2.81	1.52	1.06	1.00	1.62
Trip distance in miles	8.62	9.13	9.3	0.73	3.14	8.57
Travel time in minutes	18.9	19.2	50.1	17.1	25.3	19.6
Time at destination in minutes	117.4	120.3	181.4	88.4	105.6	115.7
Number daily trips for this person	6.04	5.10	4.27	5.73	5.62	5.77
Days worked at home last month	3.89	4.66	3.17	4.43	4.91	4.01
Distance to work in miles	14.25	12.2	12.94	12.05	9.93	13.97
Number walk trips last week	3.69	3.53	6.4	7.66	5.28	4.22
Number bike trips last week	0.21	0.61	0.44	0.46	6.77	0.4

- Auto drivers have the longest average trip distance to work, while cyclists have the shortest.

- While pedestrians would be expected to have logged the greatest number walk trips in the past week, the numbers for transit users and cyclists are similarly high; however, the rates for auto drivers and passengers are only about half of these.

- A comparable situation does not exist between bike users and walk trips; travelers by all modes other than bike made fewer than on trip by bicycle in the past week.

Finally, in tables 12 and 13 we examine differences in land use and regional accessibility factors across modes. The values shown in the tables correspond to the land use measures developed by the team using buffering techniques, described earlier. While buffers of ¼ and ½ mile radius were developed for all trip ends, we elected to focus on the ½ mile buffer for this analysis as it seemed to be more appropriate in capturing the environment we believed to be relevant. We have worked extensively with ¼ mile buffer data in previous studies, and have come to believe that it is perhaps too limiting in defining the area that may be considered one's walk shed or neighborhood.

As might be expected, transit sets the standard in these comparisons for the most "urban" values seen in regard to density, dissimilarity, design, destination accessibility and distance to transit. Walk generally follows transit with the second highest level of urban scores, followed by bicycle, although bicycle sometimes shows some surprising relationships in terms of land use characteristics that seem to suggest preferences closer to those of the auto modes than to walking or transit.

Table 12: Differences in Land Use Characteristics across Modes (all trips)

	Auto Driver	Auto Passenger	Transit	Walk	Bike	All Modes
Gross population density	11.35	11.63	22.1	15.71	13.68	12.16
Net population density	33.74	32.48	103.62	47.64	37.49	36.64
Net household density	13.73	13.06	44.45	19.85	15.5	14.99
Total SF DU's	829.8	868.9	679	869.6	904.5	839.3
Total MF DU's	1,434	1,407	3,802	2,318	1,841	1,586
Pct MF DU's	63.3%	61.8%	84.8%	72.7%	67.1%	65.4%
Acres zoned residential	202.5	208.8	193.3	216.6	212.5	205.2
Acres zoned employment	117	106.5	137.6	104.8	107	113.8
Total developed acres	320	315.2	330.9	321.4	319.5	7.22
Gross employment density	7.16	5.75	15.48	8.42	6.09	28.89
Net employment density	28.59	25.28	45.08	33.94	27.65	31.41
Retail employment	501.6	448.4	797.1	721	394	492.1
Service employment	1,419.9	1,110.2	3,018	1,787.6	1,338	1,437.7
Retail FAR	0.252	0.223	0.529	0.333	0.252	0.262
Average net FAR	0.240	0.211	0.516	0.322	0.236	0.25
Jobs + Population	9314	8743	18875	12135	9937	9745
Jobs + Population per gross acre	18.53	17.39	37.55	24.14	19.77	19.39
Jobs + population per net acre	28.79	27.22	57.63	37.44	31.32	30.16
Jobs-population balance	0.53	0.552	0.56	0.579	0.58	0.541
Retail+population balance	0.479	0.46	0.539	0.51	0.514	0.482
Land Mix	0.543	0.526	0.63	0.55	0.554	0.542
Retail + food establishments	65.6	60	164	83.4	65.4	68.7
JobMix	0.569	0.564	0.58	0.564	0.556	0.567
Dissimilarity (6 LU Types)	0.183	0.181	0.194	0.184	0.182	0.183
Dissimilarity (13 LU Types)	0.193	0.191	0.208	0.196	0.192	0.193
Net Dissimilarity (6 LU Types)	0.164	0.161	0.182	0.167	0.165	0.164
Net Dissimilarity (13 LU Types)	0.172	0.17	0.193	0.177	0.174	0.173
Entropy (13 LU Types)	0.4408	0.4406	0.4849	0.4311	0.4474	0.4406
Street centerline density	0.03	0.029	0.035	0.032	0.031	0.03
Number rail stations	0.41	0.31	2.14	0.5	0.45	0.44
Number bus stops	69.6	61.2	265.3	114	74.1	77.4
Sum of weighted intersections	56.4	54.9	74.8	66.9	66.6	57.9
Number 4-way intersections	28.1	27.6	35.4	30.6	30.1	28.5
Total intersections	110.7	108.8	113.6	125.2	124.8	112.7
Intersection density	0.881	0.866	1.0636	0.996	0.994	0.897

Density

In terms of gross population density, the values associated with transit are almost twice as high as those for auto (driver or passenger), and for walk and bicycle, 38 and 20 percent higher respectively. When population density is computed on a net (per residential land area) basis, the value for transit jumps to three times as high as for auto, more than 40 percent for walk, and slightly less, 11 percent for bicycle.

In terms of gross employment density, the average density for transit is more than twice that of the auto modes, while walk is about 18 percent higher, and bicycle is actually *less*, more on a par with auto passenger. If the measure is specified as net employment density, the transit difference falls to only about 58 percent higher, while walk stays at about 18 percent and bike draws about even to auto. This result suggests that bicycle use actually seems to favor conditions more like those for auto in terms of trip end densities—population and employment—and much less than those seen for transit, and visibly less than those for walk.

Transit use is also associated with higher numbers of multifamily vs. single-family residences, which one would expect with higher population densities. Walk and bicycle also show higher numbers of multi-family dwelling units.

Retail employment at destinations is much higher for transit and walking trips, at 59 percent and 44 percent higher than auto modes, respectively. Service employment seems even more important for transit, about 112 percent greater, while less so for walking, or 26 percent. The relationship with Retail FAR is somewhere in between Retail and Service employment: less important than Retail or Service employment for transit, more important than service for Walk. For all variables, the density of retail and service employment seems less important for bicycle (less than auto modes).

Diversity

We note that the measures for Jobs + Population, Jobs + Population per gross acre, and Jobs + Population per net acre, all have about the same level of importance as factors in relation to auto. The values for these measures for transit trips are about twice as high as for auto, they are about 30 percent higher for walk, and are only very slightly higher for bicycle.

The measures of Jobs/Population Balance, Retail + Population Balance, LandMix, and JobMix provide very little differentiation across the modes—generally less than 10 percent. However, the count of the number of retail and food establishments does seem to matter, where it is 2.5 times higher for transit, and 27 percent higher for walk trips than auto. Bicycle trips are not visibly different in their values from auto.

None of the dissimilarity indices showed much difference, nor did the measure of entropy. This is disheartening in that these measures were some of the more challenging to compute.

Design

In terms of design, it appears that the street centerline density measure has little differentiating value, but number of intersections does show a relationship as a more complete measure of connectivity and route directness between travel origins and destinations. The best of these measures appears to be the Sum of Weighted Intersections, which gives full credit to the valued four-way intersections, but also acknowledges the importance of three way intersections (albeit at half value) in the inventory. The value of weighted intersections is about 32 percent higher for transit, and 18 percent each for walk and bicycle.

While we earlier classified distance to transit stops as a separate "D" in our directory of measures, included in the design group for this discussion are measures of the number of rail stations and number of unique bus stops within the ½ mile trip buffer. The number of rail stations is enormously important for transit trips, being five times greater than the value for auto driver, 22 percent higher for walk trips, and about 10 percent higher for bicycle trips. Meanwhile, the density of bus stops is somewhat less important rail stations for transit trips, but is almost three times more important for walk trips. An important reason for this may be the relatively small proportion of the Los Angeles region that is currently served by rail transit, whereas bus service is fairly ubiquitous.

Destinations (Regional Accessibility)

The final set of built environment measures deals with access to regional activity, which we have defined in terms of population that is in proximity of the attraction trip ends. These are summarized in table 13. Basically, the measures attempt to depict how much of the region's population, measured in absolute or relative (proportion) terms, lies within 45 minutes travel time of the given trip end. One measure simply sums up the total population in all TAZs within 45 minutes travel time by the designated mode (auto or transit). The other measure is a gravity-type calculation, and more realistically "discounts" the impact of that population in relation to how far away it is from the subject trip end.

The measures that seem to do the best job of differentiating modes are the gravity-based measures using transit as the travel mode (Pop within 45 min Transit, walk access—gravity). Table 12 shows that the number of people (or proportion of the region's population) so reachable is about 87 percent higher for transit than auto driver, about 27 percent higher for walk trips, and about 11 percent higher for bicycle trips. The non-gravity measure of transit accessibility produces differences of only 56, 13, and 3 percent respectively, and the measures for auto travel—gravity are 58, 19, and 8 percent, respectively.

Table 13: Differences in Regional Accessibility across Modes (all trips)

	Auto Driver	Auto Passenger	Transit	Walk	Bike	All Modes
Pop within 45 min Transit (walk access) — gravity	125,901	127,903	235,525	159,464	139,905	133,117
Prop pop within 45 min Transit (walk access) — gravity	0.00715	0.00727	0.01338	0.00906	0.00795	0.00756
Pop within 45 min Transit (walk access) — not gravity	539,374	550,391	843,869	610,746	553,529	556,773
Prop pop within 45 min Transit (walk access) — not gravity	0.03064	0.03127	0.04794	0.03470	0.03145	0.03163
Pop within 45 min by Auto — gravity	361,846	353,855	571,612	428,856	391,587	372,493
Prop pop within 45 min by Auto — gravity	0.02056	0.02010	0.03248	0.02436	0.02225	0.02116
Pop within 45 min by Auto — not gravity	3,561,822	3,492,936	4,773,895	3,970,418	3,713,851	3,619,980
Prop pop within 45 min by Auto — not gravity	0.20236	0.19845	0.27122	0.22557	0.21100	0.20566

Sharpening Trip Purpose Definitions for Analysis

The set of trip purposes used to frame the initial examination of the data above was selected to be illustrative of some typical trip types that most people are familiar with. They obviously do not account for all the types of trips made, but with 35 different trip purposes used to classify trips in the SCAG/NHTS database, it would be difficult and impractical to examine each individual trip purpose. Hence, for the next round of analysis the population of trips was grouped into the more conventional categories of home-based work, home- based shopping, home-based other, home-based social and recreational, and non home-based that are used in transportation planning. The composition of these trip categories from the 35 trip purpose codes is explained below, with the respective purpose code indicated in brackets.

- Home-based work (HBW): includes going to work [11] or returning to work [12].

- Home-based shopping (HBS): includes shopping and errands [40], purchasing good [41], purchasing services [42], buying gasoline for auto use [43], meals [80], getting or eating a meal [82], or getting coffee or snacks [83].

- Home-based other (HBO): includes all other home-based activity that is not covered under work or shopping above, such as business trips or meetings [13], other work-related activities [14], going to school [21], school or religious activities [20], going to a religious activity [22], going to a library [23], after school or day care [24], medical or dental services [30], family business or obligations [60], using professional services [61], attending a wedding or funeral [62], using personal services [63], pet care [64], attending a civic meeting [65], transporting someone [70], picking up someone [71], taking and waiting for someone [72], dropping someone off [73], or other reason [97].

- Home-based social-recreational (HBSOCREC): includes social/recreational travel [50], going to a gym or playing sports [51], rest and relaxation or vacation [52], visiting friends and relatives [54], visiting a public place [55], or attending a social event [81].

- Non-home based (NHB): includes travel for any of the above purposes but without either end of the trip being at home. Note also that Return Home [1] is a trip purpose, but it is incorporated in each of the first four trip purpose categories.

Organized in this framework, the survey population of trips is distributed as shown in table 14. The table indicates that 10 percent of all trips are for home-based work, 22.7 percent for home-based other, 23.5 percent for home-based shopping, 15.6 percent for home-based social/recreational travel, and—the highest of all purpose categories—non-home based, which accounts for 28.2 percent of all travel.

In terms of mode, about two thirds (63.8%) of all trips are auto driver, about one-fifth (19.8%) by auto passenger, about one-eighth (12.3%) are by walking, and only 1.9 percent by transit and 1.1 percent by bicycle. Obviously, the modest sample sizes for transit and bicycle travel greatly constrain the types of quantitative analysis that can be performed with those modes, particularly for individual trip purposes such as HBSOCREC for transit where there are only 75 transit trips, or essentially any of the bicycle trips by purpose. Another observation from this table is that the percentage of walk and bicycle trips that are for social and recreational purposes is fairly high—34.8 percent and 50.1 percent, respectively—which are trips that may be substantially for exercise and not for visiting or predominately social purposes. This constrains the fairly important investigation of the extent to which built environment encourages use of non-motorized modes to perform utilitarian travel, which would be valuable in displacing the amount of daily auto travel which is made to accomplish these fundamental travel needs.

Table 14: Distribution of Trips by Mode and General Purpose

General Purpose		Auto Driver	Auto Pass	Transit	Walk	Bike	Other	Total
HBW	Count	4604	178	180	95	53	74	5184
	% of HBW	88.8%	3.4%	3.5%	1.8%	1.0%	1.4%	100.0%
	% by Mode	14.0%	1.7%	18.2%	1.5%	9.5%	13.0%	10.0%
HBO	Count	6862	2772	258	1684	70	74	11720
	% of HBO	58.5%	23.7%	2.2%	14.4%	0.6%	0.6%	100.0%
	% by Mode	20.8%	27.0%	26.1%	26.5%	12.6%	13.0%	22.7%
HBSHOP	Count	8229	2701	187	899	75	81	12172
	% of HBSHOP	67.6%	22.2%	1.5%	7.4%	0.6%	0.7%	100.0%
	% by Mode	24.9%	26.3%	18.9%	14.2%	13.5%	14.2%	23.5%
HBSOCREC	Count	3519	1866	75	2211	278	115	8064
	% of HBSOCREC	43.6%	23.1%	0.9%	27.4%	3.4%	1.4%	100.0%
	% by Mode	10.7%	18.2%	7.6%	34.8%	50.1%	20.2%	15.6%
NHB	Count	9774	2738	287	1461	79	225	14564
	% of NHB	67.1%	18.8%	2.0%	10.0%	0.5%	1.5%	100.0%
	% by Mode	29.6%	26.7%	29.1%	23.0%	14.2%	39.5%	28.2%
Total	Count	32988	10255	987	6350	555	569	51704
	% of ALL	63.8%	19.8%	1.9%	12.3%	1.1%	1.1%	100.0%
	% by Mode	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Multivariate Analysis

While the pair-wise analyses above provide some interesting preliminary insights into the role and importance of particular built environment variables at trip attractions, such an analysis is limited in not accounting for the interdependence of the many factors that influence the observed travel decisions. For example, we notice that transit users in the SCAG/Los Angeles trip database are quite different in terms of income, household structure, and other sociodemographic characteristics that are known to be important in travel decision making. Thus the only way to begin to isolate the effects of the built environment factors from background forces, as well as from each other, is through multivariate statistical analysis.

There are several statistical constructs through which this can be approached. A best-practice approach would be to attempt to model the probability that a traveler will select a given mode for a given trip purpose using sociodemographic (SED) information on the traveler and household, the modal alternatives available for the trip and their comparative levels of service (travel time and cost), plus the characteristics of the built environment at both origin and destination of the selected trip. This is an approach usually performed using logit or probit type probabilistic mode choice models, and is not uncommon for metropolitan planning organizations like SCAG, except for the addition of the detailed built environment measures at production and attraction ends of the trip. The current research effort did not have sufficient data resources to perform this type of modeling, although SCAG intends to pursue this approach with its in-house staff in the next few months building up on the database and findings resulting from this study.

While the best-practice mode choice approach described above would likely be enlightening and a major enhancement to existing modeling tools at SCAG and elsewhere, it unfortunately still leaves some very important planning and policy questions unanswered. Among these is the essential question of the extent to which land use at the attraction end has a major role in deciding trip destination choice. The goal for VMT and congestion reduction would be that constructing a greater number of compact, mixed use places would draw more trips from nearby residents, resulting in shorter trips and a greater number made by walking or biking. In this scenario, even long trips might be mitigated if the destination areas were designed such that travelers would be willing to forego driving to reach the area since they would not need a car once there. To address this set of behavioral relationships requires a more advanced statistical framework, such as point-based activity or tour-based modeling, in which these tradeoffs can be more freely modeled.

The approach we have opted to use here is much simpler than these two methods, but still has resulted in some enlightening findings with regard to the role of key built environment variables in relation to travel decision-making. Tables 15 through 20 show the results of some basic multiple regression analysis, in which we attempt to trace the relative importance of the prepared set of built environment variables in choice of mode, both for overall travel and for trips by basic HBW, HBO, HBSHOP, HBSOCREC, HBW and NHB purpose. The dependent variable in these equations is choice of the given mode, using a 0 or 1 convention to denote whether the given mode was selected. So in effect all of the trips for that trip type (purpose) regardless of mode are included in the estimation process for each mode, with the variables in the equation attempting to explain why the subject mode was chosen.

Each equation includes an array of sociodemographic variables, to help control for the relative importance of sociodemographic characteristics in influencing not only the choice of mode, but in how much of the choice is shared between the SED and the environmental (BE) variables. We have also chosen to include the same set of explanatory variables in all of the models. One would not take this approach if the goal were to isolate the most important variables and build the best equation for each case. However, in this exercise, we believe it is more revealing to keep the set of variables constant across our tests and let the estimation process reveal which variables are important (statistically significant) and which are not.

It should be noted that the particular variables in the models are the result of a considerable trial and error process in which many combinations of variables were tested before this particular set was selected as being most universally representative. This is particularly the case with the built environment variables, which is where most of the experimentation occurred. The variables shown in the table 15-20 equations were generally the most uniformly significant, well-behaved (reasonable magnitude, correct sign, no obvious conflict with other variables).

Each of the tables shows the models that were estimated for the given mode and the designated purpose. The estimated coefficient values, Beta, are shown in three color shades to denote their statistical importance. Estimates that appear in boldface are highly significant (probability is less than 1% that the estimate is not greater than zero), regular type for significant (probability of 10%), and in gray type for estimates that are not statistically significant. The R-squared value for the equation is shown at the bottom, along with the respective degrees of freedom.

The R-squared values in most of these equations are not very high, particularly those for transit and bicycle, which also have very modest sample sizes. High R-squared values are not expected for this type of data and modeling construct. However, the coefficient estimates can still be taken as a reasonable guide to their importance in relation to the choice, and the level of significance displayed in the value of the *t* statistic is an indication of the strength of the particular relationship.

Auto Driver Models

The models for auto driver in table 15 show fairly strong evidence that built environment characteristics that tend toward more urban conditions—higher density, mixed use, connected street grid, good transit service and accessibility—act to discourage auto driver trips.

The model for trips of all purposes is first used to profile the salient sociodemographic characteristics of auto drivers, which fit readily with the earlier indications that auto drivers are more likely to be male and employed, live in a single-family home that they own or are buying, and have children under age 16 living at home; the likelihood of driving also increases with the number of vehicles available per licensed driver. Race is not a distinguishing factor, nor is income, although correlation with the vehicle ownership variable (often used as an income surrogate in travel models) may be responsible for the negative sign on the income coefficient. Persons aged 65 and older are more likely to be auto drivers.

These sociodemographic relationships don't seem to change much across the trip purposes. Male gender remains significant in all models except HBW, as does employment status, vehicle ownership levels, and being a single-family home owner with children under 16.

In terms of trip characteristics, trip distance is only significant for HBO and HBSOCREC trips, where distance is positively linked to auto choice, and NHB, where longer distances make the person less likely to drive. In all trip purposes, having to carry passengers decreases the likelihood of driving alone, which shows up in the negative coefficient.

Looking at the built environment variables, we find that higher levels of both population and employment density have a discouraging (negative) effect on the decision to drive, although the relationships are not significant for most purposes and for the all purpose model. Jobs-Population Balance, a measure of mix and diversity, is also negative and significant overall and for Shop and HBW purposes. Number of weighted intersections, the design variable, has an important negative relationship in four of the models. Number of transit stops (rail and bus) has an expected negative relationship with driving, but only number of bus stops is significant in the all purposes model. Finally, regional transit accessibility has an expected negative sign and is significant in the all-purposes model, and in the HBO, HBW and NHB models.

Auto Passenger Models

The models for auto passenger in table 16 are similar to those for auto driver in relation to the built environment, but differ in predictable ways in terms of sociodemographic characteristics. Auto passengers are much more likely to be female, non-drivers, children under age 16, and less likely to be a worker. Curiously, if the subject is not themselves under age 16, the auto passenger is less likely to come from a household with children under 16 in its composition. Like auto drivers, auto passengers are likely to live in single family homes which they own or are buying. An interesting difference with the auto driver model is that household income matters in the auto passenger choice, with the likelihood of a passenger increasing with level of income; presumably this means that they are more likely to be a passenger than travel by transit, walk or bicycle. Not surprisingly, the likelihood of being an auto passenger increases if the person is not a driver, and as the demand on household vehicles increases (vehicles per driver ratio). These characteristics as seen in the model for all purposes of travel remain consistent across the different purposes of travel.

In relation to characteristics of the trip itself, the likelihood of making a trip as an auto passenger increases with the length of the trip, with travel for home based work being the only exception having a negative relationship with distance. The likelihood of a trip being auto passenger also obviously increases in proportion to the number of people on the trip.

In terms of built environment characteristics, the general view is that these characteristics do not seem to have a great deal of importance to people making auto passenger trips, which in itself is a finding—auto passenger trips are apparently made to places that are not easy to reach by a non-auto mode. Employment density does not have a significant role, and population density has a negative relationship where it is significant, meaning that auto passenger trips are more likely to go to attractions with lower population density levels. Diversity as reflected in the Job-Population Balance does not have a role, nor does density of transit stops or regional population accessibility via transit. The one measure that does seem to matter is intersection density, which has a negative relationship with auto passenger demand, again suggesting greater dependency on auto access in areas where walking is more difficult.

Transit User Models

The transit and non-motorized models show a major change in user profile and built environment impacts over auto driver and auto passenger, which begins to illustrate the major findings from the research.

Table 17 shows that the likelihood of making a trip by transit declines if the traveler is a licensed driver, is employed, is 65 or older, has higher income and more cars available per licensed driver, and lives in a single family home. Gender does not appear to different transit riders from other mode users, though there is some tendency for transit riders to be non-white. Transit riders are more likely to be renters.

In terms of trip characteristics, a person is seemingly more likely to take a trip by transit as the trip distance becomes longer, although the comparison in this decision may be in relation to walking or bicycling as opposed to traveling by auto. The likelihood of using transit decreases with the number of people along on the trip.

In terms of built environment measures, regional accessibility by transit, number of bus stops and number of rail stations both show a fairly strong positive relationship, especially when considering trips of all purposes. Intersection density does not appear as significant, which is surprising since one would expect higher intersection density to correspond to greater walkability, and hence access to transit. Also surprisingly, employment density does not appear significant, which would be expected to be a major factor in attracting transit trips, and particularly for home based work (HBW) travel. Population density does have a positive relationship, but only for total trips and HBO travel.

Our initial review of these results for transit suggests that one of two things may be impacting the less-than-robust findings with respect to built environment: (1) the overall share of persons traveling by transit in the Los Angeles region is small, and this is reflected in the small sample size in SCAG survey database; and (2) transit users in the Los Angeles region appear to be of more limited economic means, and therefore are making mode decisions based more on need than objective choice.

Pedestrian Models

The pedestrian models in table 18 show perhaps the strongest association with built environment variables. Some of this result may be attributable to a much larger sample size than transit or bicycle, and also a greater diversity of persons walking and the environment in which they travel.

Similar to the transit user, the person making a trip by walking is less likely to have a driver's license, be employed, reside in a single family home, or be over age 65. Persons making walk trips also have fewer vehicles per licensed driver, though it is not clear whether this is a reflection of lower incomes or simply a decision based on a reduced need for vehicles. Income is not a significant factor for overall travel, although it appears that fewer trips for HBO, HBShop and HBSOCREC are made by walking with higher household incomes. It is perhaps surprising to see a negative sign on the coefficient for trip makers under age 16, since some of the highest walk and bicycle trip rates come from this demographic group that does not have a driver's license.

Distance-wise, it is no surprise that the likelihood of walking declines with longer trip distances, and also with the number of persons in the travel party.

In terms of built environment variables, walking increases with higher levels of both population and employment density, with greater Jobs-Population Balance, with higher intersection densities, and with higher levels of regional transit accessibility. Number of rail transit stations or bus stops did not produce a significant result in the walk models, and were removed when their inclusion had unexplainable pervasive effects on other core variables.

Bicycle Travel Models

The bicycle models shown in table 19 appear to be the most challenged of all modes because of the small sample size. And as with transit, it is hard to tell whether the sample has adequate distribution across bicycle user situations that it is not inherently biased to particular demographics and trip types. For example, the models show a fairly strong and consistent relationship between male gender, white race, and young age (under 16) in characterizing the bicycle rider—which is similar to experience nationally wherein young fitness-minded males dominate the bicycle population, and also bike extensively for recreational and exercise purposes.

Bicycle riders are also seen to less often have a driver's license, have limits on vehicles available per licensed driver (although incomes are not significantly lower than other mode users). Bicycle travel propensity declines somewhat with trip distance (though at about the same rate as walking), and also with greater numbers of people on the trip.

In terms of built environment measures, bicycle use shows an expected increase with respect to weighted intersections and regional accessibility (note that the auto based measure was used for bicycle because it seemed to better address bicycle's need also for street and road capacity). However, the less obvious result is that higher population and employment densities do not appear to have a positive effect on bicycle travel propensity; similar findings were found in earlier research, and may be related to cyclists' aversion to vehicle traffic, which is greater in higher density locations. The significance of this relationship varies across trip purposes, however, and it is hard to proclaim it a universal finding.

Auto Trip Length Models

The final model in the series explores the relationship between auto trip length and conditions at destinations. The policy question investigated by this analysis is in whether land use at trip destinations has an impact on how far people will drive, and hence the vehicle miles (VMT) they will generate. Of course, there are multiple factors that may influence this decision: for example, people making very long trips may have no alternative but to drive if their destination is fixed, say in the case of commuters who live in rural locations and travel to a center city work place.

Table 20 shows the results of this analysis, which examines only trips made by auto drivers. Hence, the variables in the model structure exclude those factors that are directly tied to the outcome, such as having a driver's license, being over 16, and of course trip distance. The model for all trips shows that in fact auto driver trip distance increases with greater population and employment densities, which may be explained by the earlier reason that the most captive drivers may be those with the most remote locations and few alternatives. The Los Angeles region covers such a large land area and supports such far-flung travel that this outcome would not be unreasonable. It does raise the question, however, about the wisdom of advocating for higher-density development if the effect were to increase average auto trip length. To correctly address this issue it would be necessary to perform a more focused analysis on VMT in relation to total daily person and household travel to ascertain whether savings are occurring elsewhere in the daily travel inventory.

The model of all trips does show that auto trip length decreases for trips to places with better Jobs-Population Balance and higher intersection densities. However, another puzzling result is the negative effect of better transit service as reflected in number of bus stops, rail stations, and regional transit accessibility. It is noted, though, that the coefficient estimates for these transit related variables are not heavily significant, if at all.

Some initial analyses of the data have also been conducted by SCAG, with the essential difference in approach being to break down the choice of mode to different markets in terms of trip length. The trip data were partitioned into trips of ¼ mile or less, between ¼ and 1 mile, and those of over 1 mile. While these results are preliminary, they tend to show a sharpening of relationships for non-motorized trips in the 0.25 mile and 0.25 to 1 mile trip length categories, and a strengthening of the auto and transit relationships for trips over 1 mile, as might be expected. These models also tested different definitions of some of the built environment variable, and different statistical estimating techniques (logit vs. linear regression). More is expected from this analysis when SCAG staff are able to devote time to pursue additional and more sophisticated modeling constructs, such as those described earlier.

Discussion of Results

Two additional graphics are provided to help summarize the overall findings from the modeling investigations. Table 21 provides a simple summary of which variables were found to be important in each model (all purposes combined only), reducing the detail in tables 7 through 12 to a system of plus (+) and minus (-) signs to indicate whether the particular variable had a increasing or decreasing effect on the respective travel outcome (mode choice or trip length). As noted, a "double" plus or minus notation indicates that the coefficient was significant at the 1% level, while a single plus or minus indicates significance at the 10% level. The absence of notation indicates that a significant relationship was not found for that particular variable/mode combination.

The bottom of table 21 is shaded to draw focus to the built environment measures. The notation shows a fairly clear pattern in the relationships between mode choice and built environment. Each of those measures—when increased as would occur in conjunction with urbanization—results in a decline in auto driver and auto passenger activity, and an increase in transit, walk and bicycle activity. The major exception, as noted, is the negative relationship of higher densities on bicycle use.

Table 15: Trips Made as Auto Driver

	All		HBO		HBShop		HBSREC		HBW		NHB	
	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*
(Constant)	6.36E-02	3.885	-7.67E-02	-2.363	0.22	7.031	-0.202	-3.975	0.129	2.016	0.133	4.173
Gender is male	**5.85E-02**	12.775	**4.99E-02**	5.087	**9.16E-02**	10.419	**0.105**	7.345	-1.00E-02	-1.057	**5.80E-02**	7.005
Race is white	-8.86E-03	-1.678	-2.76E-02	-2.524	3.87E-03	0.374	-8.38E-03	-0.492	-3.75E-03	-0.359	6.52E-03	0.676
Driver status of S	**0.674**	63.147	**0.714**	38.405	**0.647**	33.742	**0.515**	16.366	**0.773**	18.116	**0.703**	30.582
Respondent age is less than 16	**-0.126**	-5.42	**-0.183**	-5.059	**-0.162**	-3.218	-6.96E-02	-1.113	0.131	0.789	-0.105	-2.115
Age is 65 or older	**3.44E-02**	5.247	3.93E-02	2.828	**5.08E-02**	4.288	4.23E-02	2.149	2.68E-02	1.448	2.03E-02	1.707
Subject is worker	**7.18E-02**	13.513	**3.64E-02**	3.402	**5.77E-02**	5.77	2.03E-02	1.232	1.88E-02	0.463	**4.46E-02**	4.58
Ann HH Inc ($1000)	**-2.31E-04**	-3.556	-2.91E-05	-0.213	-3.21E-04	-2.544	2.23E-04	1.091	**5.94E-04**	4.521	**-4.35E-04**	-3.648
Vehicles per driver	**8.19E-02**	16.327	**0.11**	9.927	**4.82E-02**	5.372	**9.84E-02**	5.765	**6.22E-02**	5.751	**6.91E-02**	7.726
Subject is renter	**-4.81E-02**	-6.9	-1.73E-02	-1.212	**-8.28E-02**	-6.188	-3.59E-02	-1.581	**-3.79E-02**	-2.674	**-3.92E-02**	-3.068
Subject resides in detached SF home	1.63E-02	2.675	3.31E-02	2.517	1.91E-02	1.641	1.97E-02	1.024	**5.05E-02**	4.068	-1.09E-02	-0.983
HH with children under 16	**4.88E-02**	9.22	**8.76E-02**	7.903	**6.64E-02**	6.189	2.96E-02	1.69	6.05E-03	0.592	**2.92E-02**	3.079
Count of total people on trip	**-4.43E-02**	-19.633	-1.03E-02	-2.166	**-8.25E-02**	-18.959	4.21E-03	0.644	**-9.50E-02**	-9.526	**-5.16E-02**	-13.006
Calculated Trip Distance Converted into Miles	8.85E-05	1.266	**2.71E-03**	6.802	-2.58E-04	-0.655	**2.33E-03**	7.133	1.12E-04	0.478	**-2.14E-04**	-2.885
NET_POPDEN	-3.72E-06	-0.073	-1.44E-04	-1.238	-1.42E-04	-0.958	2.79E-04	1.35	8.38E-05	1.005	-5.84E-06	-0.075
NET_EMPDEN	-1.09E-04	-1.318	3.57E-04	2.087	-3.26E-04	-1.653	2.77E-04	1.137	-3.67E-04	-2.247	**-4.46E-04**	-3.195
JOB_POP_BAL	**-3.39E-02**	-3.751	-3.48E-03	-0.171	**-5.78E-02**	-3.228	-1.97E-02	-0.647	**-6.36E-02**	-3.628	2.80E-02	1.773
Sum of weighted intersections	**-4.95E-04**	-6.226	**-8.28E-04**	-4.825	**-5.24E-04**	-3.296	6.84E-05	0.268	1.28E-04	0.767	**-5.74E-04**	-4.186
NUM_RAIL_STA	-6.42E-04	-0.974	2.62E-03	1.59	-2.81E-04	-0.182	-1.08E-03	-0.344	**-2.50E-03**	-2.314	-1.49E-03	-1.533
NUM_BUS_STOP	**-7.59E-05**	-4.206	-3.57E-05	-0.72	-5.73E-06	-0.102	-9.03E-05	-1.422	-2.66E-05	-0.944	**-1.27E-04**	-4.602
GVWTR45P	**-1.388**	-3.025	**-3.372**	-3.51	-1.16	-1.258	-0.511	-0.334	-2.03	-2.254	-1.417	-1.733
R-Squared	0.199		0.274		0.260		0.112		0.182		0.188	
df	31948		6746		7806		4432		3680		9248	

Significance codes: **BOLD** = Statistically significant at 1% level
Normal = Statistically significant at 10% level
Grey = Not statistically significant

Table 16: Trips Made as Auto Passenger

	All		HBO		HBShop		HBSREC		HBW		NHB	
	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*
(Constant)	0.381	33.343	0.373	16.065	0.393	15.622	0.214	6.795	0.468	13.434	0.482	20.674
Gender is male	**-8.24E-02**	-25.76	**-5.50E-02**	-7.845	**-0.119**	-16.87	**-0.124**	-14.003	**-1.78E-02**	-3.434	**-8.08E-02**	-13.39
Race is white	-1.42E-03	-0.386	4.08E-03	0.522	3.35E-04	0.04	-1.24E-04	-0.012	-9.68E-03	-1.698	-6.76E-03	-0.961
Driver status of S	**-0.407**	-54.512	**-0.42**	-31.603	**-0.425**	-27.545	**-0.261**	-13.366	**-0.517**	-22.155	**-0.475**	-28.323
Respondent age is less than 16	**0.14**	8.62	**0.17**	6.541	**0.198**	4.897	**0.135**	3.486	-8.56E-02	-0.941	**0.121**	3.356
Age is 65 or older	**1.75E-02**	3.814	2.38E-02	2.387	4.11E-03	0.431	-7.49E-04	-0.061	1.74E-03	0.172	**2.80E-02**	3.231
Subject is worker	**-3.04E-02**	-8.201	-1.87E-02	-2.448	**-3.53E-02**	-4.377	**-4.72E-02**	-4.627	-2.50E-02	-1.124	**-4.25E-02**	-5.979
Ann HH Inc ($1000)	**4.81E-04**	10.579	**4.16E-04**	4.26	**7.82E-04**	7.711	**6.96E-04**	5.515	-6.21E-05	-0.866	**4.07E-04**	4.681
Vehicles per driver	**-1.98E-02**	-5.637	**-2.72E-02**	-3.434	-1.39E-02	-1.919	-2.34E-02	-2.209	**-1.89E-02**	-3.196	-1.76E-02	-2.702
Subject is renter	-8.02E-03	-1.649	-4.86E-03	-0.476	-2.40E-02	-2.225	8.98E-03	0.639	-7.40E-03	-0.954	-3.21E-03	-0.345
Subject resides in detached SF home	**1.23E-02**	2.877	1.61E-02	1.717	9.08E-03	0.971	1.77E-02	1.482	-1.05E-02	-1.545	1.48E-02	1.84
HH with children under 16	**-7.46E-02**	-20.2	**-0.11**	-13.856	**-9.42E-02**	-10.906	**-8.58E-02**	-7.904	-4.84E-03	-0.866	**-4.38E-02**	-6.334
Count of total people on trip	**0.13**	82.688	**0.124**	36.41	**0.145**	41.352	**0.15**	37.032	**0.146**	26.731	**0.109**	37.625
Calculated Trip Distance Converted into Miles	1.16E-04	2.371	**1.41E-03**	4.929	**1.49E-03**	4.704	**6.66E-04**	3.288	-3.20E-04	-2.5	-1.24E-05	-0.229
NET_POPDEN	-6.87E-05	-1.917	1.28E-04	1.545	4.06E-06	0.034	-1.90E-04	-1.481	-6.28E-05	-1.378	-1.47E-04	-2.582
NET_EMPDEN	-6.12E-05	-1.058	-7.28E-05	-0.594	-4.38E-05	-0.276	-6.21E-05	-0.412	1.10E-04	1.231	-1.50E-04	-1.473
JOB_POP_BAL	-6.58E-03	-1.044	-9.94E-04	-0.068	4.75E-03	0.329	-1.33E-04	-0.007	1.11E-02	1.16	-2.04E-02	-1.777
Sum of weighted intersections	**-2.18E-04**	-3.927	**-3.34E-04**	-2.719	-2.84E-04	-2.223	-7.64E-05	-0.484	-1.71E-04	-1.877	-8.17E-05	-0.816
NUM_RAIL_STA	2.66E-04	0.578	-1.33E-03	-1.127	2.17E-03	1.747	5.33E-04	0.275	1.10E-03	1.857	-1.28E-04	-0.181
NUM_BUS_STOP	7.29E-06	0.578	-4.37E-05	-1.232	-3.62E-05	-0.805	7.91E-05	2.013	1.51E-05	0.983	1.33E-05	0.662
GVWTR45P	-0.144	-0.448	0.481	0.7	6.09E-03	0.008	-0.113	-0.119	-0.397	-0.806	-0.267	-0.448
R-Squared	0.303		0.322		0.328		0.334		0.299		0.267	
df	31948		6746		7806		4432		3680		9248	

Significance codes: **BOLD** = Statistically significant at 1% level
Normal = Statistically significant at 10% level
Grey = Not statistically significant

Table 17: Trips Made as Transit Rider

	All		HBO		HBShop		HBSREC		HBW		NHB	
	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*
(Constant)	8.89E-02	17.756	0.126	11.254	6.64E-02	7.315	4.81E-02	5.143	6.35E-02	1.726	8.99E-02	9.273
Gender is male	7.97E-04	0.569	**1.18E-02**	3.492	-2.52E-03	-0.987	-1.60E-03	-0.608	-2.21E-03	-0.405	-3.20E-03	-1.276
Race is white	-3.55E-03	-2.199	-8.60E-03	-2.28	4.15E-03	1.384	1.47E-03	0.47	-1.47E-03	-0.245	-5.94E-03	-2.034
Driver status of S	**-2.05E-02**	-6.284	-1.54E-02	-2.398	**-2.22E-02**	-3.983	**-1.74E-02**	-3.016	4.86E-02	1.973	**-3.95E-02**	-5.671
Respondent age is less than 16	-2.31E-03	-0.326	**4.49E-02**	3.582	-3.38E-02	-2.312	**-2.91E-02**	-2.539	-1.50E-02	-0.156	**-4.85E-02**	-3.226
Age is 65 or older	**-6.95E-03**	-3.469	**-2.08E-02**	-4.325	1.98E-03	0.576	-7.06E-03	-1.954	-6.31E-03	-0.592	-5.05E-03	-1.403
Subject is worker	**-5.36E-03**	-3.3	**-1.13E-02**	-3.051	**-9.46E-03**	-3.258	-8.95E-03	-2.96	2.01E-02	0.857	-4.36E-03	-1.476
Ann HH Inc ($1000)	**-1.65E-04**	-8.272	**-2.11E-04**	-4.464	**-1.35E-04**	-3.699	**-1.18E-04**	-3.165	**-3.90E-04**	-5.152	-8.39E-05	-2.32
Vehicles per driver	**-3.03E-02**	-19.786	**-4.65E-02**	-12.167	**-2.58E-02**	-9.931	**-9.75E-03**	-3.114	**-5.77E-02**	-9.244	**-2.20E-02**	-8.111
Subject is renter	**2.08E-02**	9.749	**1.89E-02**	3.831	**2.48E-02**	6.373	1.01E-02	2.433	**3.13E-02**	3.825	**1.87E-02**	4.831
Subject resides in detached SF home	**-5.44E-03**	-2.914	-1.72E-03	-0.379	-2.97E-03	-0.882	-3.10E-03	-0.879	**-2.55E-02**	-3.565	-3.77E-03	-1.126
HH with children under 16	-5.51E-04	-0.341	**-1.38E-02**	-3.61	**9.64E-03**	3.093	3.56E-04	0.111	5.96E-03	1.011	-1.60E-03	-0.555
Count of total people on trip	**-4.13E-03**	-5.982	**-9.99E-03**	-6.097	-2.29E-03	-1.812	-1.04E-03	-0.865	**-1.66E-02**	-2.883	1.46E-04	0.122
Calculated Trip Distance Converted into Miles	4.28E-05	2.002	1.31E-04	0.954	2.53E-04	2.206	-1.30E-06	-0.022	7.79E-05	0.576	2.27E-05	1.012
NET_POPDEN	**4.69E-05**	2.992	**1.23E-04**	3.061	-2.79E-05	-0.647	1.30E-05	0.342	-2.71E-05	-0.563	4.05E-05	1.71
NET_EMPDEN	-2.23E-05	-0.88	-8.39E-05	-1.419	-6.22E-05	-1.086	3.49E-05	0.781	-1.65E-05	-0.175	-5.96E-06	-0.141
JOB_POP_BAL	-3.30E-03	-1.197	**-1.49E-02**	-2.121	1.44E-03	0.277	4.21E-03	0.753	3.94E-03	0.39	-1.89E-03	-0.395
Sum of weighted intersections	-3.54E-05	-1.456	-2.45E-05	-0.413	-1.03E-05	-0.224	-3.69E-05	-0.789	9.75E-05	1.015	-8.24E-05	-1.981
NUM_RAIL_STA	**1.15E-03**	5.699	-7.05E-04	-1.241	1.68E-04	0.375	-1.65E-04	-0.287	1.00E-03	1.614	**2.43E-03**	8.257
NUM_BUS_STOP	**2.99E-05**	5.409	3.65E-05	2.133	**5.65E-05**	3.483	1.49E-05	1.279	3.47E-05	2.137	**2.62E-05**	3.147
GVWTR45P	**0.737**	5.251	**1.125**	3.39	0.586	2.19	0.19	0.677	**1.68**	3.235	0.436	1.762
R-Squared	0.053		0.183		0.053		0.023		0.093		0.055	
df	31948		6746		7806		4432		3680		9248	

Significance codes: **BOLD =** Statistically significant at 1% level
Normal = Statistically significant at 10% level
Grey = Not statistically significant

Table 18: Trips Made by Walking

	All		HBO		HBShop		HBSREC		HBW		NHB	
	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*
(Constant)	0.425	34.393	0.534	20.826	0.281	14.134	0.83	18.524	0.288	9.592	0.276	12.237
Gender is male	3.69E-03	1.065	-1.16E-02	-1.486	**1.57E-02**	2.786	-2.16E-02	-1.712	1.01E-03	0.225	1.03E-02	1.755
Race is white	5.21E-03	1.304	**3.11E-02**	3.598	**-1.34E-02**	-2.025	-4.91E-04	-0.033	-1.14E-02	-2.325	-4.75E-03	-0.697
Driver status of S	**-0.217**	-26.868	**-0.257**	-17.47	**-0.174**	-14.165	**-0.197**	-7.087	**-0.241**	-11.982	**-0.158**	-9.743
Respondent age is less than 16	**-7.33E-02**	-4.178	**-8.56E-02**	-2.979	-4.28E-02	-1.331	**-0.2**	-3.637	-8.64E-03	-0.11	2.53E-02	0.722
Age is 65 or older	**-3.30E-02**	-6.663	**-3.91E-02**	-3.548	**-4.11E-02**	-5.434	-1.85E-02	-1.07	-3.04E-03	-0.348	**-3.42E-02**	-4.071
Subject is worker	**-3.56E-02**	-8.867	-5.36E-03	-0.633	-1.12E-02	-1.745	2.47E-02	1.703	6.20E-04	0.032	-8.69E-05	-0.013
Ann HH Inc ($1000)	-2.51E-05	-0.51	-2.15E-04	-1.989	**-2.71E-04**	-3.368	**-4.86E-04**	-2.705	8.87E-06	0.143	1.33E-04	1.581
Vehicles per driver	**-3.68E-02**	-9.696	**-4.19E-02**	-4.781	-1.01E-02	-1.764	**-6.28E-02**	-4.181	-1.10E-02	-2.159	**-3.66E-02**	-5.802
Subject is renter	**2.98E-02**	5.655	7.35E-03	0.651	**7.76E-02**	9.075	1.30E-02	0.649	5.89E-03	0.881	1.22E-02	1.355
Subject resides in detached SF home	**-2.72E-02**	-5.899	**-4.10E-02**	-3.939	**-2.83E-02**	-3.821	**-5.26E-02**	-3.109	-3.36E-03	-0.574	-1.24E-02	-1.588
HH with children under 16	**2.37E-02**	5.934	**3.64E-02**	4.14	1.78E-02	2.592	**4.99E-02**	3.232	-9.89E-03	-2.053	1.08E-02	1.603
Count of total people on trip	**-7.09E-02**	-41.5	**-9.56E-02**	-25.42	**-5.17E-02**	-18.586	**-0.132**	-22.889	**-1.94E-02**	-4.125	**-4.94E-02**	-17.641
Calculated Trip Distance Converted into Miles	**-6.15E-04**	-11.623	**-4.31E-03**	-13.683	**-1.39E-03**	-5.511	**-2.94E-03**	-10.186	**-4.60E-04**	-4.169	**-2.14E-04**	-4.08
NET_POPDEN	6.28E-05	2.378	-6.59E-05	-1.056	6.91E-05	0.96	-2.03E-04	-1.356	-1.27E-05	-0.506	**2.37E-04**	6.403
NET_EMPDEN	**3.30E-04**	5.695	-1.21E-04	-0.933	**5.06E-04**	4.272	1.18E-05	0.058	**1.84E-04**	2.768	**7.99E-04**	8.88
JOB_POP_BAL	**4.61E-02**	6.804	2.68E-02	1.688	**5.11E-02**	4.493	5.95E-02	2.237	**3.63E-02**	4.42	-9.68E-03	-0.876
Sum of weighted intersections	**6.47E-04**	10.783	**1.14E-03**	8.466	**7.56E-04**	7.495	-1.70E-04	-0.76	-1.26E-04	-1.609	**6.41E-04**	6.633
GVWTR45P	**1.049**	3.043	**2.244**	2.996	0.483	0.824	0.342	0.257	0.323	0.764	**1.932**	3.373
R-Squared	0.100		0.183		0.143		0.169		0.062		0.106	
df	31948		6746		7806		4432		3680		9248	

Significance codes:

BOLD = Statistically significant at 1% level

Normal = Statistically significant at 10% level

Grey = Not statistically significant

Table 19: Trips Made by Bicycle

	All		HBO		HBShop		HBSREC		HBW		NHB	
	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*
(Constant)	3.55E-02	10.907	2.88E-02	5.672	2.60E-02	5.625	7.20E-02	4.808	5.70E-02	3.061	1.86E-02	4.196
Gender is male	**1.05E-02**	11.269	**5.55E-03**	3.456	**4.09E-03**	3.08	**3.42E-02**	7.775	**1.06E-02**	3.812	**4.52E-03**	3.868
Race is white	**3.93E-03**	3.516	3.84E-04	0.208	7.82E-05	0.048	1.16E-02	2.133	**1.15E-02**	3.66	2.45E-03	1.743
Driver status of S	**-2.38E-02**	-10.665	**-1.45E-02**	-4.576	**-1.57E-02**	-5.121	**-4.51E-02**	-4.639	**-5.77E-02**	-4.912	**-1.61E-02**	-4.92
Respondent age is less than 16	**2.86E-02**	6.174	**2.50E-02**	4.348	**3.94E-02**	5.147	3.29E-02	1.651	1.58E-04	0.003	**2.76E-02**	4.111
Age is 65 or older	**-6.97E-03**	-5.217	-3.44E-03	-1.496	**-6.55E-03**	-3.695	**-1.56E-02**	-2.579	-1.07E-02	-1.942	-3.02E-03	-1.805
Subject is worker	4.26E-04	0.395	-3.03E-03	-1.735	1.81E-03	1.2	1.14E-02	2.256	3.46E-03	0.274	2.61E-03	1.906
Ann HH Inc ($1000)	-2.15E-05	-1.642	3.58E-05	1.63	-3.09E-05	-1.656	**-2.09E-04**	-3.379	7.49E-06	0.196	-1.47E-05	-0.889
Vehicles per driver	**-4.01E-03**	-4.014	-2.59E-03	-1.504	**-4.79E-03**	-3.572	-4.74E-03	-0.94	-1.51E-03	-0.484	-2.33E-03	-1.887
Subject is renter	1.86E-03	1.263	-5.05E-03	-2.107	4.59E-03	2.174	4.05E-03	0.554	5.81E-03	1.35	8.39E-04	0.457
Subject resides in detached SF home	9.70E-04	0.761	-4.06E-03	-1.847	1.98E-03	1.11	1.07E-02	1.736	-7.46E-03	-1.999	2.79E-03	1.759
HH with children under 16	1.29E-03	1.193	1.68E-03	0.928	-2.19E-03	-1.341	**1.72E-02**	3.233	7.48E-04	0.253	-2.59E-03	-1.931
Count of total people on trip	**-5.95E-03**	-12.957	**-4.16E-03**	-5.437	**-3.76E-03**	-5.592	**-1.70E-02**	-8.5	-6.26E-03	-2.139	**-2.22E-03**	-3.984
Calculated Trip Distance Converted into Miles	-2.30E-05	-1.819	-1.37E-04	-2.206	-5.07E-05	-0.897	-8.54E-05	-0.807	**-1.90E-04**	-2.777	-3.56E-06	-0.4
GRS_POPDEN	**-1.89E-04**	-2.666	-5.83E-05	-0.49	-5.43E-05	-0.525	**-1.01E-03**	-2.581	-1.68E-04	-0.878	-5.53E-05	-0.652
GRS_EMPDEN	**-1.58E-04**	-4.253	-3.56E-05	-0.439	-1.23E-04	-1.537	-1.71E-04	-0.777	-1.35E-04	-1.755	-9.29E-05	-2.398
Sum of weighted intersections	**8.18E-05**	4.614	5.38E-05	1.777	6.01E-05	2.332	**2.89E-04**	3.261	4.97E-05	0.94	4.21E-05	1.988
GVAUT45P	**0.104**	2.148	-7.58E-02	-0.925	0.113	1.603	0.287	1.206	**0.342**	2.49	3.93E-02	0.667
R-Squared	0.014		0.016		0.017		0.035		0.018		0.010	
df	31948		6746		7806		4432		3680		9248	

Significance codes:

BOLD = Statistically significant at 1% level

Normal = Statistically significant at 10% level

Grey = Not statistically significant

Table 20: Auto Driver Trip Length

	All		HBO		HBShop		HBSREC		HBW		NHB	
	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*	Beta	*t*
Constant)	5.894	9.998	8.288	7.838	3.154	4.117	11.247	3.223	5.065	2.264	3.448	3.167
Gender is male	**2.167**	10.616	**1.997**	5.48	0.292	1.103	2.668	2.278	**3.147**	7.043	**2.57**	6.713
Race is white	-0.182	-0.77	0.201	0.494	0.195	0.62	-0.852	-0.616	-0.896	-1.802	0.181	0.402
Age is 65 or older	**-1.267**	-4.309	**-1.591**	-3.051	-0.47	-1.325	-0.776	-0.481	-1.325	-1.532	-1.212	-2.22
Subject is worker	**2.046**	8.564	**1.382**	3.529	0.303	1.002	1.217	0.904	2.514	1.337	**1.54**	3.435
Ann HH Inc ($1000)	-5.10E-04	-0.177	2.02E-03	0.401	8.36E-03	2.229	**-5.41E-02**	-3.306	**1.92E-02**	3.107	-2.30E-03	-0.419
Vehicles per driver	0.448	1.949	1.025	2.389	**0.926**	3.415	-0.764	-0.528	0.516	0.905	0.585	1.397
Subject is renter	-0.673	-2.121	-0.66	-1.219	-0.437	-1.039	-1.707	-0.915	-0.906	-1.344	-0.369	-0.613
Subject resides in detached SF home	**0.821**	2.984	0.378	0.757	0.238	0.668	1.371	0.876	0.958	1.628	1.144	2.228
HH with children under 16	**-0.964**	-4.078	**-2.705**	-6.541	**-0.9**	-2.751	-2.971	-2.057	0.979	2.01	-0.191	-0.434
Count of total people on trip	**0.333**	2.944	-0.12	-0.632	**0.861**	5.654	**2.543**	4.519	**2.897**	5.742	0.316	1.538
NET_POPDEN	**7.20E-03**	2.908	2.52E-03	0.569	6.41E-03	1.325	1.34E-02	0.913	8.95E-04	0.224	7.58E-03	1.634
NET_EMPDEN	**1.24E-02**	3.335	5.28E-04	0.086	-9.08E-03	-1.447	**6.22E-02**	3.532	1.23E-02	1.539	2.14E-03	0.314
JOB_POP_BAL	**-1.701**	-4.269	**-3.307**	-4.43	**-2.272**	-4.249	-0.463	-0.19	-1.447	-1.739	3.70E-02	0.051
Sum of weighted intersections	**-2.10E-02**	-5.721	**-2.28E-02**	-3.441	-6.98E-03	-1.414	-5.11E-02	-2.525	**-2.69E-02**	-3.388	-1.08E-02	-1.598
NUM_RAIL_STA	4.46E-02	1.44	1.83E-02	0.304	-1.32E-02	-0.274	3.37E-02	0.135	**0.161**	2.929	2.67E-02	0.516
NUM_BUS_STOP	1.64E-03	1.891	**9.61E-03**	5.412	8.08E-04	0.469	1.41E-03	0.303	4.88E-04	0.357	9.93E-04	0.606
GVWTR45P	8.564	0.411	31.997	0.875	-20.364	-0.719	-2.33	-0.019	16.35	0.375	-1.076	-0.028
R-Squared	0.022		0.053		0.018		0.027		0.053		0.016	
df	22996		4727		5717		2261		3289		6983	

Significance codes: **BOLD** = Statistically significant at 1% level
Normal = Statistically significant at 10% level
Grey = Not statistically significant

Table 21: Relative Importance and Directionality of Socio-Demographic and Built Environment Factors

	Auto Driver	Auto Passenger	Transit	Walk	Bicycle	Auto Trip Length
Gender is male	+ +	- -			+ +	+ +
Race is white			-		+ +	
Licensed driver	+ +	- -	- -	- -	- -	NA
Age is less than 16	- -	+ +		- -	+ +	NA
Age is 65 or older	+ +	+ +	- -	- -	- -	- -
Subject is worker	+ +	- -	- -	- -		+ +
Ann HH Inc ($1000)	- -	+ +	- -		-	
Vehicles per driver	+ +	- -	- -	- -	- -	+ +
Subject is renter	- -	-	+ +	+ +		-
Resid is detached SF home	+	+ +	- -	- -		+ +
HH with children under 16	+ +	- -		+ +		- -
Count of total people on trip	- -	+ +	- -	- -	- -	+ +
Trip Distance		+	+	- -	-	NA
NET_POPDEN		-	+ +	+	- -	+ +
NET_EMPDEN				+ +	- -	+ +
JOB_POP_BAL	- -			+ +		- -
Sum of weighted intersections	- -	- -		+ +	+ +	- -
NUM_RAIL_STA			+ +			
NUM_BUS_STOP	- -		+ +			+
GVWTR45P	- -		+ +	+ +	+ +*	

+ + Increasing effect on mode use, significant at 1% level
+ Increasing effect on mode use, significant at 10% level
- - Decreasing effect on mode use, significant at 1% level
- Decreasing effect on mode use, significant at 10% level

* Used auto rather than transit based accessibility measure to obtain significant relationship

NA = Not applicable in this model

Also, as earlier stated, the relationship of built environment with auto trip distance is unclear: higher densities and transit service/access seem to lead to an increase in auto trip length, while diversity (Jobs-Population Balance) and intersection density tend to reduce auto trip length. This relationship requires further analysis with different analysis methods.

Table 22 adds to this assessment by providing elasticity estimates for each of the significant variables. Again, the bottom portion of the table is shaded to draw focus on the built environment variables. The elasticities in table 22 have been computed at the mean of each respective independent variable, and represent the percent change in demand for the given mode (or miles of trip length) that would be expected in response to a 1 percent change in the respective independent variable.

Table 22: Elasticities Expressing Relationship between Travel and Characteristics of Traveler and Built-Environment at Trip Attractors

Independent Variable	Auto Driver	Auto Passenger	Transit	Walk	Bicycle	Driver Trip Length
Gender is male	0.0392	-0.2254			1.5569	0.1358
Race is white			-0.1654		0.8851	
Driver's license	0.9107	-2.2448	-1.2643	-2.0418	-7.1039	
Age is under 16	-0.0191	0.0868		-0.0775	0.9601	
Age is 65 or older	0.0103	0.0213	-0.0948	-0.0688	-0.4597	-0.0354
Subject is worker	0.0541	-0.0937	-0.1844	-0.1872		0.1443
Ann HH Inc ($1000)	-0.0253	0.2144	-0.8203		-0.5180	
Vehicles per driver	0.1345	-0.1324	-2.2730	-0.4207	-1.4524	0.0688
Subject is renter	-0.0138	-0.0094	0.2725	0.0597		-0.0181
Residence is detached SF home	0.0181	0.0554	-0.2745	-0.2097		0.0850
HH with children under 16	0.0294	-0.1838		0.0998		-0.0544
Count of total people on trip	-0.1151	1.3782	-0.4890	-1.2816	-3.4109	0.0809
Trip Distance		0.0054	0.0222	-0.0486	-0.0577	
NET_POPDEN		-0.0148	0.1129	0.0231	-2.1950	0.0355
NET_EMPDEN				0.0967	-1.4678	0.0490
JOB_POP_BAL	-0.0268			0.2537		-0.1256
Sum of weighted intersections	-0.0418	-0.0752		0.3807	1.5262	-0.1655
NUM_RAIL_STA			0.0336			
NUM_BUS_STOP	-0.0086		0.1534			0.0173
GVWTR45P	-0.0153		0.3717	0.0807	0.7095*	

* Used auto rather than transit based accessibility for bicycle mode to arrive at more meaningful overall model

In review of the elasticities, it can be seen that many of the elasticities for the sociodemographic characteristics of the traveler (listed in the top of the table) are greater in magnitude than the built environment measures at the travel destination. This is very consistent with other research, and the implications are discussed in greater detail below. For the built environment variables, the elasticities vary in level of importance across the modes. In general, the largest elasticities are those associated with transit, walk and bicycle trip making. The most influential relationships appear to be:

- the effect of population density, bus stop density, and regional transit accessibility for transit trips;

- jobs-population balance and sum of weighted intersections for walk trips; and

- population and employment density, and intersection density for bicycle trips—although the population and employment density relationship is negative as earlier discussed.

Interestingly, the elasticities for any of the built environment variables with auto driver or auto passenger have the right sign are significant statistically, but very small in magnitude, suggesting that they don't play a large role in the choice of those modes.

Since few if any studies have attempted to quantify the role of built environment effects on travel at the attraction end of trips, it is difficult to compare and validate our estimates directly against other efforts. However, we did examine the results from Ewing and Cervero's 2010 Travel and the Built Environment Meta Analysis, which is perhaps the most comprehensive and recent assessment effort on the effects of built environment.[vi] Ewing and Cervero compiled elasticity findings from more than 50 studies on the relationship between BE variables (corresponding to the earlier-defined 5D categories) and three travel outcomes—VMT, transit use and walking. All of the source studies in the meta-analysis are believed to reflect conditions only at residential trip productions, so they are not perfectly comparable to the present study of trip attractions. Interestingly, as shown in table 23 below, some interesting commonality was discovered.

- In relation to VMT, for which our proxy is driver trip length, we note some interesting similarities and some peculiar differences. For both studies, jobs-housing balance and intersection density have the effect of discouraging VMT/vehicle trip length. However, the attraction- focused modeling of our study produces elasticities that suggest that trip length increases with attraction density (residential or employment) and with improved access to transit. This suggests that persons who must travel long distances to places with high densities and who do not have access to alternative modes are relegated to driving. In contrast, those who have alternatives such as transit or carpool are more likely to shift to those modes, leaving only the longest driving trips without a mitigation option.

- The fact that transit availability is seemingly correlated with higher automobile trip lengths is not unusual. Other studies have also shown that, as shorter automobile trips are eliminated due to transit accessibility, the remaining auto trips are those with higher average trip lengths. The meta study independent variable is not average vehicle trip length. But total VMT, which is the product of number of vehicle trips generated and the length of trip, allows the reduction in auto trip-making (seen in the strong increases in transit trips and walking trips) to counteract the increase in average auto trip lengths.

- In general, effects of transit availability are dampened in LA region attraction centers when compared with the average found in other regions nationally, though still directly correlated with transit use for both bus and rail.

Table 23: Comparison of Elasticity Estimates: Trip Production-Based Effects versus Attraction-Based Effects

		VMT/Driver Trip Length [a]		Transit Use		Walking	
		Meta-Analysis (Production end)	Kuzmyak-Walters (Attraction end)	Meta-Analysis (Production end)	Kuzmyak-Walters (Attraction end)	Meta-Analysis (Production end)	Kuzmyak-Walters (Attraction end)
Density	Residential density	-0.04	+0.04	+0.07	+0.11	+0.07	+0.02
	Employment density	0.00	+0.05	+0.01	0.00	+0.04	+0.10
Diversity	Jobs-Housing balance	-0.02	-0.13			+0.19	+0.25
Design	Intersection density	-0.12	-0.17	+0.23	0.00	+0.39	+0.38
Destination Accessibility	Job accessibility by transit	-0.05	0.00			+0.15	+0.08
Distance to Transit	Distance to stop[b] vs. stop density	-0.05	+0.02	+0.29	+0.03 R +0.15 B	+0.15	0.00

Notes:

a. The meta-analysis examined the effect of built environment on VMT, while the Kuzmyak-Walters Lincoln Institute study focused on driver trip length. As explained in the second bullet above, VMT and trip length are similar but not identical measures.

b. Note that these two measures of transit proximity are similarly purposed, but different between the two sources; the meta-analysis uses distance to the nearest transit stop, while the Kuzmyak-Walters study used total number of transit stops within the buffer area.

- In relation to transit use, both sources show a modest encouraging effect due to residential density, and almost no difference with regard to employment density. Jobs-housing balance does not show up in either set of results, nor does regional accessibility by transit (a surprise finding), and intersection density does not show up as a factor in the Kuzmyak-Walters study though it carries a moderate +0.23 elasticity in the meta analysis, which would be expected. Both sources show an expected positive effect from transit proximity, although they are measured differently, with the meta-analysis using distance to bus stop and the Kuzmyak/Walters study using measures of both rail station and bus stop density (number of each within ½ mile buffer).

- Perhaps the most difficult finding to explain is the result that automobile travel is positively affected by increased density. One possibility, warranting further study, is that the effects of diversity and design, which are often highly correlated with density, are so strong that density itself is relegated to a role of adjusting the effects associated with the stronger correlated urban characteristics. Density alone does not reduce vehicle travel unless the density contains a good mix of production and attraction generating land uses and a good walking environment. Focusing the density analysis more specifically on different travel-sheds might yield a deeper understanding, as the results of preliminary analysis indicate that VMT does reduce in response to increase residential density within a ¼ mile radius of the attraction site.

- Factors that influence walking are similar in orders of magnitude and direction between the two studies. In relative terms the LA attraction center analysis expectedly shows greater sensitivity to employment density and lower sensitivity to residential density than the national study of primarily residential-based travel.

- The elasticities for walking are the most directly comparable. Both sources show modest positive elasticities with respect to both residential and employment density and for attraction accessibility, moderate elasticities for jobs-housing balance, and the highest elasticities (very similar at +0.39/0.38) for intersection density. Surprisingly, our study showed no benefit due to nearness to transit.

Table 23 focuses only on the built-environment (BE) factors found to be significant in our analysis. As shown in earlier tables socio-demographic (SED) factors also have significant influence with larger elasticities than those for the built environment characteristics. In our models, having a driver's license is clearly a major determinant in whether a person chooses to drive, be a passenger, take transit or walk or bike. Also important, of course, is household income, and its close surrogate vehicles per driver (since households with more income are likely to own more vehicles to serve their drivers). Some residential production models have separately modeled auto ownership, and found it to be substantially influenced by built environment factors, although our model structure would not allow us to do that here.[vii] The elasticities for the other SED factors, however, such as age, race, gender, housing type, etc., are fairly moderate in most cases and quite comparable to—if not smaller than—most of the built environment elasticity values.

It is also important to note that these SED characteristics constitute *inputs* to a planning application, and not policy variables in the manner that built environment characteristics can be altered in planning. They will change over time, but generally at a slow rate, so their effects on the bottom line of travel mode choice and VMT are generally not great. For example, the percentage of persons with driver's licenses should not change a great deal from today's rates. It is, however, important to account for their effects in future forecasts, particularly if there is a suspected income or ethnic bias expected in demand for a particular mode (e.g., does transit provide competitive service and draw from all travel segments or primarily the economically disadvantaged) or a particular development pattern (e.g., can TOD housing be made affordable).

Given that the socio-demographic variables may not change substantially over time, one can use the models or the elasticities in table 23 to perform "what if" analysis to examine the effect of modifying one or more of the built environment variables on travel outcomes. For example, increasing walkability and connectivity by reducing average block length from 800 feet to 400 feet (effectively doubling intersection density) would reduce auto trip generation by 4.2 percent and auto trip distance by 1.65 percent, while increasing walking by 38 percent and bicycle use by 152 percent. Doubling employment density and the job/population balance would also increase walking by about 10 percent and 25%, respectively. Based on research at commercial and employment centers throughout the LA region, reducing the separation among bus stops also increases transit ridership measurably: if the number of bus stops per square mile were to double, the likelihood of taking transit to that destination would increase by about 15 percent while the likelihood of driving would decrease by about 1 percent. These are just some simple examples of how this new information can be put to use.

Key Research Findings

We believe that our research has resulted in the following important findings:

1. Vehicle trips and vehicle miles (VT and VMT) produce the primary impacts on traffic generation, infrastructure capacity needs, GHG and emissions and other environmental concerns. When we examine urban environments at regional attractions (work places, shopping locations, schools, mixed use locations), we find that the following built environment (BE) factors have a significant effect on VT and VMT generation: employment density, job/population balance, urban design in the form of street network grain and connectivity, numbers of rail stations and bus stops, and regional accessibility of the attractions center.

2. Our analysis quantifies the effects of these factors on VT and VMT in several ways. In some cases, we can demonstrate how the factors affect individual travel "purposes", distinguishing commute trips from shopping from social from errands, and allowing us to show how such individual purposes combine to produce effects on overall VT and VMT. In other cases, we can only demonstrate how individual BE variables affect overall VT and VMT, without distinguishing the effects on individual travel purposes.

3. In addition to the built-environment factors, we examined a list of socio-demographic variables (SED). With respect to these variables, in analysis cases where we know the traveler's SED characteristics and residence distance from the attraction location, we have two options: (1) we can compute the vehicle trip generation rate based solely on BE variables while assuming SED conditions to be constant; or (2) we can also quantify the degree to which these general effects vary as a function of individual SED characteristics. Specifically, we can describe the effects of the following traveler SED characteristics: gender, age range, worker status, household income, vehicle ownership, owner/renter status, single/multi-family housing, and number of children.

4. We see important evidence that each of the BE variables has an individual influence on the key travel outcomes. However, our attempts to quantify complete relationships showing the interactions among all of the BE variables indicate that, in real-world built environments, many of the BE variables commonly co-exist—for example, intersection density, number of bus stops, and employment density. Therefore, the multi-variable

relationships we've been able to define are recommended for use in studies where coherent, internally-consistent place-types are being compared with one another. In such analyses, place-types such as those used in planning tools such as the SCAG Sustainability Tool, Envision Tomorrow, CommunityViz, iPLACE3S, and Rapid Fire/ Urban Footprint, are holistic representations of neighborhood forms in which individual characteristics such as employment density and intersection density and number of bus stops are consistent with one another.

5. There are also some variables that do not show up as strongly correlated to travel generation, mode use and trip length. Examples are non-residential use mix and certain modal competitiveness accessibility metrics. We believe that the importance of retail and service activity deserves further analysis as a critical element in characterizing the mix of our attraction areas, possibly through sub-dividing diversity walk-sheds into finer grained categories. Our analysis was able to partially demonstrate that such parsing of areas of influence for individual travel modes may further refine the analysis approach. Until then, the absence of these measures can be partly mitigated by applying the relationships we have discovered in cases where place-types can be holistically defined.

6. As one product of our research, we have also calculated elasticities between attraction-end BE variables on several outcomes that we did not expect to be able to capture, such as walk and bicycle trip generation. We must caveat that the elasticities are very preliminary and would benefit from more thorough statistical analysis. The elasticities computed for transit and bicycle should be treated with particular caution, given the small and potentially biased samples used for those modes.

We feel encouraged by the results that our research has been able to draw to date from the SCAG data, and feel confident that additional analysis using more advanced modeling constructs will further reveal the importance that trip attraction BE characteristics have on travel behavior—not only choice of mode, but choice of destination itself, and the combined effect of better-planned land use on vehicle use, VMT, and their consequences on congestion, mobility, and climate change.

Significance for Planning Practice

These findings, while only partial and preliminary, inform planning concept development and evaluation by allowing planners to assess the trade-offs among different facets of urban form by quantifying their respective effects on key impacts, development constraints and costs. The findings complement those of a substantial body of research on the effects of built environment on residential travel generation by, perhaps for the first time, providing similar evidence on the effects of built environment D factors at commercial and employment centers and mixed residential and non-residential land use.

Appendix A: Supplemental Tables Exploring Relationships by Travel Mode and Selected Trip Purpose

Table A-1: Persons per Household

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	3.16	3.13	3.77	2.68	2.77	2.58	2.85	3.02	2.99
Auto Passenger	4.05	3.79	4.45	3.60	3.75	3.37	3.48	3.89	3.85
Transit	3.42	4.00	3.94	3.30	3.70	3.15	2.35	3.48	3.33
Walk	2.99	2.83	4.57	2.91	2.98	2.56	2.96	3.26	3.18
Bike	3.30	5.00	4.47	2.28	2.57	3.00	2.71	3.34	3.35
Other	2.83	4.18	6.07	3.21	3.13	2.14	2.83	3.06	3.13
All Modes	3.19	3.10	4.32	2.88	3.00	2.78	3.03	3.24	3.19

Table A-2: Vehicles per Household

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	2.67	2.69	3.07	2.34	2.36	2.28	2.49	2.48	2.48
Auto Passenger	2.59	3.07	2.52	2.39	2.39	2.15	2.62	2.47	2.46
Transit	1.24	2.00	1.26	1.00	0.99	0.49	0.65	1.08	1.18
Walk	2.04	2.16	1.99	1.66	1.54	1.56	2.14	1.99	2.02
Bike	2.37	0.00	2.18	1.02	0.89	2.00	2.18	2.11	2.09
Other	3.08	3.55	3.14	2.91	2.97	2.57	2.76	2.59	2.74
All Modes	2.61	2.56	2.58	2.27	2.26	2.13	2.47	2.38	2.39

Table A-3: Vehicles per Driver

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	1.16	1.17	1.06	1.18	1.17	1.16	1.19	1.16	1.16
Auto Passenger	0.97	1.04	1.12	1.10	1.09	1.01	1.15	1.11	1.11
Transit	0.57	0.83	0.49	0.61	0.60	0.30	0.44	0.59	0.62
Walk	1.05	1.11	0.99	1.00	1.02	0.86	1.12	1.04	1.06
Bike	1.00	0.00	0.98	0.87	0.71	1.00	1.02	1.05	1.05
Other	1.52	1.33	1.17	1.28	1.36	2.00	1.42	1.32	1.32
All Modes	1.14	1.15	1.06	1.13	1.13	1.08	1.17	1.12	1.13

Table A-4: Vehicles per Worker

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	1.60	1.66	1.71	1.80	1.85	1.82	1.77	1.74	1.74
Auto Passenger	1.25	1.22	1.76	1.81	1.82	1.74	1.86	1.76	1.76
Transit	0.74	1.50	0.91	0.96	0.90	0.74	0.53	0.88	0.98
Walk	1.29	1.51	1.44	1.39	1.31	1.53	1.60	1.53	1.53
Bike	1.31	0.00	1.29	0.78	0.81	2.00	1.73	1.50	1.47
Other	1.90	1.98	1.82	1.79	2.22	3.33	2.07	1.97	1.97
All Modes	1.56	1.62	1.66	1.76	1.78	1.77	1.77	1.70	1.70

Table A-5: Average Age

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	46.9	47.6	26.6	55.9	56.0	58.6	51.9	51.6	51.7
Auto Passenger	37.4	45.9	11.9	39.3	37.8	47.8	39.2	32.3	32.8
Transit	42.7	46.0	19.6	45.1	42.0	45.4	46.0	41.6	42.2
Walk	44.1	49.1	13.2	47.7	46.5	54.4	44.6	43.4	44.4
Bike	36.3	45.0	14.9	44.0	43.3	34.0	40.9	37.6	36.7
Other	45.4	41.6	15.4	50.8	49.9	59.9	49.6	46.8	46.8
All Modes	46.3	47.8	15.8	51.8	51.3	55.3	47.6	46.3	46.7

Table A-6: Gender: Percent Female

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	45.5%	40.9%	51.4%	55.4%	49.7%	60.0%	42.8%	48.8%	50.0%
Auto Passenger	72.1%	57.1%	49.4%	70.0%	70.4%	64.8%	69.7%	65.3%	65.6%
Transit	52.6%	50.0%	39.6%	71.1%	71.2%	70.9%	50.0%	57.3%	59.1%
Walk	51.3%	39.6%	46.8%	61.0%	56.5%	58.8%	46.2%	54.2%	54.4%
Bike	18.5%	0.0%	17.6%	19.6%	14.3%	0.0%	35.3%	23.0%	23.3%
Other	13.5%	9.1%	71.4%	28.3%	30.0%	71.4%	37.9%	37.1%	36.1%
All Modes	46.1%	40.2%	48.8%	58.6%	54.2%	61.7%	50.3%	52.5%	53.4%

Table A-7: Percent White

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	71.7%	76.9%	69.1%	77.6%	76.1%	80.7%	77.6%	74.1%	74.4%
Auto Passenger	50.8%	71.4%	57.9%	63.9%	62.3%	72.4%	74.6%	65.3%	65.4%
Transit	47.4%	0.0%	26.4%	43.0%	43.8%	30.2%	46.2%	44.7%	45.5%
Walk	62.3%	85.9%	43.5%	58.8%	54.5%	76.5%	71.5%	63.9%	66.4%
Bike	81.5%	0.0%	76.5%	71.7%	57.1%	N/A	76.5%	72.6%	74.0%
Other	88.2%	90.9%	71.4%	62.3%	73.3%	85.7%	89.7%	73.5%	79.2%
All Modes	70.3%	78.7%	57.0%	72.9%	70.8%	76.0%	76.1%	70.5%	71.1%

Table A-8: Average Household Income in $1000

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	84.4	90.7	79.2	73.3	72.2	74.6	81.8	78.0	78.3
Auto Passenger	66.1	88.0	78.6	70.1	68.2	66.7	85.0	76.7	76.7
Transit	39.2	50.0	38.8	28.6	23.2	16.5	37.5	30.6	36.8
Walk	69.0	98.0	59.4	54.7	45.7	56.3	81.8	64.5	68.3
Bike	74.5	12.5	82.7	43.9	35.4	NA	69.2	69.4	69.5
Other	81.7	106.8	110.2	64.4	63.0	71.4	94.5	69.0	79.1
All Modes	81.9	92.3	74.2	70.4	67.8	68.9	82.3	74.9	75.9

Table A-9: Percent with Driver's License

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Auto Passenger	74.6%	92.9%	30.9%	74.6%	70.6%	66.7%	81.3%	72.2%	73.0%
Transit	93.9%	100.0%	90.2%	72.8%	63.9%	65.9%	72.0%	75.6%	78.7%
Walk	82.1%	98.7%	32.9%	77.4%	69.7%	74.2%	90.4%	79.9%	82.7%
Bike	85.2%	0.0%	41.7%	55.6%	55.6%	N/A	73.3%	75.0%	74.9%
Other	96.2%	100.0%	37.5%	84.9%	86.7%	57.1%	81.5%	78.7%	83.1%
All Modes	98.3%	99.0%	68.9%	93.9%	92.0%	90.9%	94.5%	92.8%	93.5%

Table A-10: Percent Own Residence

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	83.3%	87.0%	83.2%	85.7%	86.0%	85.7%	86.2%	84.5%	84.5%
Auto Passenger	69.7%	85.7%	78.4%	78.7%	78.7%	76.1%	84.3%	80.0%	79.9%
Transit	27.6%	50.0%	43.4%	25.0%	24.6%	16.4%	19.2%	31.1%	35.5%
Walk	64.1%	78.6%	57.9%	56.0%	55.7%	52.9%	71.8%	67.0%	70.0%
Bike	55.6%	N/A	88.2%	39.1%	34.9%	N/A	82.4%	73.0%	73.6%
Other	78.8%	100.0%	85.7%	77.4%	75.5%	N/A	93.1%	77.6%	82.1%
All Modes	80.3%	84.6%	74.6%	80.9%	80.9%	78.3%	83.7%	80.1%	80.7%

Table A-11: Percent Single Family Detached Housing

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	78.3%	81.6%	81.5%	77.6%	78.3%	78.1%	78.9%	79.1%	78.8%
Auto Passenger	64.8%	78.6%	79.4%	79.1%	79.3%	77.5%	83.3%	79.9%	79.8%
Transit	28.4%	50.0%	37.7%	38.6%	38.4%	27.3%	11.5%	34.3%	38.0%
Walk	64.1%	69.2%	59.7%	56.0%	49.4%	32.0%	65.0%	62.5%	64.9%
Bike	55.6%	N/A	76.5%	43.2%	34.6%	N/A	88.2%	70.2%	72.2%
Other	N/A	100.0%	78.6%	79.2%	80.0%	71.4%	86.2%	69.3%	76.8%
All Modes	75.7%	78.2%	74.6%	75.5%	74.8%	73.5%	78.2%	76.1%	76.4%

Table A-12: Worker

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	99.0%	99.8%	48.3%	51.4%	51.0%	38.1%	63.2%	62.4%	63.0%
Auto Passenger	97.5%	100.0%	14.7%	38.8%	38.1%	24.2%	42.9%	41.5%	41.4%
Transit	97.4%	100.0%	20.6%	29.8%	27.5%	9.1%	36.0%	44.0%	47.0%
Walk	100.0%	100.0%	24.6%	46.8%	46.0%	35.5%	64.7%	46.1%	51.1%
Bike	96.3%	NA	12.5%	68.2%	65.9%	N/A	64.3%	60.0%	62.9%
Other	98.1%	100.0%	16.7%	54.7%	51.0%	N/A	63.0%	53.7%	60.3%
All Modes	98.9%	99.9%	34.7%	49.1%	48.5%	34.4%	59.0%	57.3%	58.5%

Table A-13: Total People On Trip (incl. driver)

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	1.10	1.32	1.34	1.45	1.44	1.39	1.85	1.50	1.54
Auto Passenger	2.29	2.07	2.78	2.85	2.92	2.51	3.03	3.03	3.05
Transit	1.12	1.00	1.49	2.05	2.34	2.13	2.31	1.72	1.79
Walk	1.04	1.09	1.15	1.21	1.05	1.44	1.19	1.06	1.09
Bike	1.00	1.00	1.00	1.04	1.07	1.00	1.00	1.02	1.02
Other	1.00	1.00	1.00	1.06	1.10	1.00	1.03	1.06	1.05
All Modes	1.14	1.27	2.08	1.71	1.70	1.67	2.09	1.75	1.78

Table A-14: Total HH Members on Trip (incl. driver)

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	1.03	1.06	1.16	1.34	1.35	1.29	1.54	1.39	1.38
Auto Passenger	2.09	2.00	2.61	2.70	2.75	2.39	2.77	2.84	2.81
Transit	1.06	1.00	1.28	1.87	2.21	1.78	1.58	1.60	1.52
Walk	1.00	1.00	1.09	1.15	1.04	1.44	1.10	1.04	1.06
Bike	1.00	1.00	1.00	1.02	1.04	1.00	1.00	1.00	1.00
Other	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.02	1.02
All Modes	1.07	1.06	1.92	1.59	1.60	1.57	1.82	1.63	1.62

Table A-15: Calculated Trip Distance in Miles

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	14.02	5.27	12.37	4.68	4.50	8.49	5.79	8.62	8.62
Auto Passenger	10.18	3.65	3.79	5.24	5.69	9.39	8.23	8.94	9.13
Transit	11.98	2.28	8.06	5.28	4.68	7.63	3.53	7.67	9.30
Walk	0.89	0.41	0.61	0.57	0.58	0.42	0.49	0.75	0.73
Bike	4.03	0.33	1.44	2.54	1.35	1.11	2.19	3.02	3.14
Other	25.88	6.95	4.08	4.15	5.19	17.26	6.15	17.19	90.51
All Modes	13.65	4.00	5.25	4.47	4.35	8.40	5.86	7.65	8.57

Table A-16: Calculated Travel Time (minutes)

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	26.8	13.3	24.8	13.2	12.6	20.5	14.3	19.6	18.9
Auto Passenger	21.3	11.8	11.7	14.9	15.7	22.5	17.7	19.2	19.2
Transit	58.4	37.5	44.4	41.5	39.7	56.5	38.2	53.1	50.1
Walk	15.5	9.1	13.9	14.1	16.0	9.7	12.1	17.3	17.1
Bike	25.4	11.7	17.2	24.5	14.5	15.0	19.5	22.7	25.3
Other	37.4	24.3	18.2	13.3	14.5	31.1	18.8	25.2	39.4
All Modes	27.6	12.5	16.5	14.1	14.0	22.7	15.2	19.9	19.6

Table A-17: Calculated Dwell Time at Destination (minutes)

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	404	203	269	33	37	65	47	NA	117
Auto Passenger	394	155	386	41	51	72	56	NA	120
Transit	479	377	362	75	93	92	73	NA	181
Walk	336	227	359	29	26	48	42	NA	88
Bike	419	93	416	32	43	160	44	NA	106
Other	376	148	443	36	30	130	52	NA	136
All Modes	405	207	355	35	40	68	49	NA	116

Table A-18: Number Daily Trips for this Respondent

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	4.47	6.44	4.88	6.55	5.94	6.15	6.46	5.72	6.04
Auto Passenger	3.96	6.14	3.62	5.85	5.24	4.91	5.66	4.84	5.10
Transit	3.25	3.00	3.28	4.67	4.15	4.16	4.65	3.73	4.27
Walk	4.60	6.39	3.54	5.88	5.17	5.24	6.41	5.49	5.73
Bike	4.48	N/A	3.65	6.65	5.71	N/A	6.00	5.46	5.62
Other	4.48	7.91	3.21	6.28	4.97	2.57	6.03	4.31	5.21
All Modes	4.41	6.45	3.87	6.34	5.69	5.70	6.22	5.46	5.77

Table A-19: Number of this Trip

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	1.74	4.07	1.91	3.40	3.38	2.65	3.49	4.37	NA
Auto Passenger	1.57	3.93	1.32	3.49	3.16	2.41	3.28	4.07	NA
Transit	1.41	3.00	1.45	2.30	2.26	1.51	2.50	3.03	NA
Walk	2.38	4.04	1.36	3.33	3.29	2.47	3.20	4.06	NA
Bike	1.15	6.33	1.00	3.15	3.09	N/A	3.29	3.96	NA
Other	1.77	5.09	1.07	3.47	3.33	1.71	3.79	3.71	NA
All Modes	1.73	4.08	1.46	3.33	3.31	2.52	3.39	4.23	NA

Table A-20: Frequency of Working at Home in Last Month (days)

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	2.32	1.49	NA	4.21	4.83	4.83	3.14	4.17	3.89
Auto Passenger	1.80	N/A	NA	NA	4.89	5.25	5.94	4.88	4.66
Transit	3.25	N/A	NA	NA	N/A	N/A	N/A	3.29	3.17
Walk	1.38	1.67	NA	4.30	4.19	N/A	2.39	5.38	4.43
Bike	5.33	N/A	NA	NA	N/A	0.00	N/A	4.40	4.91
Other	4.67	3.25	NA	NA	N/A	0.00	3.20	2.86	2.84
All Modes	2.33	1.62	NA	4.52	4.77	6.29	3.31	4.36	4.01

Table A-21: Distance to Work (in miles)

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	14.05	12.71	N/A	13.89	13.8	15.4	15.15	13.94	14.25
Auto Passenger	10.19	9.94	N/A	11.7	11.64	16.7	13.57	12.02	12.2
Transit	13.68	8	N/A	11.07	11.89	N/A	4.51	10.3	12.94
Walk	8.02	15.55	N/A	10.63	9.03	15.4	14.96	11.17	12.05
Bike	3.64	N/A	N/A	9.14	7.89	N/A	8.24	10.35	9.93
Other	28.83	51.6	N/A	19.02	20.62	N/A	40.93	15.47	30.37
All Modes	13.91	13.99	N/A	13.38	13.2	15.6	15.06	17.6	13.97

Table A-22: Number of Trips by Walking, Past Week

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	3.25	3.83	2.31	3.77	3.73	3.75	3.84	3.7	3.69
Auto Passenger	2.97	1.5	3.2	3.51	3.42	2.87	3.74	3.46	3.53
Transit	6.7	3.5	6.42	7.34	8.52	5.43	6.31	6.37	6.4
Walk	7.79	5.82	6.93	6.92	7.48	4.59	6.79	7.92	7.66
Bike	3.78	3	3.76	6.28	6.79	N/A	4.94	5.45	5.28
Other	2.88	3.18	2.5	5.66	5	4	5.62	4.24	4.21
All Modes	3.45	4.27	3.8	4.03	4.14	3.68	4.16	4.28	4.22

Table A-23: Number of Trips by Bike, Past Week

	Go To Work	Return To Work	Go To School	Shopping, All	Shopping, HB only	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.19	0.22	0.24	0.18	0.21	0.12	0.23	0.22	0.21
Auto Passenger	0.23	0.36	0.8	0.5	0.56	0.37	0.5	0.64	0.61
Transit	0.67	0	0.36	0.35	0.48	0.27	0.46	0.5	0.44
Walk	0.31	0.34	1.04	0.36	0.51	0.09	0.42	0.51	0.46
Bike	7.63	6	8.06	8.67	7.39	N/A	10.88	6.55	6.77
Other	0.19	0.45	0	0.58	0.87	0	0.52	0.41	0.32
All Modes	0.26	0.28	0.79	0.31	0.37	0.18	0.38	0.43	0.4

Table A-24: Gross Population Density

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	10.36	10.47	9.69	11.11	11.13	11.88	11.49	11.66	11.35
Auto Passenger	11.94	11.61	11.65	10.94	11.27	42.56	10.70	12.07	11.63
Transit	17.15	41.42	17.89	23.15	18.88	127.65	25.43	24.85	22.10
Walk	16.53	16.00	18.39	18.93	20.86	42.72	17.41	16.09	15.71
Bike	13.02	46.30	12.67	18.95	20.65	38.91	14.67	14.84	13.68
Other	10.74	10.36	15.25	12.56	12.34	107.67	13.77	11.57	11.34
All Modes	10.81	12.19	12.78	11.90	12.26	42.94	12.05	12.61	12.16

Table A-25: Net Population Density

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	54.36	45.45	30.23	33.75	34.10	14.76	37.38	26.42	33.74
Auto Passenger	53.35	36.87	26.75	35.55	36.55	17.91	36.64	27.00	32.48
Transit	126.61	662.01	50.81	142.50	125.65	53.59	153.64	67.60	103.62
Walk	78.31	126.57	48.25	64.07	51.68	17.16	80.97	38.35	47.64
Bike	47.44	114.83	29.44	51.76	52.56	15.79	37.49	35.92	37.49
Other	57.82	52.00	49.37	37.80	38.50	50.06	61.03	31.22	43.69
All Modes	57.26	68.56	32.96	38.04	37.93	17.90	42.80	29.03	36.64

Table A-26: Net Household Density

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	22.64	18.49	11.80	13.73	13.78	14.76	15.94	10.39	13.73
Auto Passenger	22.31	14.45	10.34	14.41	14.63	17.91	15.54	10.30	13.06
Transit	55.75	299.69	21.33	61.42	54.25	53.59	68.00	27.87	44.45
Walk	34.65	55.20	18.69	27.32	21.30	17.17	35.01	15.54	19.85
Bike	19.59	49.80	10.16	21.24	21.23	15.79	16.08	14.67	15.50
Other	24.67	21.66	10.34	16.94	17.33	50.06	25.44	12.39	18.31
All Modes	24.00	28.96	12.73	15.62	15.42	17.90	18.30	11.44	14.99

Table A-27: Number SF Dwelling Units

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	552	592	738	754	762	730	729	993	830
Auto Passenger	537	621	944	711	717	671	697	1021	869
Transit	581	80	685	662	763	634	567	761	679
Walk	606	463	1012	764	851	900	682	952	870
Bike	646	294	910	714	812	1374	949	995	905
Other	565	594	901	624	660	693	775	906	74
All Modes	554	556	895	745	762	718	717	988	839

Table A-28: Number MF Dwelling Units

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	1,519	1,473	1,143	1,485	1,469	1,698	1,673	1,293	1,434
Auto Passenger	1,858	1,663	1,311	1,456	1,482	1,573	1,548	1,271	1,407
Transit	2,992	9,063	2,895	3,947	2,908	3,790	4,865	4,281	3,802
Walk	2,967	2,865	2,440	3,417	3,417	2,782	2,983	2,283	2,318
Bike	2,025	9,800	1,365	3,088	3,225	1,981	2,186	1,990	1,841
Other	1,481	1,462	968	2,138	2,075	4,846	1,946	1,310	1,501
All Modes	1,616	1,901	1,551	1,653	1,692	1,848	1,808	1,482	1,586

Table A-29: Percent MF Dwelling Units

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	73%	71%	61%	66%	66%	70%	70%	57%	63%
Auto Passenger	78%	73%	58%	67%	67%	70%	69%	55%	62%
Transit	84%	99%	81%	86%	79%	86%	90%	85%	85%
Walk	83%	86%	71%	82%	80%	76%	81%	71%	73%
Bike	76%	97%	60%	81%	80%	59%	70%	67%	67%
Other	72%	71%	52%	77%	76%	87%	72%	59%	95%
All Modes	74%	77%	63%	69%	69%	72%	72%	60%	65%

Table A-30: Acres Zoned Residential

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	139.7	146	175.3	183.2	182.4	189.9	184.9	238.1	202.5
Auto Passenger	146.7	148.3	226.5	170.7	169.6	178.9	178.4	238.5	208.8
Transit	155.8	134.5	197.4	174.5	177.4	167.7	179.6	224.7	193.3
Walk	171.6	132.7	226.4	198.5	202	219.9	177.5	232.7	216.6
Bike	169.9	202.7	236.6	197	197	N/A	208.3	228.5	212.5
Other	141.8	125.3	210.9	181.12	173.2	190.2	178.4	219.7	187.4
All Modes	141.5	142.6	213.3	181.11	181.6	187.5	182.6	237	205.2

Table A-31: Acres Zoned Employment

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	179.3	175.6	181.5	143.4	143.6	145.2	140.6	76.8	117
Auto Passenger	175.5	184.5	226.5	150.3	150.6	153.2	136.9	74.3	106.5
Transit	169.4	169.5	134.9	165.1	161.1	174.3	167.4	106.6	137.6
Walk	150.9	187.2	112.2	130.7	129.2	121.9	151.3	89.8	104.8
Bike	169.3	162.6	113	135.9	137	N/A	122.2	92.9	107
Other	162.2	165.4	168.7	151.1	155.8	145.6	153.7	86.6	117.5
All Modes	177.9	178.6	124.8	144	144.4	147.7	141	78.8	113.8

Table A-32: Total Developed Acreage

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	319.0	321.6	356.9	326.6	326.1	335.2	325.6	315.0	320.0
Auto Passenger	322.2	332.8	328.6	370.9	320.2	332.2	315.3	312.9	315.2
Transit	325.3	303.9	332.4	339.6	338.5	342.0	346.9	331.4	330.9
Walk	322.5	319.9	338.6	329.2	331.2	340.8	328.8	332.5	321.4
Bike	339.2	365.3	349.6	332.9	334.0	N/A	330.5	321.4	319.5
Other	303.9	290.7	379.6	332.2	329.0	335.8	332.1	306.4	304.9
All Modes	319.4	321.2	338.1	326.1	325.6	335.1	323.6	315.8	319.0

Table A-33: Gross Employment Density

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	14.61	11.89	7.47	8.57	8.55	12.67	8.87	3.61	7.18
Auto Passenger	14.59	12.66	4.36	8.02	8.01	14.48	8.16	3.28	5.76
Transit	24.60	43.28	8.45	25.51	24.38	17.56	32.77	8.21	15.45
Walk	18.61	31.83	5.55	12.71	12.12	8.54	21.24	5.42	8.42
Bike	12.25	9.22	4.10	11.43	11.56	N/A	8.37	4.74	6.09
Other	15.49	16.69	8.32	8.93	8.54	23.57	13.91	4.69	8.77
All Modes	15.03	17.19	5.53	9.04	8.97	13.28	10.19	3.89	7.22

Table A-34: Net Employment Density

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	39.66	33.21	24.97	30.08	29.84	44.10	32.88	31.95	32.11
Auto Passenger	40.20	39.32	21.58	27.06	26.91	45.80	30.05	22.20	25.79
Transit	62.07	98.25	30.04	59.27	57.61	50.72	76.83	32.97	45.08
Walk	49.52	82.80	24.22	43.49	42.31	36.43	63.51	28.12	34.43
Bike	34.57	28.49	16.35	44.97	44.34	N/A	34.11	25.14	28.01
Other	39.44	48.72	21.86	32.70	29.33	63.56	35.25	24.69	32.04
All Modes	40.60	46.49	23.16	31.07	30.73	44.80	35.70	29.36	31.41

Table A-35: Retail Employment

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	734	634	343	835	818	692	710	247	502
Auto Passenger	740	420	309	880	869	778	714	226	448
Transit	1,191	625	553	1,299	1,116	878	1,540	472	797
Walk	824	1,897	321	829	543	572	1,011	338	721
Bike	653	247	198	877	855	510	467	326	394
Other	720	983	318	748	664	958	740	272	480
All Modes	753	973	328	849	806	718	748	260	492

Table A-36: Service Employment

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	2,836	2,206	2,068	1,546	1,464	3,218	1,578	759	1,420
Auto Passenger	2,884	3,134	988	1,304	1,240	3,538	1,346	704	1,110
Transit	4,208	2,868	1,926	5,115	4,038	4,609	6,500	1,767	3,018
Walk	4,487	6,997	1,212	2,492	1,686	2,267	437	1,227	1,788
Bike	2,999	2,290	1,014	2,533	1,760	14,528	1,690	1,056	1,338
Other	2,934	2,120	1,812	1,589	1,322	6,752	2,903	883	1,596
All Modes	2,923	3,460	1,332	1,631	1,492	3,367	1,864	833	1,438

Table A-37: Retail FAR

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.374	0.315	0.171	0.271	0.270	0.337	0.295	0.196	0.252
Auto Passenger	0.451	0.348	0.182	0.247	0.246	0.393	0.259	0.189	0.223
Transit	0.720	0.724	0.327	0.748	0.720	0.586	0.955	0.401	0.529
Walk	0.477	0.752	0.261	0.452	0.439	0.319	0.600	0.288	0.333
Bike	0.328	0.506	0.112	0.476	0.482	N/A	0.280	0.247	0.252
Other	0.415	0.489	0.140	0.335	0.314	0.870	0.435	0.202	0.289
All Modes	0.390	0.432	0.200	0.289	0.287	0.366	0.324	0.211	0.262

Table A-38: Average Net FAR

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.359	0.301	0.152	0.259	0.257	0.326	0.279	0.186	0.240
Auto Passenger	0.410	0.342	0.172	0.234	0.233	0.371	0.244	0.177	0.211
Transit	0.704	0.713	0.320	0.725	0.699	0.586	0.926	0.391	0.516
Walk	0.473	0.736	0.253	0.441	0.427	0.315	0.584	0.274	0.322
Bike	0.311	0.504	0.100	0.462	0.468	N/A	0.246	0.232	0.236
Other	0.400	0.471	0.131	0.324	0.304	0.853	0.414	0.194	0.279
All Modes	0.375	0.418	0.188	0.276	0.273	0.353	0.308	0.200	0.250

Table A-39: Jobs + Population

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	12,555	11,242	8,624	9,892	9,958	12,343	10,233	7,678	9,314
Auto Passenger	13,335	12,197	8,052	9,532	9,475	12,824	9,481	7,718	8,743
Transit	20,983	42,575	13,088	24,462	23,201	20,159	28,251	16,615	18,875
Walk	17,662	24,036	12,035	15,906	15,767	13,446	19,428	10,813	12,135
Bike	12,697	27,906	8,428	15,275	15,593	25,267	11,578	9,840	9,937
Other	13,188	13,599	11,848	10,804	10,760	23,692	13,914	8,175	10,108
All Modes	12,987	14,769	9,203	10,526	10,474	13,011	11,180	8,294	9,745

Table A-40: Jobs + Population per Gross Acre

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	25.0	22.4	17.2	19.7	19.6	24.6	20.4	15.3	18.5
Auto Passenger	26.5	24.3	16.0	19.0	18.9	25.5	18.9	15.4	17.4
Transit	41.7	84.7	26.0	48.7	46.2	40.1	58.2	33.1	37.6
Walk	35.1	47.8	23.9	31.6	31.4	26.8	38.7	21.5	24.1
Bike	25.3	55.5	16.8	30.4	31.0	50.3	23.0	19.6	19.8
Other	26.2	27.1	23.6	21.5	21.4	47.1	27.7	16.3	20.1
All Modes	25.8	29.4	18.3	20.9	20.8	25.9	22.2	16.5	19.4

Table A-41: Jobs + Population per Net Acre

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	39.3	34.5	25.9	29.8	29.7	36.7	31.5	23.7	28.8
Auto Passenger	42.0	37.3	24.0	28.9	28.8	38.3	30.1	23.9	27.2
Transit	64.9	149.7	39.6	74.4	71.3	60.8	90.0	49.7	57.6
Walk	54.2	77.7	35.8	48.5	47.7	39.0	61.7	32.9	37.4
Bike	38.6	76.4	23.8	46.5	47.3	76.8	36.2	30.7	31.3
Other	41.6	51.4	32.1	32.1	32.2	73.8	43.1	25.2	33.0
All Modes	40.6	46.5	27.4	31.8	31.6	38.7	34.9	25.5	30.2

Table A-42: Jobs + Population Balance

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.380	0.394	0.516	0.486	0.485	0.436	0.493	0.604	0.530
Auto Passenger	0.415	0.390	0.623	0.476	0.472	0.388	0.484	0.607	0.552
Transit	0.428	0.410	0.563	0.540	0.544	0.492	0.504	0.661	0.560
Walk	0.481	0.300	0.661	0.564	0.573	0.640	0.455	0.618	0.579
Bike	0.490	0.998	0.709	0.576	0.587	0.177	0.597	0.604	0.580
Other	0.384	0.391	0.642	0.441	0.453	0.510	0.588	0.570	0.501
All Modes	0.386	0.373	0.604	0.491	0.491	0.436	0.488	0.607	0.541

Table A-43: Retail + Population Balance

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.453	0.458	0.490	0.506	0.501	0.578	0.530	0.452	0.479
Auto Passenger	0.465	0.571	0.476	0.474	0.467	0.568	0.499	0.445	0.460
Transit	0.526	0.632	0.548	0.559	0.553	0.578	0.648	0.544	0.539
Walk	0.520	0.510	0.526	0.579	0.590	0.680	0.542	0.511	0.510
Bike	0.607	0.910	0.549	0.618	0.616	0.865	0.686	0.507	0.514
Other	0.474	0.464	0.743	0.459	0.475	0.513	0.591	0.485	0.470
All Modes	0.459	0.477	0.496	0.507	0.503	0.579	0.526	0.461	0.482

Table A-44: Land Use Mix—5 LU Types (incl. Residential)

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.599	0.624	0.541	0.626	0.621	0.652	0.630	0.456	0.543
Auto Passenger	0.611	0.648	0.483	0.628	0.632	0.661	0.624	0.453	0.526
Transit	0.615	0.772	0.561	0.667	0.628	0.660	0.737	0.618	0.630
Walk	0.669	0.709	0.573	0.634	0.615	0.641	0.644	0.526	0.550
Bike	0.643	0.782	0.803	0.672	0.649	0.747	0.628	0.538	0.554
Other	0.551	0.726	0.555	0.644	0.665	0.674	0.638	0.450	0.513
All Modes	0.601	0.649	0.518	0.628	0.623	0.654	0.631	0.469	0.542

Table A-45: Retail + Food Establishments

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	98.3	78.2	52.4	89.6	87.9	90.2	90.6	38.6	65.6
Auto Passenger	110.1	78.9	42.6	90.2	90.5	112.7	88.6	37.2	60.0
Transit	240.1	275.5	90.7	289.1	231.9	147.7	356.2	97.0	164.0
Walk	159.2	210.4	67.6	134.8	97.0	93.2	172.4	61.3	83.4
Bike	87.6	287.0	37.7	126.9	106.0	106.0	87.6	57.2	65.4
Other	114.9	127.6	64.8	107.7	87.2	130.0	138.0	56.1	80.2
All Modes	104.9	114.5	51.9	96.3	91.8	98.5	101.1	42.8	68.7

Table A-46: Employment Entropy (4 Employment Types)

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.552	0.591	0.491	0.628	0.627	0.554	0.617	0.544	0.569
Auto Passenger	0.587	0.527	0.526	0.621	0.62	0.561	0.618	0.542	0.564
Transit	0.61	0.575	0.534	0.626	0.62	0.527	0.613	0.564	0.58
Walk	0.59	0.57	0.546	0.613	0.608	0.61	0.591	0.565	0.564
Bike	0.559	0.63	0.515	0.63	0.644	0.246	0.608	0.555	0.556
Other	0.583	0.612	0.574	0.609	0.578	0.454	0.637	0.54	0.568
All Modes	0.556	0.563	0.522	0.626	0.624	0.555	0.614	0.547	0.567

Table A-47: Dissimilarity (6 LU Types)

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.187	0.189	0.178	0.188	0.187	0.191	0.188	0.176	0.183
Auto Passenger	0.195	0.195	0.180	0.187	0.186	0.192	0.187	0.176	0.181
Transit	0.192	0.220	0.180	0.200	0.194	0.202	0.219	0.190	0.194
Walk	0.196	0.200	0.182	0.193	0.188	0.188	0.195	0.181	0.184
Bike	0.191	0.198	0.174	0.200	0.195	0.182	0.181	0.179	0.182
Other	0.184	0.199	0.188	0.194	0.194	0.202	0.181	0.181	0.183
All Modes	0.188	0.192	0.180	0.188	0.187	0.192	0.189	0.177	0.183

Table A-48: Dissimilarity (13 LU Types)

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.197	0.198	0.188	0.198	0.197	0.204	0.198	0.186	0.193
Auto Passenger	0.205	0.209	0.191	0.197	0.196	0.203	0.198	0.185	0.191
Transit	0.203	0.238	0.194	0.212	0.206	0.216	0.239	0.204	0.208
Walk	0.210	0.211	0.195	0.206	0.203	0.203	0.207	0.194	0.196
Bike	0.201	0.196	0.184	0.215	0.209	0.203	0.190	0.190	0.192
Other	0.192	0.208	0.196	0.202	0.202	0.214	0.190	0.190	0.192
All Modes	0.198	0.202	0.191	0.199	0.198	0.204	0.199	0.187	0.193

Table A-49: Net Dissimilarity (6 LU Types)

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.171	0.172	0.163	0.170	0.169	0.174	0.170	0.156	0.164
Auto Passenger	0.176	0.181	0.161	0.168	0.167	0.174	0.168	0.155	0.161
Transit	0.180	0.202	0.169	0.190	0.183	0.193	0.213	0.177	0.182
Walk	0.181	0.188	0.169	0.180	0.176	0.174	0.181	0.164	0.167
Bike	0.173	0.167	0.159	0.190	0.185	0.180	0.171	0.162	0.165
Other	0.166	0.186	0.171	0.171	0.169	0.193	0.170	0.157	0.162
All Modes	0.172	0.177	0.163	0.171	0.170	0.175	0.171	0.157	0.164

Table A-50: Net Dissimilarity (13 LU Types)

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.179	0.180	0.171	0.179	0.178	0.185	0.180	0.164	0.172
Auto Passenger	0.186	0.190	0.169	0.176	0.176	0.185	0.177	0.163	0.170
Transit	0.189	0.218	0.179	0.200	0.193	0.205	0.229	0.189	0.193
Walk	0.193	0.197	0.179	0.191	0.188	0.188	0.191	0.174	0.177
Bike	0.182	0.177	0.167	0.200	0.196	0.188	0.179	0.170	0.174
Other	0.173	0.190	0.176	0.180	0.178	0.202	0.178	0.166	0.170
All Modes	0.180	0.185	0.172	0.180	0.179	0.187	0.181	0.165	0.173

Table A-51: Entropy (6 LU Types)

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.216	0.236	0.222	0.202	0.179	0.251	0.260	0.136	0.181
Auto Passenger	0.203	0.231	0.186	0.193	0.170	0.283	0.198	0.137	0.170
Transit	0.223	0.217	0.238	0.223	0.223	0.259	0.273	0.247	0.236
Walk	0.238	0.244	0.205	0.185	0.154	0.226	0.236	0.123	0.160
Bike	0.237	0.264	0.202	0.217	0.222	N/A	0.227	0.179	0.087
Other	0.182	0.256	0.227	0.223	0.233	0.291	0.227	0.163	0.177
All Modes	0.216	0.238	0.200	0.200	0.177	0.257	0.243	0.137	0.176

Table A-52: Entropy (13 LU Types)

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.368	0.479	0.343	0.334	0.329	0.419	0.374	0.312	0.331
Auto Passenger	0.263	0.347	0.283	0.314	0.302	0.435	0.356	0.312	0.325
Transit	0.599	0.428	0.364	0.388	0.398	0.458	0.485	0.384	0.418
Walk	0.381	0.349	0.327	0.358	0.342	0.468	0.558	0.276	0.316
Bike	0.335	0.406	0.264	0.395	0.359	0.390	0.468	0.310	0.301
Other	-0.207	0.407	0.289	0.339	0.365	0.554	0.433	0.280	0.250
All Modes	0.364	0.441	0.309	0.334	0.328	0.427	0.390	0.308	0.329

Table A-53: Street Centerline Density

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.028	0.029	0.028	0.030	0.030	0.031	0.030	0.030	0.030
Auto Passenger	0.029	0.029	0.029	0.028	0.028	0.030	0.029	0.030	0.029
Transit	0.034	0.039	0.033	0.035	0.036	0.036	0.036	0.036	0.035
Walk	0.032	0.035	0.034	0.064	0.035	0.032	0.035	0.032	0.032
Bike	0.030	0.035	0.028	0.036	0.037	0.042	0.036	0.032	0.031
Other	0.029	0.028	0.029	0.029	0.028	0.042	0.031	0.029	0.029
All Modes	0.029	0.030	0.030	0.030	0.030	0.031	0.030	0.030	0.030

Table A-54: Number Rail Transit Stations

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	1.06	0.75	0.65	0.46	0.46	0.57	0.59	0.11	0.41
Auto Passenger	1.31	0.43	0.17	0.42	0.56	0.53	0.72	0.10	0.31
Transit	2.88	3.55	1.18	1.58	0.83	2.96	1.08	0.78	2.14
Walk	1.53	3.40	0.47	0.65	0.45	0.00	1.59	0.16	0.50
Bike	1.56	0.00	0.00	0.31	0.22	0.00	0.24	0.26	0.45
Other	1.30	0.00	0.00	0.18	0.27	1.71	0.48	0.42	0.76
All Modes	1.15	1.52	0.38	0.48	0.48	0.66	0.72	0.13	0.44

Table A-55: Number Bus Stops

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	135.8	95.8	73.8	57.6	72.6	85.5	79.0	44.3	69.6
Auto Passenger	157.1	85.9	51.4	53.8	69.3	104.8	74.9	43.9	61.2
Transit	379.3	1142.5	154.9	75.2	348.0	265.8	487.8	153.5	265.3
Walk	229.5	393.1	104.5	76.6	76.6	104.1	268.8	77.4	114.0
Bike	114.8	231.0	48.6	85.2	84.2	82.0	61.2	68.0	74.1
Other	137.8	115.8	77.5	57.7	58.0	297.0	203.1	67.8	100.5
All Modes	146.6	176.4	71.4	58.8	59.0	101.7	101.6	51.1	77.4

Table A-56: Sum of Weighted Intersections

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	56.8	54.8	54.5	57.6	57.3	62.8	60.4	54.2	56.4
Auto Passenger	56.3	59.8	53.7	53.8	54.0	62.4	57.6	53.6	54.9
Transit	77.5	81.0	64.3	75.2	75.8	75.0	80.3	72.9	74.8
Walk	72.2	84.6	69.7	76.6	76.6	65.3	85.2	64.7	66.9
Bike	62.2	99.7	55.2	85.2	84.2	121.2	80.2	70.0	66.6
Other	54.3	58.2	65.8	57.7	558.0	113.8	59.7	55.5	58.2
All Modes	57.8	62.9	57.5	58.8	59.0	63.9	62.5	56.0	57.9

Table A-57: Number 4-Way Intersections

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	30.9	29.3	28.6	29.8	29.4	30.4	30.1	25.6	28.1
Auto Passenger	31.1	32.4	26.9	30.0	29.8	31.0	29.6	25.7	27.6
Transit	37.8	33.8	32.0	37.9	36.4	35.1	41.0	33.1	35.4
Walk	34.8	37.9	31.9	35.3	35.6	33.5	36.7	29.4	30.6
Bike	29.7	63.4	28.6	39.0	39.5	43.3	27.2	31.0	30.1
Other	33.2	29.7	29.4	27.4	28.1	38.2	26.5	25.6	28.2
All Modes	31.3	31.8	28.5	30.4	38.2	31.0	30.7	26.3	28.5

Table A-58: Total Intersections

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	106.4	106.0	106.6	111.5	111.5	119.7	116.1	110.0	110.7
Auto Passenger	105.9	110.0	107.8	104.4	105.3	117.4	111.7	108.8	108.8
Transit	132.6	148.5	120.5	131.4	134.4	134.3	136.0	134.3	113.6
Walk	128.2	142.8	130.1	135.8	135.5	120.3	146.8	123.9	125.2
Bike	118.7	134.0	107.9	143.3	142.4	201.0	159.5	130.2	124.8
Other	101.3	112.4	122.2	112.2	112.0	189.4	117.9	110.0	111.6
All Modes	107.7	115.9	112.5	112.6	113.3	120.6	118.5	112.3	112.7

Table A-59: Intersection Density

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.846	0.843	0.858	0.888	0.888	0.953	0.924	0.875	0.881
Auto Passenger	0.842	0.875	0.858	0.831	0.838	0.934	0.889	0.866	0.866
Transit	1.056	1.182	0.956	1.046	1.069	1.069	1.084	1.069	1.064
Walk	1.020	1.136	1.036	1.080	1.079	0.958	1.168	0.986	0.996
Bike	0.945	1.066	0.859	1.140	1.134	1.600	1.269	1.036	0.994
Other	0.806	0.894	0.972	0.893	0.891	1.508	0.938	0.874	0.888
All Modes	0.857	0.922	0.895	0.896	0.901	0.960	0.943	0.894	0.897

Table A-60: Entropy (13 land uses)

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.447	0.467	0.457	0.483	0.481	0.538	0.491	0.346	0.441
Auto Passenger	0.455	0.419	0.452	0.472	0.476	0.524	0.477	0.336	0.441
Transit	0.461	0.548	0.449	0.504	0.496	0.545	0.600	0.476	0.485
Walk	0.484	0.414	0.458	0.496	0.496	0.516	0.504	0.393	0.431
Bike	0.512		0.402	0.512	0.508	0.508	0.543	0.403	0.447
Other	0.413	0.305	0.398	0.441	0.441	0.625	0.487	0.362	0.402
All Modes	0.447	0.448	0.453	0.483	0.482	0.536	0.491	0.355	0.441

Table A-61: Population within 45 mins by Transit (walk access)—Gravity formulation

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	145,995	140,044	121,596	120,675	122,849	131,642	122,777	121,506	125,901
Auto Passenger	159,472	138,922	124,452	124,092	130,394	136,553	113,330	127,858	127,903
Transit	225,086	425,011	228,954	243,457	221,355	263,257	224,410	241,726	235,525
Walk	177,991	210,219	178,251	181,851	187,016	170,285	179,501	154,493	159,464
Bike	151,065	352,981	143,213	196,503	176,463	126,460	122,906	139,764	139,905
Other	156,790	124,616	178,441	99,291	103,557	204,230	154,255	138,627	134,868
All Modes	150,262	159,636	138,875	128,043	131,981	142,093	127,634	130,919	133,117

Table A-62: Proportion of regional population within 45 mins by Transit (walk access)—Gravity Formulation

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.008	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007
Auto Passenger	0.009	0.008	0.007	0.007	0.007	0.008	0.006	0.007	0.007
Transit	0.013	0.024	0.013	0.014	0.013	0.015	0.013	0.014	0.013
Walk	0.010	0.012	0.010	0.010	0.011	0.010	0.010	0.009	0.009
Bike	0.009	0.020	0.008	0.011	0.010	0.007	0.007	0.008	0.008
Other	0.009	0.007	0.010	0.006	0.006	0.012	0.009	0.008	0.008
All Modes	0.009	0.009	0.008	0.007	0.008	0.008	0.007	0.007	0.008

Table A-63: Population within 45 mins by transit—not Gravity

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	626,749	625,243	541,286	514,425	528,102	555,647	527,104	524,522	539,374
Auto Passenger	694,715	627,373	545,954	527,746	542,727	613,619	491,253	549,375	550,391
Transit	808,186	1,416,782	889,810	841,490	773,709	960,770	741,563	865,568	843,869
Walk	628,719	782,025	682,769	635,495	655,698	634,326	659,527	596,360	610,746
Bike	610,473	1,083,769	630,822	693,473	639,867	300,931	469,795	547,721	553,529
Other	720,634	562,119	918,660	381,210	394,682	655,640	643,215	560,860	569,819
All Modes	636,405	675,506	587,368	529,902	544,922	588,239	533,126	548,814	556,773

Table A-64: Proportion of regional population within 45 min by transit—not Gravity

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.036	0.036	0.031	0.029	0.030	0.032	0.030	0.030	0.031
Auto Passenger	0.039	0.036	0.031	0.030	0.031	0.035	0.028	0.031	0.031
Transit	0.046	0.080	0.051	0.048	0.044	0.055	0.042	0.049	0.048
Walk	0.036	0.044	0.039	0.036	0.037	0.036	0.037	0.034	0.035
Bike	0.035	0.062	0.036	0.039	0.036	0.017	0.027	0.031	0.031
Other	0.041	0.032	0.052	0.022	0.022	0.037	0.037	0.032	0.032
All Modes	0.036	0.038	0.033	0.030	0.031	0.033	0.030	0.031	0.032

Table A-65: Population within 45 mins by Auto—Gravity formulation

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	400,065	376,122	377,263	354,898	355,168	377,412	366,809	350,823	361,846
Auto Passenger	405,757	422,986	357,069	358,193	373,050	367,558	342,928	349,593	353,855
Transit	567,207	872,040	508,680	599,262	571,357	608,523	601,980	576,837	571,612
Walk	467,032	523,429	494,452	490,824	498,093	464,490	493,066	421,774	428,856
Bike	480,180	892,972	326,204	507,996	469,216	564,885	436,592	397,167	391,587
Other	406,910	404,793	343,929	298,997	318,974	517,906	414,816	337,409	350,035
All Modes	407,127	414,094	388,889	369,410	375,253	389,885	375,572	364,799	372,493

Table A-66: Proportion of regional population within 45 mins by Auto—Gravity

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.023	0.021	0.021	0.020	0.020	0.021	0.021	0.020	0.021
Auto Passenger	0.023	0.024	0.020	0.020	0.021	0.021	0.019	0.020	0.020
Transit	0.032	0.050	0.029	0.034	0.032	0.035	0.034	0.033	0.032
Walk	0.027	0.030	0.028	0.028	0.028	0.026	0.028	0.024	0.024
Bike	0.027	0.051	0.019	0.029	0.027	0.032	0.025	0.023	0.022
Other	0.023	0.023	0.020	0.017	0.018	0.029	0.024	0.019	0.020
All Modes	0.023	0.024	0.022	0.021	0.021	0.022	0.021	0.021	0.021

Table A-67: Population within 45 mins by auto—not Gravity

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	3,808,822	3,614,578	3,757,338	3,480,294	3,483,721	3,617,295	3,583,202	3,515,610	3,561,822
Auto Passenger	3,859,283	4,199,605	3,563,222	3,509,335	3,621,727	3,508,197	3,422,976	3,479,555	3,492,937
Transit	4,798,090	6,239,603	4,380,445	4,910,218	4,774,639	4,822,180	4,903,333	4,799,696	4,773,895
Walk	4,105,889	4,420,103	4,519,270	4,345,424	4,348,129	4,142,847	4,390,878	3,941,955	3,970,418
Bike	4,498,564	6,769,668	3,219,907	4,424,127	4,224,654	4,419,760	4,227,504	3,761,392	3,713,851
Other	3,903,970	4,018,579	3,330,082	2,816,324	3,027,033	4,340,029	4,085,320	3,302,400	3,403,557
All Modes	3,846,581	3,826,888	3,780,589	3,570,231	3,610,223	3,657,002	3,636,063	3,591,710	3,619,980

Table A-68: Proportion of regional population within 45 min by auto—not Gravity

	Go To Work	Return To Work	Go To School	Shopping (All)	Shopping (HB only)	Medical/ Dental	Food Related	Return Home	All Trips
Auto Driver	0.216	0.205	0.213	0.198	0.198	0.206	0.204	0.200	0.202
Auto Passenger	0.219	0.239	0.202	0.199	0.206	0.199	0.194	0.198	0.198
Transit	0.273	0.354	0.249	0.279	0.271	0.274	0.279	0.273	0.271
Walk	0.233	0.251	0.257	0.247	0.247	0.235	0.249	0.224	0.226
Bike	0.256	0.385	0.183	0.251	0.240	0.251	0.240	0.214	0.211
Other	0.222	0.228	0.189	0.160	0.172	0.247	0.232	0.188	0.193
All Modes	0.219	0.217	0.215	0.203	0.205	0.208	0.207	0.204	0.206

References

[i] Kuzmyak, J. R., R. H. Pratt, B. Douglas and F. Spielberg. "Land Use and Site Design." *TCRP Report 95: Traveler Response to Transportation System Changes.* Vol. 15. Transit Cooperative Research Program, Transportation Research Board of the National Academy of Sciences, Washington, DC (2003).

[ii] Krizek, Kevin J. "Residential Location And Changes In Travel — Does Neighborhood-Scale Urban Form Matter?" *APA Journal*, Vol. 69, No. 3 (Summer 2003).

[iii] Ewing, R., P. Haliyur and G. Page. "Getting Around a Traditional City, A Suburban Planned Unit Development, and Everything in Between." *Transportation Research Record 1466* (1994).

[iv] Solimar Research Group, Inc. *Mixed-Use Centers in the South Bay: How Do They Function and Do They Change Travel Demand?* Report to the South Bay Cities Council of Governments, Los Angeles, CA (June 2005).

[v] Ewing, R., et al. "Traffic Generated by Mixed-Use Developments — A Six-Region Study Using Consistent Built Environmental Measures." *ASCE Journal of Urban Planning and Development*, 2010

[vi] Ewing, R. and R. Cervero. "Travel and the Built Environment: A Meta-Analysis." *Journal of the American Planning Association*, Vol. 76, No. 3 (Summer 2010).

[vii] *Development of Local Sustainability Model*. Final Report. Southern California Association of Governments, Los Angeles, CA (March 2010).