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https://doi.org/10.15760/etd.987

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Improving Vehicle Trip Generation Estimations for Urban Contexts:

A Method Using Household Travel Surveys

to Adjust ITE Trip Generation Rates

by

Kristina Marie Currans

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science
in
Civil and Environmental Engineering

Thesis Committee:
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Portland State University
2013

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Abstract

The purpose of this research is to develop and test a widely available, ready-to-use method for adjusting the Institute of Transportation Engineers (ITE) *Trip Generation Handbook* vehicle trip generation estimates for urban context using regional household travel survey data. The ITE *Handbook* has become the predominant method for estimating vehicle trips generated by different land uses or establishment, providing a method for data collection and vehicle trip estimation based on the size of the development (e.g. gross square footage, number of employees, number of dwelling units). These estimates are used in traffic impact analysis to assess the amount of impact the development will have on nearby transportation facilities and, the corresponding charges for mitigating the development's negative impacts, with roadway expansions, added turning bays, additional parking or traffic signalization, for example.

The *Handbook* is often criticized, however, for its inability to account for variations in travel modes across urban contexts. For more than fifty years, ITE has collected suburban, vehicle-oriented data on trip generation for automobiles only. Despite the provision of warnings against application in urban areas, local governments continue to require the use of the ITE *Handbook* across all area-types. By over predicting vehicle traffic to developments in urban developments, developments may be overcharged to mitigate these developments locating in urban environments despite the lower automobile mode shares, discouraging infill development or densification. When ITE's *Trip Generation Handbook* overestimates the vehicle impact of a development, facilities are

also overbuilt for the automobile traffic and diminishing the use of alternative modes. When ITE's *TGH* underestimates this impact, adjacent facilities may become oversaturated with traffic, pushing cars onto smaller facilities nearby. Currently, there is momentum amongst practitioners to improve these estimation techniques in urban contexts to help support smart growth and better plan for multiple modes.

This research developed and tested a method to adjust ITE's *Handbook* vehicle trip generation estimates for changes in transportation mode shares in more urban contexts using information from household travel surveys. Mode share adjustments provide direct reductions to ITE's *Handbook* vehicle trip estimations. Household travel survey (HTS) data from three regions were collected: Portland, Oregon; Seattle, Washington; and Baltimore, Maryland. These data were used to estimate the automobile mode share rates across urban context using three different adjustment methodologies: (A) a descriptive table of mode shares across activity density ranges, (B) a binary logistic regression that includes a built environment description of urban context with the best predictive power, and (C) a binary logistic regression that includes a built environment description of urban context with high predictive power and land use policy-sensitivity. Each of these three methods for estimating the automobile mode share across urban context were estimated for each of nine land use categories, resulting in nine descriptive tables (Adjustment A) and eighteen regressions (Adjustments B and C). Additionally, a linear regression was estimated to predict vehicle occupancy rates across urban contexts for each of nine land use categories.

195 independently collected establishment-level vehicle trip generation data were collected in accordance with the ITE *Handbook* to validate and compare the performance of the three adjustment methods and estimations from the *Handbook*. Six land use categories (out of the nine estimated) were able to be tested. Out of all of the land uses tested and verified, ITE's *Trip Generation Handbook* appeared to have more accurate estimations for land uses that included residential condominiums/townhouses (LUC 230), supermarkets (LUC 850) and quality (sit-down) restaurants (LUC 931). Moderate or small improvements were observed when applying urban context adjustments to mid-rise apartments (LUC 223), high-turnover (sit-down) restaurants (LUC 932). The most substantial improvements occurred at high-rise apartments (LUC 222) and condominiums/townhouses (LUC 232), shopping centers (LUC 820), or coffee/donut (LUC 936) or bread/donut/bagel shops (LUC 939) without drive-through windows. The three methods proposed to estimate automobile mode share provides improvements to the *Handbook* rates for most infill developments in urban environments.

For the land uses analyzed, it appeared a descriptive table of mode shares across activity density provided results with comparable improvements to the results from the more sophisticated binary logistic model estimations. Additional independently collected establishment-level data collections representing more land uses, time periods and time of days are necessary to determine how ITE's *Handbook* performs in other circumstances, including assessing the transferability of the vehicle trip end rates or mode share reductions across regions.

To my snickerdoodles…

…and everyone in the lab.

Acknowledgements

I would like to acknowledge Dr. Kelly Clifton and my committee for advising me through this research. Additionally, thank you to Brian Bochner of the Texas Transportation Institute and Robert Schneider of the University of Wisconsin-Milwaukee for providing good insight and advice during the analysis of this study. I would also like to acknowledge the Dwight David Eisenhower Graduate Fellowship program and the Oregon Transportation Research and Education Consortium for funding me during my education. Thank you to the Institute of Transportation Engineers for providing data to help with this analysis. Finally, thank you to Daft Punk, Justice and Deadmau5 for picking up the pace during the writing process, my fellow lab students and coworkers for being an excellent support net, and Suki's for always being open.

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1.0 Introduction

The Institute of Transportation Engineers (ITE) *Trip Generation Handbook* (Institute of Transportation Engineers, 2004) and its corresponding *Information Report* (Institute of Transportation Engineers, 2008)[1] has become the predominant method for estimating vehicle trips generated by different land uses or establishments. With data collected from more than 5,500 studies across 170 land uses, the *Handbook* provides average trip rates and equations to estimate vehicle trips generated for land uses ranging from coffee shops to commercial airports. The *Handbook* was originally developed to provide a widely available, ready-to-use method for determining the impact of new or renovated developments on the nearby transportation facilities (Institute of Transportation Engineers, 2004; Gard, 2007) and has become the industry standard.

The typical, generalized process of traffic impact analysis is shown in Figure 1.A following. Here, the practitioner considers the land use being developed, estimates the vehicle trip generation (e.g., applies the ITE *Trip Generation Handbook*), and assesses the change in the value of performance measures (e.g., changes in the facility level of service). The practitioner then determines whether to (a) change the amount of traffic generated by alternating the development (such as building a smaller store or residence),

[1] The ITE *Trip Generation Handbook* provides data collection and usage guidance for the *Informational Report*, which contains all the collected data. References to the *Handbook* include both a reference to the data collection and vehicle trip estimation methodologies, as well as the data provided by the *Informational Report.*

or (b) mitigate the problem through improved transportation facilities in order to meet the local performance measure standards.

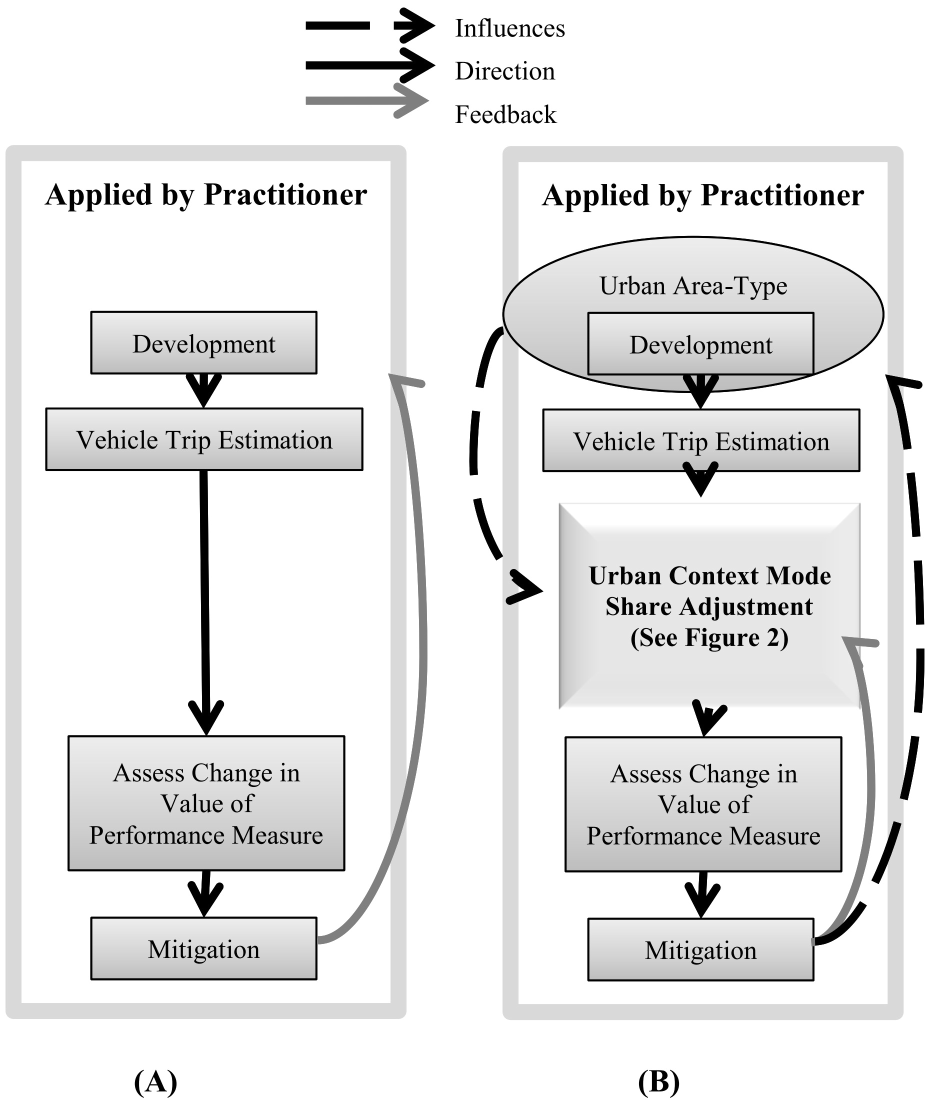

Figure 1. (A) Typical Traffic Impact Analysis Process, Generalized, and (B) Proposed Adjustment to Traffic Impact Analysis for Urban Context

Regardless of intentions, ITE *Trip Generation Handbook* is often applied incorrectly in many urban contexts. “If the site is located in a downtown setting, served by significant public transportation… the site is not consistent with the ITE data” (Institute of

Transportation Engineers, 2004). For these area-types, ITE recommends using local data instead, collected in locations similarly situated within the urban context. Despite this limitation, for more than fifty years, this nationally-available method has been applied to countless developments across urban, suburban and exurban area-types to estimate development impacts on transportation facilities and is used as a basis for prescribing vehicle-oriented design, such as adding capacity to roadways, increasing maintenance and operation funding for nearby facilities, increasing or adding turning bays into the development, or altering signalization to accommodate these additional vehicle trips. ITE recognizes the limitations of the *Handbook's* data, and reminds the analyst to consider the environment (e.g., amount of mixed use, employment or population density, floor-to-area ratio of development scale, availability of high-quality transit) surrounding the development before applying the estimation methodology. There is limited information in the *Handbook* to account for more urban contexts or multimodal trips as it "provides no recommended practices, procedures, or guidelines" (Institute of Transportation Engineers, 2004). ITE is currently in the process of updating both the methodology for data collection and estimation of traffic, but extensive multimodal, detailed data will not likely be available for some time. For the time being, local governments continue to be hampered by methods of estimating transportation impact that are simply not sensitive to any urban environment (Clifton, Currans, & Muhs, 2012; Nelson\Nygaard Consulting Associates, 2005; Rizavi & Yeung, 2010; Schneider, Shafizadeh, & Handy, 2013; Shafizadeh, Lee, Niemeier, Parker, & Handy, 2012).

When urban settings are not considered while applying ITE's *Trip Generation Handbook*, the resulting multimodal traffic is ignored and all persons arriving/leaving the development are assumed to come by vehicle. As a result, vehicle trip counts are often overestimated for many land uses (Clifton, Currans, & Muhs, 2012; Daisa, et al., 2009; Schneider, Shafizadeh, & Handy, 2013). This, potentially inflated, vehicle trip generation estimate forms the basis of traffic impact analysis on facilities adjacent and nearby the planned development. The local government's standards mitigate these impacts by charging the developer transportation impact fees to increase capacity of the local roadways to account for added vehicle traffic. Overestimation of vehicle trips, therefore, leads to more vehicle-oriented design often to the exclusion of other modes. If we are consistently over-predicting automobiles trips coming to urban land uses we may be over charging for their transportation impacts. Likewise, these capacity-increasing mitigations may be creating more obstacles and barriers in the long run for the patrons that are arriving by bike, foot or transit.

This research addresses the need for adjusting vehicle trip estimates derived from ITE's *Trip Generation Handbook* for urban contexts accounting for non-automobile travel in areas with greater density, accessibility to transit, or a diversity of land uses. In this research, we utilize data from regional household travel surveys (HTS) to develop these methods to adjust the *Handbook's* vehicle-oriented trip rates. These methods of adjustment are then tested using independently collected, establishment-level data for a variety of land uses in accordance with ITE's *Trip Generation Handbook* methodologies. The aim of this research is not to replace ITE's *Handbook* and data, but rather to develop a widely-available, ready-to-use adjustment for urban contexts to supplement the *Handbook* until more urban-sensitive data can be collected and more robust methods for estimation are available (Figure 1.B).

The adjustment approach used in this research is a mode share and vehicle occupancy adjustment. Here, we assume ITE's *Handbook* estimates are only collected in explicitly vehicle-oriented location, as they suggest, and therefore observe only vehicle trips (no walking, biking or transit), unless otherwise stated. Additionally, we assume that the number of persons per vehicle is one, unless otherwise stated. From these assumptions, a mode share and vehicle occupancy adjustment applies a direct reduction, substituting vehicle trips for additional vehicle passengers or non-automobile person trips. The process for calculating a mode share adjustment is shown in Figure 2 and elaborated further in Chapter 3.0. The result of this framework is a vehicle trip estimate that account for the urban context and corresponding non-automobile mode share.

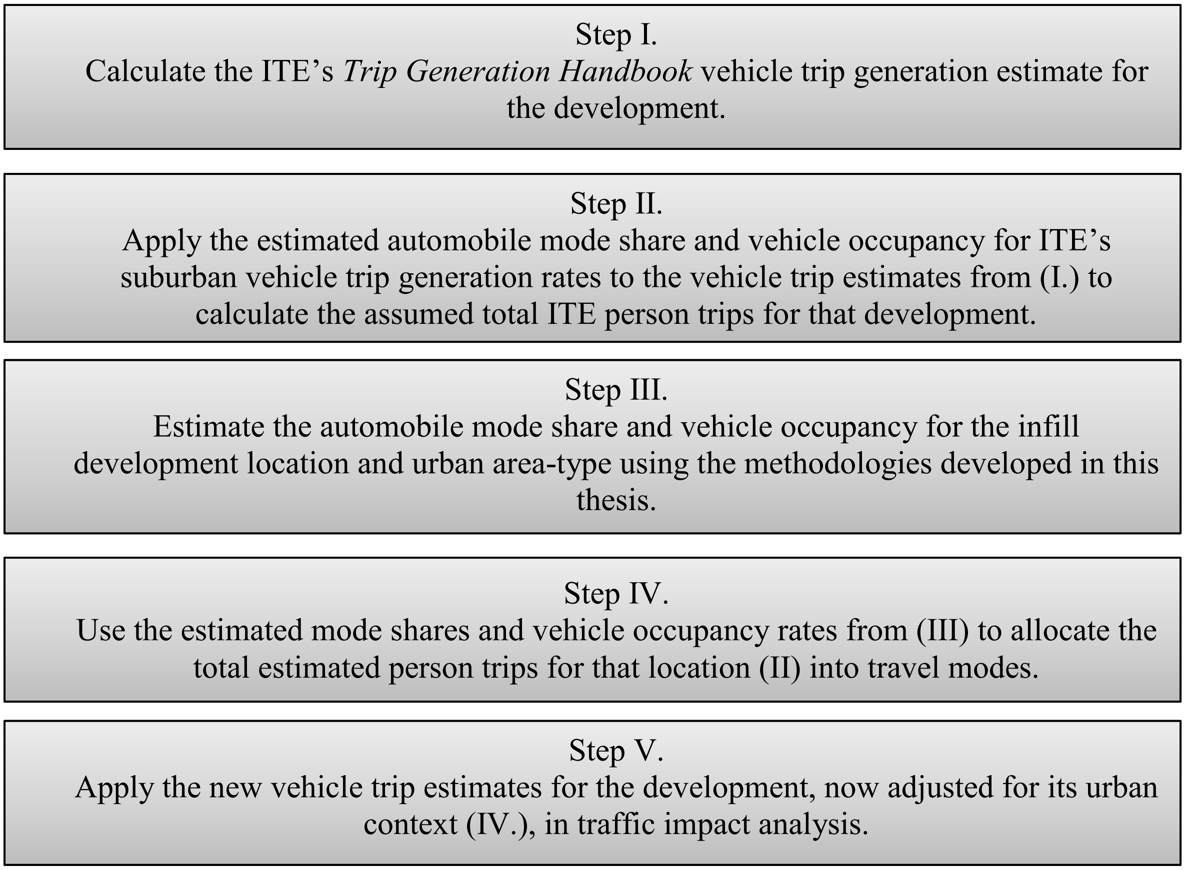

Figure 2. Urban-Context Mode Share Adjustment: Applied to ITE's *Trip Generation Handbook* Vehicle Trip Estimates

The product of this research is to provide a method to estimate automobile mode shares and vehicle occupancy rates at urban locations (Step III, Figure 2) within the proposed urban-context mode share adjustment. Two types of data are used to develop the equations necessary for estimation of the automobile mode shares and vehicle occupancy rates: household travel survey (HTS) data and built environment information. The HTS data allows us to observed travel choices across a broad spectrum of urban contexts. From this data, we collect information related to the timing of the arrival and departure, the day of the week and the month in the year. These data are related to the urban context by collecting built environment information in the locations surrounding each trip end, such as the residential density, intersection density, and percent of employment that is retail. Automobile mode share and vehicle occupancy equations are then estimated by relating these travel observations from HTS further defined by the trips urban context. The product of this research is then equations for estimating automobile mode share and vehicle occupancy rates to apply to ITE's *Trip Generation Handbook* using a mode share adjustment (see Figure 3 for the process of this thesis). Multiple methods of estimation are developed in this process, and therefore these methods are tested and compared to ITE's *Trip Generation Handbook* estimation using independently-collected data.

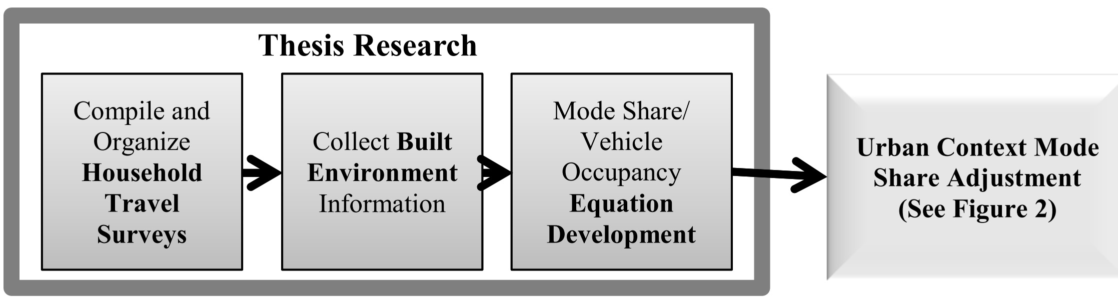

Figure 3. Process and Contribution of This Research

The remainder of the thesis is organized as follows. First, the literature review in Chapter 2.0 investigates: the degree of error found in ITE's *Handbook* estimates for land uses in a variety of urban environments (Section 2.1), the range of tools available for estimating vehicle trip generation and how different jurisdictions deal with vehicle trip generation estimation (Section 2.2), and an academic literature review investigating the known relationships between the built environment and travel behavior (Section 2.3). The results of this review suggest that there are few widely-accessible, ready-to-use tools available to improve vehicle trip estimations in urban areas without requiring a substantial amount of local data.

Chapter 3.0 outlines the framework used to develop an urban-context, mode-share adjustment using household travel survey. This chapter discusses the three different mode share adjustment approaches developed during this analysis (Section 3.0):

Adjustment A: Single mode share table by a single built environment metric;

Adjustment B: Regression using the built environment metric with the best model performance; and

Adjustment C: Regression using a built environment metric with a strong model performance that is sensitive to land use policy.

The first methodology is a simple, descriptive table summary of the multimodal mode share; the second and third are automobile-specific mode share models. For each land use category considered (e.g., general residential, multifamily residential, single-family residential, office, retail, restaurants, non-restaurant service, entertainment/recreational, all land uses), all three adjustments were developed for a total of nine multimodal mode share tables (Adjustment A) and eighteen binary logistic regressions predicting automobile mode share (Adjustment B and C). Additionally, linear regression models were developed to estimate vehicle occupancy for each of the nine land use categories. Section 3.2 provides additional information on how the data were collected, organized and applied to each of these adjustment methods.

To validate the application of these adjustments, the methodologies were applied to 195 independently collected vehicle trip generation data points collected in accordance with ITE's *Trip Generation Handbook*. Section 3.4 describes the application of the three urban adjustment methods to the establishment-level data and how these adjusted estimates compared to ITE's *Handbook* estimates.

The results of the three adjustment methodologies are discussed in Chapter 4.0. In this chapter, the nine tables and twenty-seven regressions are provided and discussed. Additionally, the results of the validation process are compared for each of the land uses categories. The performance of ITE's estimates and the urban context adjustments varies for each specific land use tested. One trend can be seen, however. For many of the land uses, the urban-context adjustment estimates provide improvements in the overall accuracy of estimation. Moreover, Adjustment A, the table of average mode shares by urban context provides competitive results with the more sophisticated binary logistic models of automobile mode shares, suggesting that a crude adjustment based on overall mode shares may perform just as well as a more sophisticated model. Additionally, using a descriptive table of mode shares across urban context allows for more detailed information about observed non-automobile mode shares which may help the analyst provide non-automobile facilities in areas where there will likely be a greater walk, bike or transit mode shares. Chapter 5.0 provides a discussion on the overall conclusions from this research including the limitations of using household travel surveys, the representation of the built environment in the adjustment models developed and advancing the techniques applied in this research for more robust estimation.

2.0 Literature Review

This literature review has three purposes. First, this review summarizes the academic and professional studies examining the predictive ability of ITE trip generation rates for different urban contexts. Second, we identify approaches to deal with the deficiencies in ITEs trip rates for different contexts. The last section relates the literature on the relationship between travel behavior and the built environment to this study: we aim to better inform which aspects of the built environment should represent context.

2.1 Evaluation of ITE Trip Generation Rates

There have been many studies which evaluate the error in estimation of ITE Trip Generation rates compared to observed study values. These ranges of error, shown in Table 1[2], identify the large error range of results found from the variety of studies. To compare the error in ITE trip generation estimation, Equation 1is used. A negative rate indicates estimated vehicle trip counts being larger than those observed in the study.

Equation 1. ITE Trip Rate Error Equation

$$Estimated\ Error = \frac{Observed\ Vehicle\ Trip\ Rate - ITE\ Estimated\ Vehicle\ Trip\ Rate}{ITE\ Estimated\ Vehicle\ Trip\ Rate}$$

As shown in Table 1, the greatest range of error in ITE estimation of vehicle trips occurs in Central Business District/Urban Core/Downtown areas. One retail shop studied in

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[2] Sources include (Samdahl, 2010; Hooper, 1989; Fehr & Peers, 2008; Schneider R. J., 2011; Lee, et al., 2011; Daisa, et al., 2009; Cervero & Arrington, 2008a; Cervero & Arrington, 2008b; Dill, 2008; Lapham, 2001; Colorado/Wyoming ITE Section Technical Committee - Trip Generation, 1987; Jeihani & Camilo, 2009; Sperry, 2010).

Oakland, California had an observed AM peak trip count of 133 vehicle trips and an ITE estimated trip count of 11 vehicle trips. When this establishment is treated as an outlier, Mixed-Use Developments then show the greatest range of variation in error in estimation. Retail and residential developments tend to be both over and under estimated when using ITE Trip Generation rates. Standard deviations provided by ITE Trip Generation rates were not used in this assessment.

Prediction of vehicle trip generation rates is most complex when a variety of land uses are accessible within a single dense development site. For these sites, ITE provides a methodology to handle the interaction of land uses. But, this method has not been shown to be as effective as other alternatives (see the next section) developed to estimate vehicle trip generation rates at mixed-use sites (Lee, et al., 2011).

Table 1. ITE Trip Rate Error: Findings from the Literature

	AM Peak			PM Peak			Automobile Mode Share		
Central Business District/Urban Core/Downtown	**-93%**	to	**1109%**	**-99%**	to	**11 %**	**8**	to	**100 %**
Eating / Restaurant	-93%	to	-57%	-99%	to	-70 %	17	to	57 %
Office	-80%	to	-22%	-62%	to	-21 %	56	to	95 %
Residential	-83%	to	15%	-80%	to	11 %	14	to	85 %
Restaurant		-35%			-26%		34	to	60 %
Retail	-17%	to	1109%*	-22%	to	8 %	8	to	100 %
Services		-14%			-66%				
Shopping		30%			3%				
Mixed-Use Development	**-109%**	to	**181%**	**-170**	to	**61 %**			
Mixed	-109%	to	38%	-80	to	61 %			
Town Center	-108%	to	181%	-170	to	-35 %			
Transit-Oriented Development	**-90%**	to	**20%**	**-92**	to	**35 %**	**50**	to	**96 %**
Office							50	to	96 %
Residential	-90%	to	20%	-92	to	35 %	53	to	93 %
Development near transit	**-58%**	to	**72%**	**-36**	to	**51 %**	**28**	to	**90 %**
Office							28	to	90 %
Residential	-58%	to	72%	-36	to	51 %	33	to	82 %
Suburban Activity Centers and Corridors	**-37%**	to	**-5%**				**54**	to	**98 %**
Office	-37%	to	-20%						
Residential		-5%							
Shopping							54	to	98 %

* This retail shop located in Oakland, California had an observed AM peak trip count of 133 vehicle trips and an ITE estimated trip count of 11 vehicle trips.

The automobile mode share is provided in Table 1 for studies that counted person trips and calculated persons taking a vehicle. The Central Business District/Urban Core/Downtown area shows the largest range of automobile mode share. But, sites in Suburban Activity Centers and Corridors contain a substantial range: automobile mode shares were observed to be as small as 54%.

2.2 Adjustments & Alternatives to ITE methodology

The ITE Trip Generation Report and Handbook are the most commonly referenced and utilized practical guidelines for predicting vehicle trip rates during the development process. However, sites studied by ITE are often limited to vehicle-oriented, suburban locations with little to no public transportation or bicycle and pedestrian facilities. Jurisdictions that require traffic impact studies often provide guidelines on how to approach local vehicle trip rate adjustments for sites with mixed-uses, presence of transit, bicycle/pedestrian amenities, or transportation demand management practices in place. This section reviews a selection of jurisdictional guidelines in North America and then reviews existing models that predict vehicle trip generation rates based on factors that encompass context and mixed land uses.

2.2.1 Jurisdictional Guidelines on Adjustment to ITE Trip Generation

This section details a review of 23 jurisdictional guidelines for local adjustment from around the United States and Canada. These guidelines originate from mega cities like New York City, New York to smaller, lower-density places like Bend, Oregon. These compiled guidelines identify trends in estimation of trip generation rates and traffic impact studies currently in practice. Table 2[3] shows how the guidelines approach ITE

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[3] Sources include (Bedford County Department of Planning, 2004; Baltimore City Department of Transportation, 2007; Montgomery Planning, 2010; Harris County, Texas, 1991; City of Vancouver, 2010; City of Sedro-Woolley, 2004; City of Henderson, Department of Public Works, 2009 February; Charlotte Department of Transportation, 2006; City of Pasadena, 2005 August 24; Georgia Regional Transportation Authority (GRTA), 2002; Southern New Hampshire Planning Commission, 2010; San Francisco Planning Department, 2002; City of Bend, 2003 May 7; San Diego Municipal Code, 2003; San Diego Association of Governments (SANDAG), 2010; Virginia Department of Transportation, 2010; City of Rockville, 2011;

vehicle trip rates and adjust vehicle trip rates based on public transit, bicycle and pedestrian facilities, and mixed-use sites. More generally, the guidelines are summarized as follows:

- 22 jurisdictions reference ITE Trip Generation rates and methods as being appropriate in their local contexts, barring the presence of local rates or studies are not available.[4]

- Six jurisdictions have methods that allow for bicycle, pedestrian or transit adjustments to be applied from mode share information. One of these jurisdictions requires documentation of vehicle occupancy data in order to apply these adjustments (City of Frisco, 2005).

- Six jurisdictions provide local vehicle trip generation rates of some sort. These areas tend to be more urban or have large authority areas (Montgomery Planning, 2010; Southern New Hampshire Planning Commission, 2010; San Francisco Planning Department, 2002; San Diego Municipal Code, 2003; City of Mississauga, 2008; New York City, 2010).

- 11 jurisdictions provide conditions or thresholds that require a traffic impact study at a particular development site. Conditions are based on vehicle traffic

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City of Los Angeles Department of Transportation, 2010; City of Mississauga, 2008; New York City, 2010; State of Flordia Department of Community Affairs, 2006; City of Salem, 1995; City of Bellingham, 2012a; City of Bellingham, 2012b)

[4] The 23rd study did not specifically reference the *ITE Trip Generation Handbook* as being appropriate or not appropriate. It appears that ITE methodologies may be acceptable, provided no better-fitting methods are available.

thresholds, land use plan requirements, or stipulations associated with development near roadway facilities with congestion and/or access problems. Of these jurisdictions, ten jurisdictions use vehicle trip thresholds. Table 3 shows the wide range of vehicle trip thresholds for a traffic impact study used by these ten jurisdictions. Decisions on the depth required of the impact analysis typically occur on a case-by-case basis.

Table 2. Traffic Impact Study Guidelines: Findings from 23 Jurisdictions

Trip Generation Methodologies

- 15of 23: Allow use of ITE Trip Generation rates as a primary method.
- 7 of 23: Allow use of ITE Trip Generation rates as an alternative method (typically after the use of locally provided rates or comparable data collection).
- 4 of 23: Provide some maximum reduction applicable to trip generation methodologies.
- 3 of 23: Recommend using previously collected and stored trip generation rates. WSDOT
- 6 of 23: Provide local trip generation rates to be used as a primary source for estimation. Three of these include some combination between local rates and ITE rates using travel surveys to inform the transition between vehicle trips and person trips (mode share and vehicle occupancy).
- 6 of 23: Recommend comparable data collection to development type and location. This is also recommended with in ITE Trip Generation methodologies.
- 1 of 23: Allow for alternative methods to be used, upon approval.

Transit Adjustments

- 14 of 23: Allow some adjustment for transit use.
- 7 of the 14: Provide fixed trip credit or percent adjustment for transit accessibility.
- 6 of 14: Allow for application of mode share rates. One of these mentioned the need for documentation of vehicle occupancy.
- 2 of 14: Provide maximum transit reductions limitations.
- 2 of 14: Provide reductions based on location within Transit-Oriented Development (TOD) or Area (TOA).

Bike/Walk Adjustments

- 13 of 23: Allow some adjustment walking or bike travel.
- 6 of 13: Allow for application of mode share rates. One of these mentioned the need for documentation of vehicle occupancy.
- 3 of 13: Provide fixed trip credit or percent adjustment for walk/bike amenities.
- 1 of 14: Provide maximum reductions (combined with transit reductions) limitations.

Mixed-Use or Internal Capture Adjustments

- 14 of 23: Allow some internal capture or mixed-use adjustments.
- 5 of 14: Accept ITE Trip Generation Internal Capture methods or data as being acceptable.
- 2 of 14: Provide maximum internal capture rate adjustments.
- 2 of 14: Provide fixed internal capture adjustments or guideline based on local context.

Miscellaneous Comments

- 7 of 23: Allow for reductions for transportation demand management (TDM) methods.
- 4 of 23: Provide some adjustment or special local rate by area-type or district.
- 11 of 23: Provide some guidance on a threshold of requirements before a Traffic Impact Study (TIS).

Table 3. Trip Generation Thresholds Requiring Traffic Impact Study (TIS)

Jurisdiction	Daily Threshold (vehicle trips)	PM Peak Hour Threshold (vehicle trips)	Peak Hour Threshold (vehicle trips)
Bedford County, VA	500	-	-
Montgomery County, MD	-	-	30
Pasadena, CA	70	-	11
Sedro-Woolley, CA	500	-	50
Henderson, NV	-	-	100
Charlotte, WV	2,500	-	-
San Francisco, CA	-	50	-
San Diego, CA	500-1000	-	50-100
Mississauga, Canada	-	-	75
New York City, NY*	-	-	50

For sources, see page 13, footnote 3.

*Also provides thresholds for transit trips and pedestrian/bike trips generated as basis of required transit and pedestrian/bicycle impact studies.

2.2.2 Alternative Models and Approaches

ITE also recommends using an approach developed by JHK & Associates, et al. (1996) published in the ITE Handbook (Institute of Transportation Engineers, 2004) with considers reductions in vehicle trip generation for locations in closer proximity to transit with supportive land uses (e.g. greater density, higher floor-to-area ratios, available pedestrian and bike facilities). This report was published as a draft, and is only presented in the handbook as a guide, does not necessarily pressent reductions based on context. ITE has also supported other methodologies for determining reductions including Gard's approach for transit-oriented developments (2007) using multimodal information to provide development wide reductions (assuming vehicle-occupant trip to non-vehicle trip substitution). There is evidence of at least one firm that is attempting to provide a summary of context-sensitive, establishment-level data collections online at a site called TripGenie. The company ARUP has collected data from published studies, similar to those summarized in Table 1, and created a query-based tool to search for similar land uses and urban contexts (ARUP, 2012).

Internationally, there are two systems which have considered context in developing trip generation methods. Both the Trip Rate Information Computer System (TRICS) of the UK and Ireland and the New Zealand Trips and Parking Database Bureau (NZTPDB) provide an online data sets which include information on the area-type the data site was collected in, allowing the user to determine if the trip rates provided meet the environment of the site being estimated. Although the NZTPDB is relatively new, the established TRICS data set provides multimodal information for each site collected, and only retains sites less than 10 years old (New Zealand Trips and Parking Database Bureau (NZTPDB), 2012; Trip Rate Information Computer System (TRICS), 2012).

The Austrailian-based system “New South Wales Roads and Traffic Authority” provides a dataset comparible to the ITE Handbook, and like ITE, does not consider urban context in vehicle trip generation estimates. All data are aggregated into trip rate statistics and no site-level information is provided. When land use trip rates are not available for Austrailia, the ITE Handbook is a recommended option (New South Wales Roads and Traffic Authority, 2002). There has been little literature providing comparisons and justifications for sharing intercountry trip generation data (Clark, 2007).

There are also a few models available for application to the site-level development to determine potential adjustments to trip generation. URBEMIS is a pivot-model developed by Nelson/Nygaard Consulting Associates et al (2005) which applies relationships developed from previous literature between a variety of build environment characteristics with vehicle trip generation rates. The adjustment in estimated vehicle trips is then applied to the ITE trip generation estimates. A “default” or “standard” understanding of contexts for ITE trip generation data are assumed. A portion of the model was also developed fo rthe California air pollution control disticts to help developers understand and mitigate emmissions problems at the development-level. For an area such as Kent, Washington, the URBEMIS model estimated reductions in ITE Trip Generation rates for the Central Business District to be rougly 15-20% (Samdahl, 2010).

Another post-processor is the INDEX tool used to assess the environmental impact at site-level developments baesd on changes to the built environment. This GIS-based post-procesor utilizes regional 4-step model output to determine changes in the built environment which may effect certain aspects of travel. While this tool to not explicitly estimate changes to estimates of vehicle trips generated, it remains a potential source for evaluating changes in site-level development (Hagler Bailly Services, Inc. and Criterion Planners/Engineers, 1999).

Although out of the scope for this study, a few models and projects have been focusing on multi-use developments which tend to have increased levels of internal-capture due to the close proximity and design of such developments.

Recent research has been working to improving the estimates of internal trip capture at mixed-use developments. NCHRP Report 684, “Enhancing Internal Trip Capture Estimation for Mixed-Use Developments”, identifies of mixed-use development characteristics that affect the level of internal capture trips. The report also investigates data collection frameworks and protocols to develop reduction rates based on internal capture levels. For mixed-use sites, this method has been shown to improve accuracy reducing error from observed rates from 35-59% using ITE methods to 13% using the provided method (Bochner, Hooper, Sperry, & Dunphy, 2011). As with the research discussed earlier, this research only applies to multi-use development sites, not locations within areas of high mixed-use.

There are also two models, MXD model (Fehr & Peers) and the 4D model (Environmental Protection Agency - EPA) which account for elasticities and impacts of contextual factors like density and diversity when predicting vehicle demand. Both models can be applied universally and do not require local data collection. Research suggests that the use of the MXD model may result in a 26% error compared with actual surveyed counts, compared with a roughly 40% error using *ITE Trip Generation Handbook* rates and a 32% error using *ITE Trip Generation Handbook* rates and reductions (Walters, 2009). The San Diego Association of Governments have utilized the MXD model to determine “smart growth” vehicle trip generation rates that are better suited for the local region, including some application on multi-use and internal capture at sites such as transit-oriented developments. One study suggests that use of the MXD model and application of local households travel survey data provides reductions in error from 29% to 9%, compared to locally derived vehicle trip rates (San Diego Association of Governments (SANDAG), 2010).

Additionally, in progress is the NCHRP 8-66 Project, *Trip-Generation Rates for Transportation Impact Analyses of Infill Developments*, which aims to:

> "develop an easily applied methodology to prepare and review site-specific transportation impact analyses of infill development projects located within existing higher-density urban and suburban areas. For the purposes of this study, "methodology" refers to trip-generation, modal split, and parking generation. The methodology will address both daily and peak-hour demand for all travel modes."

There are alternative methodologies to adjust *ITE Trip Generation Handbook* rates, but as of yet, none have shown to deliver consistent results (Lee, et al., 2011).

2.3 Travel Behavior in Urban Contexts

This section reviews the literature on travel behavior and the built environment as it pertains to urban context. Recognizing that this is a vast literature, we focus on a few meta-studies and emphasize vehicle trips and mode choices, rather than vehicle miles traveled. We seek to identify the built environment characteristics that relate to contextual definitions and are associated with reduced automobile traffic and greater non-automobile travel.

2.3.1 Built Environment

This section introduces built environment attributes that are shown in the literature to have a significant impact on automobile trips. These elements of the built environment are often grouped into categories reflecting the "D's of development": Density, Diversity, Design, and Distance to Transit (Cervero & Kockelman, 1997; Ewing & Cervero, 2001). This section is categorized as such.

Density

Employment and residential density both influence mode choice. One study suggests that the main benefit to greater densities is destinations become closer to origins (Lund, Cervero, & Willson, 2004). Another study found relevance in employment and residential density: by doubling residential density, household vehicle miles traveled may be reduced by 5%, and in some locations as much as 25% when additional factors like proximity to transit and mixed land use are also improved (Committee for the Study on the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption 2009). High-density residential and employment areas also allow for easy provision of high-quality transit (those with lower service headways) because origin-destination pairs become concentrated.

Overall, the literature suggests increased density is correlated with reductions in the number of vehicle trips taken. In a synthesis of influences on the built environment, the aggregate (linear) elasticity of density and vehicle trips is -0.05, suggesting that as density increases by 10%, the number of vehicle trips decreases by 5% (Ewing & Cervero, 2001).

Diversity (Land Use Mix)

Diversity, or land use mix, is measured in many ways. Simple measures include the percentage of commercial land use to total land and the percentage of single-family detached dwellings to total dwellings. More complex are measures of entropy, gravity or dissimilarity (D'sousa, et al., 2012). The results of one study suggest that although density is often used to justify the development of transit, it is the land use mix which tends to support transit use (Seskin, Cervero, & Zupan, 1996). In vehicle trip generation studies, areas with mixed uses tend to have greater reductions in vehicle trip generation. For example, Fehr & Peers conducted a trip generation study in Sacramento and the San Francisco Bay Area within the following mixed-use developments: (1) a medium-sized, dense suburban area; (2) a medium-sized, medium/high density downtown area with high employment; and (3) a large, low density, suburban residential area. They found that the downtown area (2) had roughly 12% fewer vehicle trips compared with ITE estimates. The areas in the suburbs (1) and (3), tended to have 45% fewer trips than ITE estimates. This same study calculated the internalization of trips and found that for all three mixed-use types, roughly 30%, 25%, and 7% reductions in internalization of trips compared with *ITE Trip Generation Handbook* was possible even at low densities when mixed land uses are present (Meisel, 2010).

Another study found that the greater density of discretionary businesses located within an area promotes non-motorized trips, and land use mix measured within a quarter mile of a traveler's residence tends to be correlated with additional observed reductions in motorized discretionary travel (Guo, Bhat, & Copperman, 2007). In a 2001 synthesis, the aggregate (linear) elasticity of diversity or mix and vehicle trips was found to be -0.03: as diversity increases by 10%, the number of vehicle trips decreases by 3% (Ewing & Cervero, 2001).

Design

Design here reflects the street network within a particular area: typical measures include average block size, proportion of four-way intersections, number of intersections per area, sidewalk coverage, average building setbacks, average street widths, presence or number of pedestrian crossings, presence of street trees, street lights, street furniture, or other pedestrian-oriented amenities. The macro-scale measures here—average block size, proportion of four-way intersections, intersections per area—are characteristics that reflect street network connectivity. Micro-scale measures of street trees, street lights, street furniture, and pedestrian amenities reflect the walkability of neighborhoods.

The macro-scale design measures that describe the broader street network are typically significant in determining many travel behavior measures. Higher connectivity enables travelers to walk shorter distances to get from point A to point B. A grid street network (the pattern with the highest connectivity) allows multiple routes that are rather direct between two points, whereas a layout with cul-de-sacs and arterial roads restricts the number of possible routes and usually increases travel distance on the network. Research shows that high street connectivity (Lund, Cervero, & Willson, 2004) and smaller block sizes (Seskin, Cervero, & Zupan, 1996) are associated with transit use. Network connectivity near the residence also significantly affects the number of non-motorized trips taken by travelers (Guo, Bhat, & Copperman, 2007). In a synthesis of influences on the built environment, the aggregate (linear) elasticity of street network density (a design measure) and vehicle trips is -0.05, suggesting that as street network density increases by 10%, the number of vehicle trips decreases by 5% (Ewing & Cervero, 2001).

Micro-scale design measures—presence of street trees, street lights, and street furniture—have positive impacts on neighborhood walkability (Lund, Cervero, & Willson, 2004). But, these effects are modest when compared to measures representing the other D's of development and data for these site-level measures are more difficult to gather than larger and broader built environment measures.

The design measures of sidewalk coverage and barriers to walking have been studied as they relate to transit use. Transit ridership and the amount of streets with sidewalks are positively correlated (Seskin, Cervero, & Zupan, 1996). The number of "conflict points" on a pedestrian route surrounding a transit station is negatively correlated to accessing transit by foot (Seskin, Cervero, & Zupan, 1996).

Distance to Transit

The *ITE Trip Generation Handbook* provides some guidance on typical transit accessibility reductions based on other built environment characteristics such as density and presence of pedestrian facilities. As the distance from transit increases, the ridership or demand of transit decreases. The handbook also suggests that distance to rail generates different demand than distance to bus. *ITE Trip Generation Handbook* suggests rate reductions between 5% and 20% for locations within a quarter mile of light rail or near transit centers. The *ITE Trip Generation Handbook* suggested rate reductions are 2.5% to 10% for locations within a quarter mile of bus transit corridors. The ranges of *ITE Trip Generation Handbook* reductions are due to accounting floor area ratios and mixed land uses. As floor area ratios and mixing of land uses increase, higher levels of reductions occur (Institute of Transportation Engineers, 2004).

Reducing vehicle trip generation rates near transit is supported in the literature. A San Francisco Bay Area study surveyed more than 1,000 large employment sites to examine connections between commuters' use of rail and locations near stations. This study found that commuting by transit was higher at sites within one quarter mile of transit stations than it was at sites between one quarter and one half mile from stations (Dill, 2003). Another study found that proximity to transit was more significant than street connectivity and other built environment measures, suggesting that proximity to transit is very important in reducing automobile mode shares (Lund, Cervero, & Willson, 2004). This same study also examined other factors involved with transit ridership and found that one quarter to one third of a mile is the most significant area around a transit station where mode shares are affected. These authors also found that bus headways under 15 minutes or rail headways under 50 minutes significantly affect mode shares within transit station areas (Lund, Cervero, & Willson, 2004). A meta-study conducted by Ewing and Cervero (2010) suggests that proximity to transit is associated with slightly fewer vehicle trips and is positively associated with walking and transit usage. These authors also found positive correlations between destination accessibility (jobs within one mile) and both automobile travel and walking. There is a slightly negative correlation between job accessibility and transit (within 30 minutes).

2.3.2 Area Types

The previous review of built environment measures relating to travel behavior has focused on individual measures independently. It is important to acknowledge that these measures do not stand alone in our physical environments. Rather, they interact with one another and characterize different places and neighborhoods. These interactions and resulting types of places are what planners and practitioners seek to encompass when categorizing the built environment into different area types, or urban contexts. Area types are typically qualitatively defined neighborhood typologies. This section explores travel behavior research as it relates to them.

Central Business District, Urban Core and Downtown Areas

The Central Business District (CBD) and Urban Core (UC) areas, defined as the core of the commercial district within the city, contain many of the built environment characteristics that are significantly correlated with reduced vehicle trips generated at establishments. Dense employment and residential populations, high accessibility to transit, pedestrian amenities, dense intersection networks (high street connectivity), and limited/paid parking work together to significantly reduce the amount of vehicle trips within these areas (Seskin, Cervero, & Zupan, 1996).

CBD, UC, and downtown areas are highly associated with lower vehicle mode shares. A study in San Francisco found vehicle mode shares to 3 pharmacies in UC areas between

8% and 13%, while 17 similar establishments in San Francisco suburbs had vehicle mode shares between 54% and 98%. UC locations had significantly higher land use mixes, on-street/paid parking, smaller site development setbacks, and pedestrian access (Wisconsin Department of Transportation, Bicycle Federation of Wisconsin, 2005). A separate study on commuting modes in the San Francisco Bay Area found that downtown stations in Oakland, Berkeley and San Jose had the highest use of commuter rail (Dill, 2003).

Walking tends to have a greater mode share in CBDs. For commuting trips, research in Chicago and San Francisco found that almost all residents in CBD areas walk to their destinations instead of driving or taking transit (Seskin, Cervero, & Zupan, 1996).

Transit-Oriented Development

Travel behavior in and near Transit-Oriented Developments (TODs) or Transit-Oriented Areas (TOAs) has been researched extensively to assess the effectiveness of implementing smart growth TOD policies. By definition, TODs include a transit center or station with high density and mix of residential and employment land uses within a quarter to a half mile of the station. These areas are developed in an effort to reduce automobile travel. The research on TOD design is inconclusive in finding the best combination of the built environment measures, such as land use mix, density and pedestrian amenities, to minimize vehicle trip generation. The TOD literature identifies residential and employment densities, pedestrian amenities and connectivity, accessibility to transit, high-quality transit, and trip purpose as having influence on vehicle mode shares.

Traffic impact studies have shown that ITE vehicle trip generation rates at rail TODs are overestimated by up to 50% (Cervero & Arrington, 2008b). The same research shows that implementing TOD can decrease residential vehicle trips to an average of 44% below *ITE Trip Generation Handbook* estimates.

But, not all developments near transit have the same effects on travel. Transit-Adjacent Developments (TAD) are places near transit that are not necessarily designed to capitalize on that proximity. They typically lack pedestrian connectivity to transit and tend to have vehicle-oriented design characteristics. TADs show significantly smaller reduction in vehicle mode shares compared with TOD locations (Renne, 2005).

Some research has investigated whether transitioning suburban areas into TODs is effective at reducing vehicle travel. A Toronto, Canada study found that increasing transit accessibility and residential density over 25 years lowered the automobile-driver share of A.M. peak period trips 6% increased transit use 4%, and increased non-motorized mode share 2% (Crowley, Shalaby, & Zarei, 2009).

The built environment factors identified in the literature as significant in reduced vehicle travel at TODs are the following: residential density (Renne, 2005; Crowley, Shalaby, & Zarei, 2009), proximity to employment (Lund, Cervero, & Willson, 2004), pedestrian access (Dill, 2008; Crowley, Shalaby, & Zarei, 2009), land use mixing (Lund, Cervero, & Willson, 2004), parking costs at the site (Cervero & Arrington, 2008a), transit service frequency (Cervero & Arrington, 2008a), and trip purpose (Dill, 2008). Excluding the latter three, all of these factors are encompassed in the D's of development identified in the built environment and travel behavior literature. Clearly, there is agreement in the TOD literature and the built environment literature on the measures associated with reduced vehicle travel.

Mixed-Use Developments

Mixed-Use Developments (MXD) are defined in the *ITE Trip Generation Handbook* as having more than two land uses, typically planned as a single real-estate project between 100,000-2,000,000 square feet in size with some trips between on-site land uses, and not located on major streets (Institute of Transportation Engineers, 2004). No part of this definition includes access to transit for mixed-use developments. One of the main phenomena observed in MXD areas include internal capture, the ability to perform multiple activities at a single development due to the close proximity to a variety of land uses and potentially greater pedestrian amenities. Internal capture is a critical issue to the *ITE Trip Generation Handbook* methodology because vehicle trip rates are typically estimated for each individual establishment and not the entire site; if people instead make one trip to the site and then walk to multiple establishments within the site then *ITE Trip Generation Handbook* estimates will over-predict vehicle trips.

Research has attempted to address this issue, but at this point in time is not comprehensive. Internal capture rates at mixed-use developments along the MAX corridor in Portland, Oregon were found to be between 2% and 20% of all trips to or from retail establishments during the PM peak hour and between 4% and 28% of all daily trips to or from retail (Lapham, 2001). Another project—NCHRP 8-51, "Enhancing Internal

Trip Capture Estimation for Mixed-Use Developments"—provides a method to estimate internal capture rates based on site characteristics and urban context. This research found that the highest levels of internal capture were at sites with diverse and balanced land use mixing, compact (or dense) development, and high connectivity between establishments, providing further agreement with the built environment measures identified in section 2.3.1.

Suburban City Centers and Corridors

ITE Trip Generation rates are typically collected at suburban-type locations (Institute of Transportation Engineers, 2004), but evidence suggests that even these locations are difficult to estimate with accuracy. Table 1 shows the actual vehicle trips seen in developed suburban city centers range from 5 to 37% below ITE estimates. Medium-density suburban locations near transit corridors with small parcels and low single-family housing percentages tend to promote walking and biking of shorter trips (Committee for the Study on the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption, 2009). Only the most suburban and vehicle-oriented sites are estimated accurately with ITE methods.

2.4 Summary

From the evaluation of *ITE Trip Generation Handbook* methods and excluding the most suburban and automobile-oriented sites, we see that there does not appear to be any area type in which vehicle trip generation rates are well estimated. Vehicle trip rates are consistently over-predicted by ITE, necessitating further investigation in area types other than highly suburban sites.

Alternatives to the *ITE Trip Generation Handbook* methodology exist. Many jurisdictions provide recommendations to their regions to develop local rates as alternative to ITE, but their requirements across jurisdictions are not consistent. Other methods and models are being developed and refined to address ITE's shortcomings, but as stated by the authors of a recent evaluation the available smart growth trip generation methodologies, "no clear 'winner' emerges among currently available methods" (Lee, et al., 2011). These methods and models are typically focused on either mixed-use development, air quality, or infill development.

A vast body of research informs us that the built environment is significantly related to travel behavior. The D's of development—measures of density, diversity, design, and distance to transit—were related to reduced automobile travel. Area types, or urban contexts, encompass many individual built environments together to categorize places, and they are also significantly related to levels of automobile travel. The literature shows that places in central business district, urban core, and downtown areas tend to have the lowest levels of automobile mode shares and the greatest differences to ITE rate estimates. Urban contexts also encompass development patterns like mixed-use, TOD, and infill, and provide a means to analyze these patterns and individual built environment measures together.

In this study, we present a mode-share and vehicle occupancy estimation method to adjust ITE *Trip Generation Handbook* estimates based on urban contexts. The models presented were estimated from pooling household travel surveys from three regions: Portland, Oregon; Puget Sound, Washington, and; Baltimore Maryland and were sensitive changes in the built environment, access to transit-oriented development and the location of the development within the region. This method and these models provide a readily available adjustment to account for urban contexts when applying ITE *Trip Generation Handbook* estimates, and it improves upon alternatives introduced in the literature. The framework for this adjustment discussed in the following chapter is followed by validation of this method using data collected independently and in accordance with ITE *Trip Generation Handbook*.

3.0 Framework and Data

The purpose of this chapter is to discuss the urban-context adjustment framework proposed in this thesis, including: an overview of how the developed adjustments are applied to establishment-level data collected in accordance with ITE's *Trip Generation Handbook*, the process of development for the adjustment methods, and an overview of the how the data were organized and applied. The objective of this research is to develop and test an urban-context adjustment methodology to use as a widely-available, ready-to-use adjustment methodology for ITE's *Trip Generation Handbook* vehicle trip generation estimates. This methodology must be applicable to establishments looking to develop in non-suburban areas with low to high activity densities (population and employment) located within a metropolitan planning organization (MPO). Additionally, relevant development locations may or may not be near rail or high-quality transit areas, and therefore, must be sensitive to differences in transit quality. Finally, this methodology must consider the limited data availability for most regions of the United States, and should not require jurisdictions to collect substantial amounts of additional data in order to apply this adjustment.

Recalling Figure 2 from the Introduction (repeated below), there are five steps to applying a mode share adjustment to ITE's *Trip Generation Handbook* estimates for any given urban development.

Step I.
Calculate the ITE's *Trip Generation Handbook* vehicle trip generation estimate for the development.

Step II.
Apply the estimated automobile mode share and vehicle occupancy for ITE's suburban vehicle trip generation rates to the vehicle trip estimates from (I.) to calculate the assumed total ITE person trips for that development.

Step III.
Estimate the automobile mode share and vehicle occupancy for the infill development location and urban area-type using the methodologies developed in this thesis.

Step IV.
Use the estimated mode shares and vehicle occupancy rates from (III) to allocate the total estimated person trips for that location (II) into travel modes.

Step V.
Apply the new vehicle trip estimates for the development, now adjusted for its urban context (IV.), in traffic impact analysis.

Figure 2. Urban-Context Mode Share Adjustment: Applied to ITE's *Trip Generation Handbook* Vehicle Trip Estimates

In Step II, the analyst converts ITE vehicle trip estimates to a person trip estimate, and then in Step IV., they allocate the estimated person trips into different modes based on the urban context mode share and vehicle occupancy estimated in Step III. Equation 2 and Equation 3, below, describe mathematically the process of conversion between vehicle trips to person trips and back to vehicle trips discussed in Steps II. and IV. Although Section 3.3 describes three different methods for estimating the urban-sensitive automobile mode share, the framework for applying any of these three mode-share adjustments remains the same as shown in Equation 2 and Equation 3.

Equation 2. Converting an ITE Vehicle Trip End Estimate into an ITE Person Trip End Estimate

$$\mathbf{PTE}_{ITE} = \frac{\mathbf{VTE}_{ITE} * \%\mathbf{AUTOMODE}_{ITE}}{\mathbf{VEHOCC}_{ITE}}$$

Equation 3. Converting an ITE Person Trip End Estimate into an Urban Context Adjusted (UCA) Vehicle Trip End Estimate

$$\mathbf{VTE}_{UCA} = \frac{\mathbf{PTE}_{ITE} * \%\mathbf{AUTOMODE}_{UCA}}{\mathbf{VEHOCC}_{UCA}}$$

Where,

$\mathbf{VTE}_{UCA}$ ≡ This is the outcome of the adjustment, a vehicle trip end estimate adjusted for urban context [vehicle trip ends per independent variable per time period studied].

$\%\mathbf{AUTOMODE}_{UCA}$ ≡ Urban context adjustment automobile mode share as a percent of total person trip ends, estimated using a HTS UCA methodology described within this section.

$\mathbf{VEHOCC}_{UCA}$ ≡ Urban context adjustment vehicle occupancy rate as a percent of total person trip ends, estimated using a HTS UCA methodology described within this section.

$\mathbf{PTE}_{ITE}$ ≡ ITE's *Trip Generation Handbook* Estimated Person Trip Ends, from ITE's Trip Generation Handbook vehicle trip end estimates [person trip ends per independent variable per time period studied].

$\mathbf{VTE}_{ITE}$ ≡ ITE's *Trip Generation Handbook* vehicle trip end estimations [vehicle trip ends per independent variable per time period studied].

$\%\mathbf{AUTOMODE}_{ITE}$ ≡ ITE automobile mode share as a percent of total person trip ends, provided within the ITE's *Trip Generation Handbook* and representative of a suburban "base case" land use. If no values are available, assume a 100% automobile mode share.

$\mathbf{VEHOCC}_{ITE}$ ≡ ITE vehicle occupancy rate as a percent of total person trip ends, provided with the ITE's *Trip Generation Handbook* and representative of a suburban "base case" land use. If no values are available, assume a rate of one person per vehicle.

Step I. is covered in detail in ITE's *Trip Generation Handbook* and will not be discussed in this thesis. The assumptions used in this proposed mode share adjustment are discussed further in Section 3.1. Following the diagram discussed in the introduction, and repeated below in Figure 3, the HTS data compiled and organized to provide observations of individual-level travel at a wide range of urban contexts is discussed Section 3.2.1; the built environment data used to define the urban context is discussed in Section 3.2.2. Utilizing both of these data sources, automobile mode share and vehicle occupancy equations are developed in Section 3.3. These equations are usable for estimating the urban context mode share adjustment proposed in Figure 2.

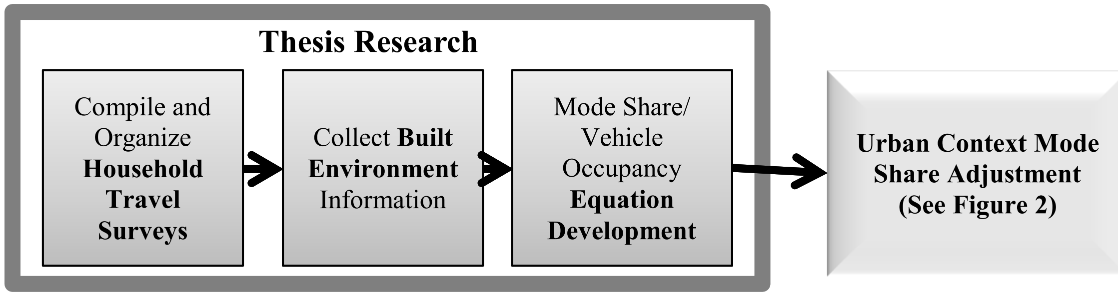

Figure 3. Process and Contribution of This Research

Moreover, independently collected establishment-level data were used to test for improvements in the accuracy of vehicle trip estimates compared with the original ITE's *Trip Generation Handbook* estimates (Section 3.4). The results of this chapter are discussed in the following Chapter 4.0.

3.1 Assumptions for Mode Share Adjustments

As discussed previously, the adjustment methodology presented in this report are all mode share/vehicle occupancy adjustments to ITE's *Trip Generation Handbook*. This means that ITE's *Trip Generation Handbook* vehicle trip end estimates are calculated, and then adjusted based on differences in urban context. First, the vehicle trip end estimates are converted to person trip ends based on assumed mode share and vehicle occupancy rates for ITE's *Trip Generation Handbook* (Equation 2). These person trip end estimates are then converted back into context-adjusted vehicle trip estimates, based on the context-sensitive mode share and vehicle occupancy rates for that urban context (Equation 3). The main assumption is that ITE's *Trip Generation Handbook* data are, in fact, collected at suburban, single-land use locations, which are mainly vehicle-oriented, and their automobile model shares are, therefore, 100-percent automobile. Additionally, vehicle occupancy rates observed (but not reported) are assumed to be one person per vehicle, unless otherwise reported in the *Handbook*. The underlying supporting assumption is that person trip rates are constant, on average, across urban contexts, and can therefore be converted from (Equation 2) and reverted into (Equation 3) estimates of vehicle trip ends based on changes in mode shares or vehicle occupancy across urban contexts. This is an important assumption, which is difficult to test, and is discussed further within the conclusions.

Three methodologies calculating context-sensitive automobile mode shares are described in Section 3.3. The application of these three adjustment methodologies is the same, however, using the same assumptions and equations to adjust ITE's *Trip Generation Handbook* vehicle trip end estimations for changes in urban context.

3.2 Data

This section describes the data used to develop and verify the adjustment methodology developed for vehicle trip end count estimation in urban context. Two types of data are used: (1) data for developing the methodology (household travel surveys) and (2) built environment to quantify the urban context each location falls within. The following sections detail these data used for analysis.

3.2.1 Household Travel Surveys

In order to explain variation in mode shares and vehicle occupancy across a range of urban forms, household travel surveys (HTS) provide trip-level observations spread spatially across regions capturing a range of built environments.

HTS are often made available to the public, but few published data sets include spatial coordinate information for trip end locations. Usable HTS data sets were limited to those with disaggregate, spatial information available. The three HTS used in analysis include: the 2011 Oregon Household Activity Survey (OHAS) for the Portland metropolitan area; the 2006 Puget Sound Regional Travel Survey from the Puget Sound Regional Council (PSRC), and; the 2001 National Household Travel Survey Add-On Program for the Baltimore Regional Transportation Board (Baltimore).

Table 4. Summary Statistics of HTS Trip End Data Set: All Trip Ends

		Trip Ends	Percent of Total
Total		243,671	100%
OHAS		41,795	17%
PSRC		150,040	62%
Baltimore		51,836	21%
		Average	**St. Dev.**
Built Environment (defined within a 1/2 mile)			
Activity Density	People and employment per acre	20.1	38.4
Employment Density	Employment per acre	11.9	34.5
Intersection Density	Intersections per acre	0.20	0.15
Percent of Intersections with 4 or more approaches	Percent of intersections with 4 or more approaches	34%	
Percent Retail Employment	Percent of employment in the retail service	13%	
Distance to the CBD	Miles to the MPO CBD	12.4	10.4
Near a TOD	Percent of trip ends near a TOD	11%	
Household Characteristics			
Size	Count	2.9	1.4
Vehicle ownership	Persons per vehicle	2.1	1.1
Drivers	Count	2.0	0.7
Income	Percent with Income below $50,000	27%	
	Percent with Income above $100,000	26%	
Workers	Count	1.5	0.9
Trip-maker Characteristics			
Age	Years	42	21
Sex	Percent Female	55%	
Travel Characteristics			
Travel Distance (mi)	Average/SD	6.9	20.0
Vehicle Occupancy	Average/SD[5]	1.72	1.07
Vehicle Mode Share	Percent	81%	
Walk Mode Share	Percent	11%	
Transit Mode Share	Percent	7%	
Bike Mode Share	Percent	1%	
Time			
AM Peak Period (7-9AM)	Percent	15%	
PM Peak Period (4-6PM)	Percent	17%	
Midday Period (9AM-4PM)	Percent	43%	
Date			
Weekend (Saturday, Sunday)	Percent	2%	
Friday	Percent	14%	
Winter (Nov. thru Feb.)	Percent	5%	

[5] The sample size for vehicle occupancy was 210,502 trip ends.

Each HTS is disaggregated to a trip-level basis, and each origin and destination of the trip is included as a separate record, providing parody with ITE's *Trip Generation Handbook* methodology which estimates total trip ends. Entering traffic (trip destinations) and exiting traffic (trip origins) each represent unique observations in this analysis. The trip ends are not weighted for two reasons. First, the population arriving at each land use type is unknown. Appropriate weighting at the trip-end-level would require an understanding of who is traveling to each land use type. Second, weighting to the establishment-level would be appropriate, but the universe of land uses (unique businesses) is also unknown at the time of each survey. This type of weighting would also require knowledge of the availability of each establishment across urban contexts to provide an adequate weight. Summary statistics for all trip ends used in analysis is provided in Table 4.

Data are organized similarly to ITE's *Trip Generation Handbook*. Trip end observations that occur throughout the day are segmented into peak hour periods that correspond to the common peak periods for the facilities: AM peak period is from 7-9AM; PM peak period is from 4-6PM; the Midday time period stretches from 9AM to 4PM, and; all other times are grouped into the alternative "all other times". Additionally, indicators for the day of the week identify observations which occur on the weekends (Saturday or Sunday) and Fridays[6]. Only a few land uses contained observations that may vary depending on the time of the year. A variable was created to indicate observations that occur during winter

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[6] ITE's *Trip Generation Handbook* does not distinguish between weekdays and Friday time periods. However, Friday observations were found to be significantly different than Monday through Thursday observations for certain land uses.

months to determine potential seasonal differences in observations for November through February. Built environment information surrounding each trip end was then calculated as described in the following section.

Relating HTS Trip Purposes to Land Use Types

In order to use household travel survey (HTS) data to understanding variation of mode shares and vehicle occupancy rates at land uses, a crosswalk must be developed to link the activity occurring at the trip end and likely land uses. HTS data rarely provide information detailing at which land use each activity or trip occurs. HTS trip purpose categories also vary greatly in depth from survey to survey, ranging from a dozen general purposes to well over a hundred.

Moreover, it is these purposes and activities that are often difficult to relate with the actual land uses being visited. For example, person A may use a coffee shop land use as a "school" activity to do homework; person B may use the same coffee shop to "eat outside of their home"; and person C may travel to the coffee shop to "work". Some trip purposes may represent travel to many land use types making it nearly impossible to know what land uses are being visited. For example, the Baltimore NHTS Add-on survey includes a trip purpose labeled "Pet care (walk the dog, vet visits)". This trip purpose may include land uses defined as medical (Animal Hospital/Veterinary Clinic – Land Use Code[7]

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[7] Land use codes (LUC) from ITE's *Trip Generation Handbook*, 8th Edition are

(LUC) 640), retail (Pet Supply Store – LUC 866), or Recreational (any type of park – LUC 411-413,417 or possibly travel for travel's sake).

This chapter outlines the procedure used to relate HTS trip purposes to land use categories. Crosswalks for nine land use categories are provided: office, restaurant, residential (single-family detached, multi-family, and general residential), service (non-restaurant), retail, entertainment/recreational and a ninth category considering all trip ends[8]. The data sets are then segmented into land use category data sets and used to develop several mode share-based adjustment methods for estimating vehicle traffic while controlling for urban contexts in Section 3.3.

Framework for Relating Trip Purposes to Land Uses

Segmenting the data into land use specific trip end datasets begins by determining the relationships between trip purposes and potential land use categories. We cannot say that any given trip purpose or activity always and definitely occurs at a specific land use. Therefore, a "confidence of match" ranking system allows trip purposes to be categorized into confidence levels (i.e., high, low or none) for each land use (Figure 4). To determine which trip ends can be classified within each of the different land uses, trip ends are categorized using a three-part process. First, trip purposes are assessed and split into five categories (Figure 4, Part 1):

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[8] Hotels and entertainment or recreational land uses are also important infill land uses to consider. Household travel surveys are typically centered around regional household travel, however, and therefore, capture little hotel activity. For hotels, a similar analysis of regional visitor's surveys is recommended.

1. ***High Confidence***: Trip purposes that are more likely to occur at the land use being investigated (i.e., "eating outside of the home" would be a *high confidence* trip purpose in the "Restaurant" land use category).
2. ***Low Confidence***: Trip purposes that may occur at the land use being investigated, but with vague certainty, or trip purposes that may occur at a number of land uses (i.e., "personal business" would be a *low confidence* trip purpose under the "Services (non-restaurant)" land use category because this type of purpose may relate to a variety of activities at many land use types).
3. ***No Confidence***: Trip purposes which have little or no potential for occurring at the land use being investigated (i.e., "personal business" would be a *no confidence* trip purpose for the "Restaurant" land use category).
4. ***Work-Related***: Trip purposes which depend on the trip-maker's workplace industry type (i.e., "work" trip purposes may relate to a waiter at a restaurant or an office manager at a bank or financial institution).
5. ***Home-Related***: Trip purposes which depend on the trip-maker's home-place (e.g., "home – paid work", "all other at home activities").

After trip purposes receive their initial classification, workplace industry classifications are analyzed for their fit into each land use category and are also segmented into *high confidence*, *low confidence*, and *no confidence* industry types for each land use (Figure 4, Part 2). Similarly, home-related trip purposes are assumed to have a strong relationship with the trip-maker's home-place location, and therefore, the home structure type are categorized into *high confidence*, *low confidence*, and *no confidence* industry types for each residential land use category (Figure 4, Part 3).

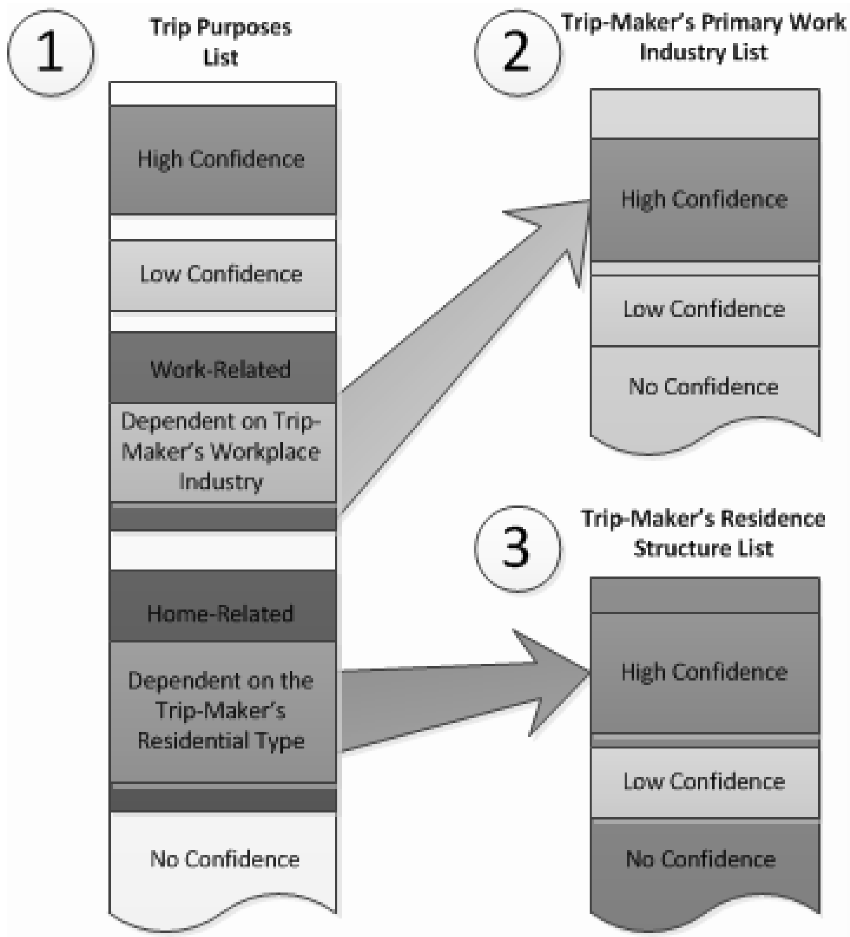

Figure 4. Examining Household Travel Survey for Parody with Land Use Categories

To segment the total trip end data set into each land use category, trip ends were aggregated into *high confidence* and *low confidence* data sets for each land use. *No confidence* trip ends were discarded. For trip ends with work-related purposes, the trip-maker's workplace industry type was used to determine whether the trip end was classified in each land use trip ends data set[9]. Likewise, trip ends with a home-related trip purposes depends on the trip-maker's home place structure type for classification in either a single-family or multifamily data set.

Any *high confidence* trip ends were considered the "base" data set for that land use, and any *low confidence* trip purposes were compared against the "base" data set to determine any indication of similar travel. Mode shares and vehicle occupancy rates of each *low confidence* trip purpose were grouped into activity density[10] quartiles[11]. These mode shares and vehicle occupancy rates were then compared against the *high confidence* trip end data set[12]. *Low confidence* trip purposes that showed similarities with the *high confidence* data set were analyzed further to compare similarities across time-of-day

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[9] For trip-makers with multiple workplaces, it is assumed that the primary workplace industry does not vary from the secondary workplace industry. For example, for a person maintaining two jobs with a primary workplace in a "technical" industry, it is also assumed that the second workplace will be within the same industry type. Therefore, any trip a person takes related to work also means that the trip is to a "technical" type workplace. In this example, it is determined that this trip would be classified as an office-type land use in *high confidence* (see APPENDIX B).

[10] Activity density is highly correlated with other built environment measures, such as population density, transit accessibility or intersection density. Activity density was, therefore, only selected as an initial proxy to compare mode shares and vehicle occupancy rates.

[11] Activity density is defined as residents and employment per acre in the surrounding half-mile Euclidian buffer around the trip end. For more information on the built environment measure, see Section 3.2.2. Quartiles were calculated for the range of all observed trip ends and were as follows: 0-5.4, 5.4-9.9, 9.9-16.5, 16.5-324.0 people per acre. Further analysis was completed for the most urban context to show statistical similarities in mode shares and vehicle occupancy rates for more refined ranges. Limits in the sample size and interpretability across the most urban context limited the ability to use smaller ranges for comparison.

[12] Statistical tests included a comparison between two proportions for automobile mode shares with a two-tailed, 99% confidence level and a comparison between two means with a two-tailed, 99% confidence level. Although vehicle occupancy distributions tend to be non-parametric, a normal t-test between two means is utilized to reflect the use of the typically summary statistic of "average vehicle occupancy", such as in ITE's *Trip Generation Handbook*.

distributions for “entering”, “exiting” and “total” trip ends[13]. *Low confidence* categories that have similar travel patterns to the *high confidence* “base” data set were aggregated with the “base” data set and are used to develop the mode share and vehicle occupancy adjustments in the following section.

The overall sample size for each land use type used in this analysis is provided in Table 5. Further descriptive statistics for each data set used in analysis is provided in APPENDIX D on page 120.

Table 5. Trip End Data Sets for each Land Use Type

Land Use Types	Trip Ends (Sample Size)
All Trip Ends	243,671
Retail	28,781
Residential - General	84,674
Single-Family	62,499
Multifamily	18,078
Entertainment/Recreational	18,749
Service (non-restaurant)	26,126
Restaurant	17,622
Office	10,924

3.2.2 Built Environment (BE) Measures

The most disaggregate way to describe urban context is through individual built environment (BE) measures, such as residential density or land-use mix. There is a large

[13] Time-of-day distributions across non-automobile mode shares were also compared, but were not the determining factor for inclusion into the working data set. The household travel survey urban context adjustment discussed in this study is an automobile-based adjustment, and therefore, only automobile mode share distributions were included in consideration. Implications of this are discussed in APPENDIX E.

literature investigating which relationships between the BE and travel behavior are the most substantial or significant, but the findings are inconclusive (Ewing & Cervero, 2001; Ewing & Cervero, 2010), and representation of the BE as a way to describe urban context vary from hundreds of individually calculated measures (D'sousa, et al., 2012; Ewing & Cervero, Travel and the Built Environment: A Synthesis, 2001; Ewing & Cervero, 2010) to composite indices or clusters built from individual measures (Clifton, Currans, Cutter, & Schneider, 2012; Cervero & Kockelman, 1997; Krizek K. J., 2003; Cao, Mokhtarian, & Handy, 2009; Frank, Saelens, Powell, & Chapman, 2007).

While a significant amount of the literature is aimed at quantifying the impact of BE on travel behavior, the purpose of this research is to select BE measures that can be calculated using data widely available across the United States, such as the Census. Portland, for example, has a rich data set including: sidewalk coverage, tree cover, bike corral parking, LiDaR elevations, floor-to-area ratio estimation, zoning and land use reconciled for the region, and lot coverage. This detailed information, while possibly influential in decision making of where and when to travel (Schneider R. J., 2011), is not often easily available. For these reasons, only ubiquitously available data sets were used to calculate BE information for each trip, as shown in Table 6.

Table 6. Built Environment Measures: Data Sources

Data Source	Year	Files
Census Transportation Planning Package (CTPP)	2000	Part 2, Table 4: Place of Work by Industry
Census Summary File 3 (SF3)	2000	Table P1: Total Population Table H1: Housing Units Table H5: Urban and Rural
TIGER Files	2009	Edges and Faces
Transit-Oriented Development (TOD) Database	2012	Point locations of TODs within each region

Each measure was calculated for a half-mile buffer around the trip end. All Census and CTPP data are polygon data; therefore, an apportionment method was used to determine a weighted average of each variable within the trip end buffer when it falls across Census Block Boundaries (D'sousa, et al., 2012, p. 49). The BE measures calculated and used within the analysis are shown in Table 7. Descriptive statistics of the BE measures for all trip ends used are shown in Table 4. These trip ends are then segmented into land use categories based on the activity performed at each origin and destination, which is detailed later in Section 3.2.1.

Table 7. Built Environment Measures for Model Development: Definitions[14]

Measure	Units	Source
Distance of Destination to CBD	Miles, Euclidian	
Presence of TOD	Binary	TOD Database
Residential		
Population Density	Residents per acre	Census 2000 SF3, P1
Household Density	Households per acre	Census 2000 SF3, H1
Urban Density	Number of "urban" households	Census 2000 SF3, H5
Rural Density	Number of "rural" households	Census 2000 SF3, H5
Employment		
Employment Density	Employees per acre	CTPP
Retail Employment Density[15]	Employees per acre	CTPP
Professional Employment Density[16]	Employees per acre	CTPP
Arts/Entertainment Employment Density[17]	Employees per acre	CTPP
FIRE Employment Density[18]	Employees per acre	CTPP
Percent Retail Employment	Percent of total employment	CTPP
Percent Professional Employment	Percent of total employment	CTPP
Percent Arts/Entertainment Employment	Percent of total employment	CTPP
Percent FIRE Employment	Percent of total employment	CTPP
Activity		
Activity Density (Population + Employment)	Employees and residents per acre	CTPP
Percent Population of Activity	Percent of total employment and residents	CTPP and Census 2000 SF3, P1
Connectivity		
Total Intersection Density	Intersections per acre	TIGER
Four Approach (or more) Intersection Density	Intersections per acre	TIGER
Percent Four Approach of Total Intersections	Percent of total intersections	TIGER
Median Block Perimeter	Miles	TIGER
Median Block Area	Acres	TIGER

[14] All items, unless otherwise noted, were calculated using GIS protocols set forth by D'sousa et al (2012). Area calculations for each trip end buffer used to calculate densities do not include water area.

[15] Retail Employment includes "retail trade" employment from the CTPP, Part 2, Table 4x6.

[16] Professional Employment includes "professional, scientific, management, administrative, and waste management services" employment from the CTPP, Part B, Table 4x10.

[17] Arts/Entertainment Employment includes "arts, entertainment, recreation, accommodation and food services" employment from the CTPP, Part 2, Table 4x12.

[18] FIRE Employment includes "finance, insurance, real estate, and rental and leasing industry" employment from the CTPP, Part 2, Table 4x9.

3.3 Methodologies for Calculating Automobile Mode Shares and Vehicle Occupancy Rates

This section details the different methodologies used to calculate mode shares in order to adjust ITE's *Trip Generation Handbook* vehicle trip generation rates for urban context. Three methodologies for adjustment were developed:

Adjustment A: Single mode share table by a single built environment metric;

Adjustment B: Regression using the built environment metric with the best model performance; and

Adjustment C: Regression using a built environment metric with a strong model performance that is sensitive to land use policy.

The first methodology (A) is a simple, multimodal mode share table (see Section 3.3.1); the second (B) and third (C) are automobile-specific mode share models (see Section 3.3.2). All three methodologies include the same application of vehicle occupancy rates described in Section 3.3.3. The outcome of these methodologies are also the same: a method to estimate the automobile mode share (as a percent) and vehicle occupancy rates at a development that can be applied within Equation 2 and Equation 3 to adjust ITE's *Trip Generation Handbook* suburban-oriented vehicle trip ends estimates.

3.3.1 Adjustment A: Multimodal Mode Share Aggregate Table

The first methodology for calculating an urban context sensitive mode share is simply a table of observed mode shares across urban contexts. Each trip end data set for each land use category is segmented into ranges of the built environment. For the purpose of simplicity, activity density is used as a measurement of urban context. There are a number of potential urban context proxy measures (e.g., intersection density, employment density, access to transit, and percent of total intersections that have four or more approaches). Activity density, a total measurement of residents and employment per acre within a half-mile of the trip end, serves only as a proxy of the many elements that may make up or describe urban form. The mode share tables developed for Adjustment A were calculated for all twenty-one, performing ANOVA tests on differences in proportions across varying segmented ranges of the built environment (i.e. activity densities of 0-10, 10-20, 20-30, etc. as well as 0-25, 25-50, 50-75, etc.). In this analysis, activity density was selected to represent the built environment, and therefore define the urban context of each trip end. Ranges of fifty people per acre (residents and employment within a half-mile Euclidian buffer of the trip end) were chosen for this adjustment.

To develop this adjustment, activity density for a half-mile location around the development site was calculated, and trip ends are segmented by their activity density value, summarizing the mode split for each activity density range. The resulting table (or chart, see Figure 5) provides a means for the practitioner to look up the relevant automobile mode share (or alternative bike/walk/transit) mode share observed within the three study regions. APPENDIX F provides the vehicle mode shares across activity density for each of the trip ends data set, including the sample size used for each discrete category. Multimodal mode splits are provided. These mode share tables for each land use serve as a look up table which allows the analyst performing a traffic impact analysis to estimate what a possible multimode share split may be.

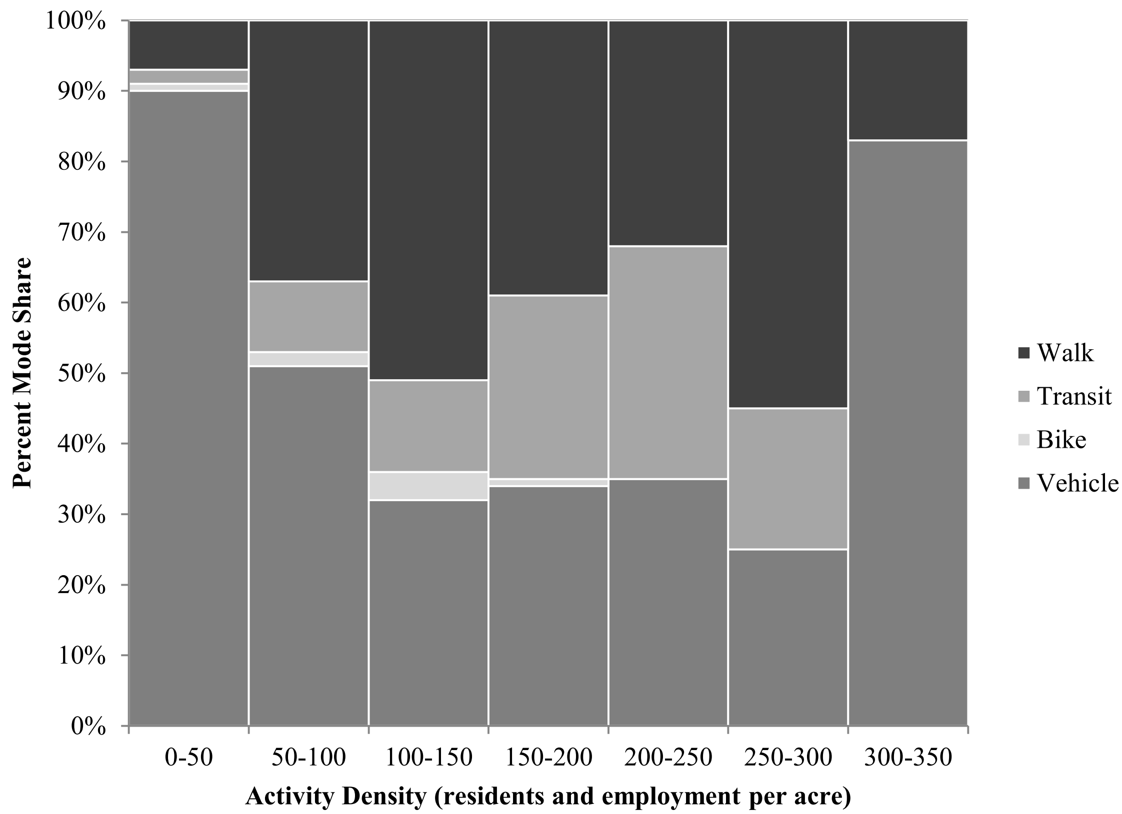

Figure 5. Adjustment A: Mode Share Table for Retail Land Use Types

A simple table of aggregate mode share distributions allows for an easy widely-available, ready-to-use method for mode share adjustments. Testing this method against more complicated modeling methods provides insight into whether more detailed approaches will achieve substantially better results. Additionally, multimodal mode shares (e.g., bike, walk, transit trips) can also be summarized and accounted for within the traffic impact analysis process.

Unfortunately, a simple summary table does not control for differences in mode shares when other metrics change, e.g. time-of-day or access to rail transit. One way to control for these differences is to perform a regression analysis on the trip-level mode choice while controlling for, or partially out the effects of, additional trip characteristics that may bias the mode shares across different urban forms. This process is described in the next section.

3.3.2 Adjustment B & C: Automobile Mode Share Model

Both Adjustment B and Adjustment C use binary logistic regression analysis to study the relationship between urban contexts and the automobile mode share across urban context, controlling for other measures describing the characteristics of each trip end. Multiple models are estimated for each land use considering each of the built environment measures listed in Table 7. Twenty-one models were estimated for each land use type and each Adjustment B, C and the corresponding vehicle occupancy rate estimation, one for each built environment measure calculable from the widely-available data discussed in Section 3.2.2. Statistical tests (e.g., likelihood ratio tests, improvement of goodness-of-fit such as Nagelkerke R^2, t-tests of variable significance) were performed on the addition of each built environment measure, as well as the variables used to distinguish the time of day, day of the week and whether the trip was taken during the winter.

First, for each land use type, each of the 21 models (one for each built environment measure) is examined for its Nagelkerke R^2, a measure of model fit[19], as well as the significance of the contribution of the built environment measure[20]. For each land use

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[19] The Nagelkerke R^2 may also be called the pseudo R^2 and ranges from 0 to 1. A value of 1 indicates 100% variance explained in the likelihood of the dependent variable by the predictor variables.

[20] The deviation within the model after the addition of the built environment measure is compared with an unrestricted model containing all the same variables, except for the built environment parameter. The difference in deviance is tested using the χ^2 table for statistical significance. Measures that were not

category, two models are selected: the model with the greatest model fit (hereby called Adjustment B), and the model with a good model fit that was also a policy sensitive model (Adjustment C). For example, when comparing all models within the Restaurant land use category, the top performing model (based on model fit) was a model including intersection density as the urban context indicator. This measure does not allow for much flexibility when being applied for policy initiatives. If urban planners would like to increase the non-automobile mode shares within an established development, and if intersection density is used as the urban context indicator for which mode shares are estimated, the conclusion would be that an increase in non-automobile mode share rates would be achieved by increasing the intersection density within the immediate area. Adding more intersections is not necessarily a sustainable method for encouraging biking, walking or transit usage.

For the Restaurant land use category, however, a model with a slightly lower model fit (Nagelkerke R^2 = 0.26 versus 0.29) which considers population density (residents per acre) allows for more flexibility in policy decisions. With this model relationship, planners may be able to estimate how the surrounding built environment could be developed to help the goal of a greater non-automobile mode split. None of these models control for individual-level characteristics that may account for self-selection or socio-demographic characteristic bias, nor do they account for the behavior at surrounding land uses or neighborhoods. Note that neither do ITE's *Trip Generation Handbook* estimates

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considered statistically significant contributions to the binary logistic model were not considered to be potential urban context indicators within the adjustment models.

which are often used to estimate vehicle impact at potential land uses. A policy-sensitive metric used for mode share estimation provides some understanding on how development policies surrounding the location of interest may influence the mode share at a single establishment.

The outcome of a binary logistic regression analysis is an equation describing the odds that a person would take an automobile (instead of walking, biking or taking transit, collectively) given their trip end location, the time of day, or their access to rail transit, for example. The estimated "odds ratio" for each development location can then be converted to a probability which describes, for that location, the percent probability that patrons will arrive or leave the site in an automobile. This probability represents that automobile mode share for that urban context.

For each land use data set compiled in Section 3.2.1, twenty-one models were estimated considering each of the built environment measures listed in Table 7. Each of the models controls for the same base case variables: the time of day, the day of the week, the distance to the central business district (CBD) and access to a transit-oriented development. Only the built environment variable was allowed to vary from model to model. The model structure, shown in Equation 3, controls for measures analogous to ITE's *Trip Generation Handbook* as it defined the time of day and the day of the week. Additionally, the distance from the CBD of the region was included as a proxy to control for regional accessibility[21]. Additionally, a variable identifying whether the trip end is in close proximity to a transit-oriented development (TOD) controls for additional transit accessibility near the location. The models selected for each land use category for Adjustment B and C are shown in APPENDIX G and APPENDIX H, respectively.

Equation 4. Binary Logistic Regression Structure: Automobile Mode Share

$$Automobile\ Mode\ Share\ (\%) = \frac{e^{\boldsymbol{INTERCEPT+TIME+DAY+DISTCBD+TOD+BE}}}{1 + e^{\boldsymbol{INTERCEPT+TIME+DAY+DISTCBD+TOD+BE}}}$$

$$\boldsymbol{INTERCEPT} = Intercept\ constant\ for\ the\ model$$

$$\boldsymbol{TIME} \equiv Time\ of\ Day$$

$$= \begin{cases} AM\ Peak\ (7-9AM)\ Coefficient \\ PM\ Peak\ (4-6PM)\ Coefficient \\ before\ 7AM, after\ 6PM\ Coefficient \\ Midday\ (9AM-4PM)\ Coefficient = 0\ (base\ case) \\ Daily\ Coefficient \end{cases}$$

$$\boldsymbol{DAY} \equiv Day\ of\ the\ Week$$

$$= \begin{cases} Friday\ Coefficient \\ Weekend\ (Saturday, Sunday) Coefficient \\ Weekday\ (Monday\ through\ Thursday) Coefficient =\ 0\ (base\ case) \end{cases}$$

$$\boldsymbol{DISTCBD}$$

$$= Coefficient$$

$$*\ Distance\ to\ the\ regional\ Central\ Business\ District\ (CBD), in\ miles$$

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[21] Portland, Oregon's CBD is at Pioneer Square; Seattle, Washington's CBD is at Union Square; Baltimore, Maryland's CBD is at City Hall.

$$\boldsymbol{TOD} = \begin{cases} TOD\ is\ located\ within\ a\ \frac{1}{2}\ miles\ Coefficient \\ there\ is\ no\ TOD\ within\ a\ \frac{1}{2}\ mile\ Coefficient = 0\ (base\ case) \end{cases}$$

$$\boldsymbol{BE} = Coefficient * Built\ Environment\ Measure\ Considered\ in\ Model\ Analysis$$

To illustrate the differences between Adjustment A and Adjustment B, the two selected models for retail land use types (see APPENDIX G and APPENDIX H) were depicted in Figure 6 and Figure 7 below. For these examples, the relationship between the built environment (intersection density and population density, respectively) and automobile mode share is shown across varying distances to the central business district. In both these figures, a weekday, PM peak hour was shown, without access to transit-oriented developments and observed during non-winter months (March through October).

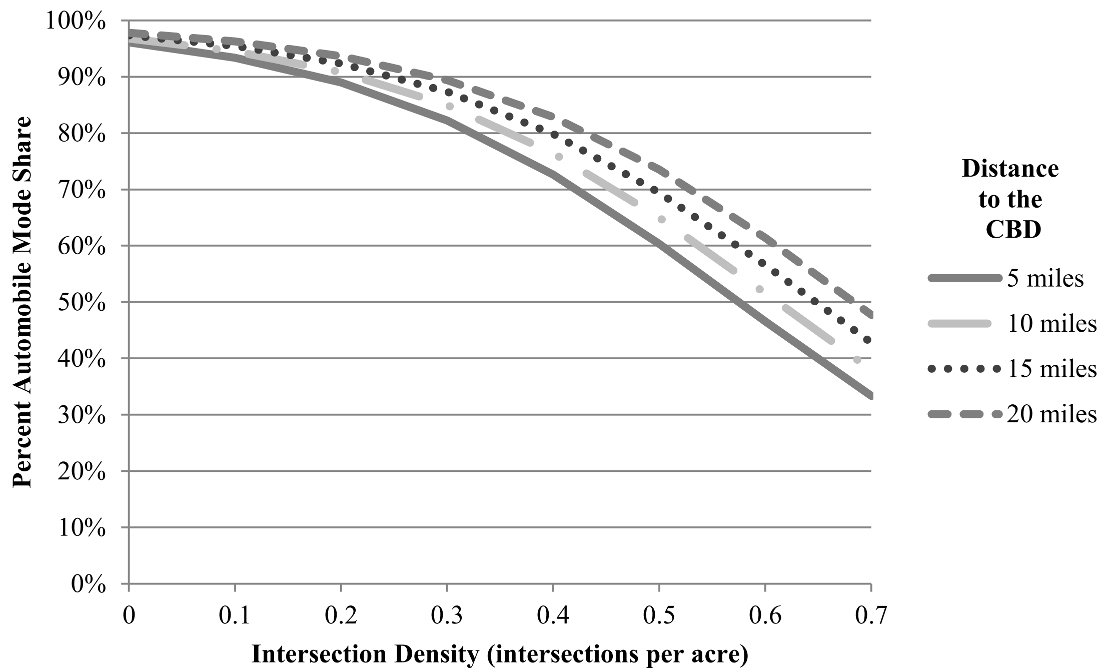

Figure 6. Adjustment B: Regression, Automobile Mode Shares - Built Environment Measure with Best Model Performance: Retail Land Use Types

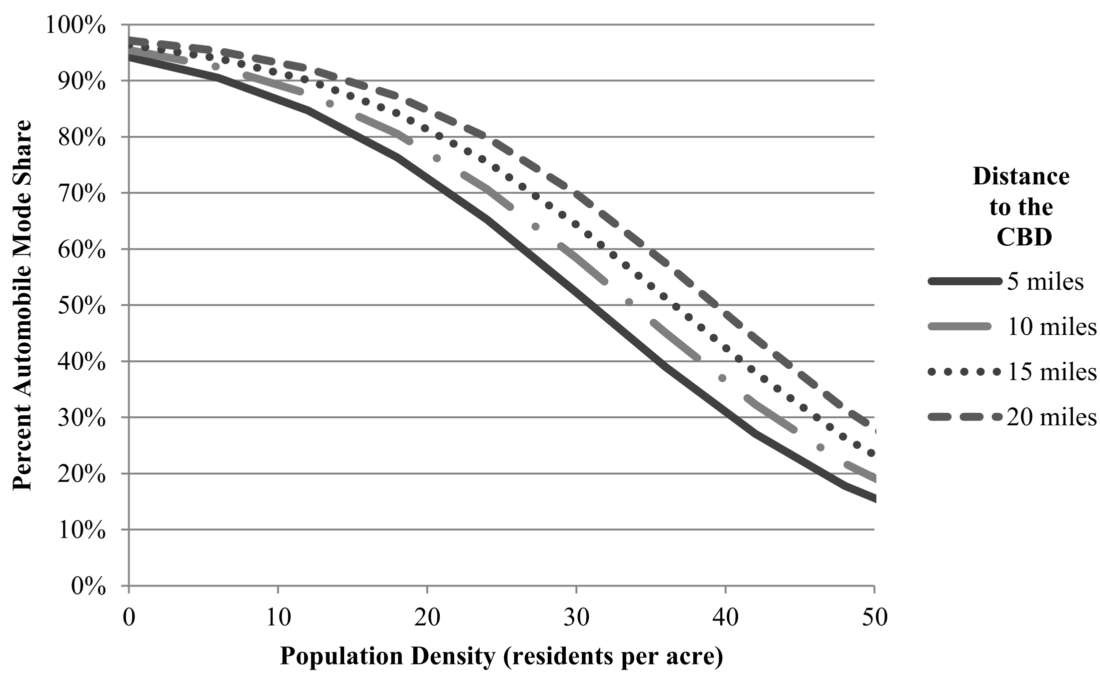

Figure 7. Adjustment C: Regression, Automobile Mode Shares - Built Environment Measure Policy Sensitivity: Retail Land Use Types

3.3.3 Vehicle Occupancy Models

The second component of a mode share adjustment is to account for changes in vehicle occupancy across land use categories and urban context. To estimate vehicle occupancy rates, linear ordinary least square (OLS) regression as used. The model structure is shown in Equation 3. Although all twenty-one measures of the built environment were used in the regression analysis, no one model estimated provided a moderate or strong statistical fit explaining the variation in vehicle occupancies. Statistical tests (e.g., improvement of goodness-of-fit such as R^2, t-tests of variable significance) were performed on the addition of each built environment measure, as well as the variables used to distinguish the time of day, day of the week and whether the trip was taken during the winter.

The structure of the model was developed around data organized similarly with ITE's *Trip Generation Handbook* data, possibly limiting in the ability to explain individual-level characteristics of the trip-maker, such as vehicle ownership, household income, trip length distance. Additionally, vehicle occupancy information is reported in household travel surveys as unit values. The distribution of these count data are also not normally distributed around the mean values, suggesting the OLS regression may not be the best model structure for estimating vehicle occupancy.

ITE's *Trip Generation Handbook* provides limited vehicle occupancy information for any land use. Quality restaurants and high-turnover (sit-down) restaurants, for example, were the only restaurant-type land uses that have reported vehicle occupancy rates reported. Although a large difference in vehicle occupancy rates would result in significantly different vehicle trip rates, the limited information provided by the *Handbook* prevents accurate conversions between estimated vehicle trip ends and person trip ends. Additionally, the effect size of vehicle occupancy rates across urban context was small, indicating only a small observed relationship between the built environment and vehicle occupancy.

To avoid overcomplicating this portion of the adjustment method, especially since ITE's *Trip Generation Handbook* vehicle occupancy rates are so often unreported, activity density was selected as a proxy for the urban environment for all land use categories.

Equation 5. Linear Regression Structure: Vehicle Occupancy

$$\boldsymbol{Vehicle\ Occupancy} = \boldsymbol{INTERCEPT} + \boldsymbol{TIME} + \boldsymbol{DAY} + \boldsymbol{DISTCBD} + \boldsymbol{TOD} + \boldsymbol{ACTDEN}$$

$$\boldsymbol{INTERCEPT} = Intercept\ constant\ for\ the\ model$$

$$\boldsymbol{TIME} \equiv Time\ of\ Day$$

$$= \begin{cases} AM\ Peak\ (7-9AM)\ Coefficient \\ PM\ Peak\ (4-6PM)\ Coefficient \\ before\ 7AM, after\ 6PM\ Coefficient \\ Midday\ (9AM-4PM)\ Coefficient = 0\ (base\ case) \\ Daily\ Coefficient \end{cases}$$

$$\boldsymbol{DAY} \equiv Day\ of\ the\ Week$$

$$= \begin{cases} Friday\ Coefficient \\ Weekend\ (Saturday, Sunday) Coefficient \\ Weekday\ (Monday\ through\ Thursday) Coefficient = 0\ (base\ case) \end{cases}$$

$$\boldsymbol{DISTCBD} = Coefficient *$$

$$Distance\ to\ the\ regional\ Central\ Business\ District\ (CBD), in\ miles$$

$$\boldsymbol{TOD} = \begin{cases} TOD\ is\ located\ within\ a\frac{1}{2}miles\ Coefficient \\ there\ is\ no\ TOD\ within\ a\frac{1}{2}mile\ Coefficient = 0\ (base\ case) \end{cases}$$

$$\boldsymbol{ACTDEN} = Coefficient *\ Activity\ Density$$

3.4 Verification of Methodologies: Process and Data

In order to test the application of each of these methodologies for adjustment, data were collected from land uses around the United States for a different land uses, during a range of time periods and throughout a variety of urban contexts. Vehicle trip ends were estimated using ITE's *Trip Generation Handbook* methodology, and then adjusted (see Section 3.0) using on the nine land use type adjustment methods estimated and described previously:

Adjustment A: Single mode share table by a single built environment metric;

Adjustment B: Regression using the built environment metric with the best model performance; and

Adjustment C: Regression using a built environment metric with a strong model performance that is sensitive to land use policy.

Site-level data are limited. Because of this, a full validation across all land uses, time periods and days of the week was not possible. This section includes the results and discussion of the methodology verification, which tests the applicability of this methodology to adjust site-level data collections for urban context. Further data collection to verify beyond the scope of what was tested in this section is necessary to determine the usefulness of HTS mode share and vehicle occupancy adjustment applications for those cases.

To compare the estimation methods, the normalized root-mean-squared error (NRMSE) was calculated for each land use category, data set and adjustment method. The NRMSE metric, shown in Equation 6, is an approximation of the standard deviation of the error of the estimate normalized across the range of observed vehicle trip end[22] values. This measure is expressed as a percent. When a limited range in vehicle trip end counts are observed, which happens when the sample size is small and the establishments are similar in size within a category, the NRMSE may be inflated since the variation of the error is measured relative to the range of observed values. Generally, smaller percentages are preferred which indicate a rate of error that is small respective to the range of vehicle trip end counts.

Equation 6. Normalized Root Mean Squared Error (NRMSE)

$$\boldsymbol{NRMSE} = \frac{\sqrt{\frac{\sum_{i=1}^{n}(\boldsymbol{Observed}-\boldsymbol{Estimated})^{2}}{\boldsymbol{n}-\boldsymbol{1}}}}{\boldsymbol{Maximum}(\boldsymbol{Observed})-\boldsymbol{Miniumum}\ (\boldsymbol{Observed})}$$

Where,

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[22] Vehicle trip rates were not used as a comparison due to the variation ITE's *Trip Generation Handbook* methods used for estimation (e.g. weighted average rates or equations) and independent variable predictors (e.g. dwelling units, gross floor area or seats for restaurants).

$$NRMSE \equiv Normalized\ Root\ Mean\ Squared\ Error, expressed\ as\ a\ percent$$

$$Observed \equiv Observed\ Vehicle\ Trip\ Ends$$

$$Estimated \equiv Estimated\ Vehicle\ Trip\ Ends$$

$$n \equiv Number\ of\ Land\ Use\ Sites\ Studied$$

3.4.1 Establishment-Level Data

In order to test this methodology, vehicle trip generation data collected in accordance with ITE's *Trip Generation Handbook* was compiled. Only studies collected after the year 2000 were evaluated. Data were provided by three sources: Dr. Kelly J. Clifton at Portland State University from a 2011 study (Clifton, Currans, & Muhs, 2012), a California-based data collection prepared by Kimley-Horn and Associates (Daisa, et al., 2009), and more recent data collections provided by the Institute of Transportation Engineers (ITE)[23]. The majority of the verification sample was collected in California and Oregon, but a small portion of the sample was located in Maryland and Vermont (Table 8).

Table 8. Distribution of Establishment-Level Data for Verification of Methodology

Metropolitan Organization (MPO)	City	State	Sample Percent
Metropolitan Transportation Commission	Oakland	California	15%
San Diego Association of Governments	San Diego	California	4%
Southern California Association of Governments	Los Angeles	California	5%
Metropolitan Washington Council of Governments	near Washington D.C.	Maryland	1%
Portland Area Comprehensive Transportation System	Portland	Oregon	71%
Chittenden County MPO	South Burlington	Vermont	1%
Non-MPO	---	Vermont	4%

[23] The 8th edition of the ITE's *Trip Generation Handbook* was applied to estimate vehicle trip ends, therefore, data that were included within the 8th edition were not included within this analysis.

Additionally, data were collected at a variety of land uses during a range of time periods. Table 9 details the distribution of the sample used to analyze the application of the adjustment methodology to verify the use at a range of land uses across typical time periods defined by ITE's *Trip Generation Handbook*. The majority of the sample tested is for the PM Peak Hour of the adjacent street traffic.

Table 9. Time of Data Collection for Establishment-Level Data for Verification Methodology

ITE's *Trip Generation Handbook* Land Use Codes and Names	AM Peak, Adjacent Street, Weekday	PM Peak, Adjacent Street, Weekday	Midday, Weekday	Peak, Generator Saturday	Sample Size	Winter (Nov. - Feb.)
222: High-Rise Apartments	1	1			2	100%
223: Mid-Rise Apartments	7	8			15	27%
230: Residential Condominiums / Townhouses	1	1			2	0%
232: High-Rise Residential Condominiums / Townhouses	1	1			2	0%
710: General Office Building	4	4			8	0%
820: Shopping Center	3	8	1	1	13	31%
850: Supermarket	1	13			14	14%
851: Convenience Market (Open 24-Hours)		39			39	0%
925: Drinking Place		31			31	0%
931: Quality (Sit-Down) Restaurant		2	2		4	100%
932: High-Turnover (Sit-Down) Restaurant	1	58			59	3%
936: Coffee/Donut Shop without Drive-Through Window	2	2			4	0%
939: Bread/Donut/Bagel Shop without Drive-Through Window	1	1			2	0%
Total Observations	22	169	3	1	195	9%

3.4.2 Built Environment Measures

To apply any of the adjustment methods described previously, six measures defining the built environment, regional accessibility, and transit accessibility must be calculated. Only some of the built environment measures need to be calculated to apply any one of the three adjustment methods selected for each land use. The built environment measures utilized for each land use are listed in the adjustment specific models and tables in APPENDIX F through APPENDIX I. The sources for the required built environment measures are shown in Table 10 and Table 11.

Table 10. Built Environment Measures for Application: Data Sources

Data Source	Year	Files
Census Summary File 1	2010	Table P1: Total Population
Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics	2008	Workplace Area Characteristics (WAC), All Jobs[24]
TIGER Files	2009	Edges and Faces
Transit-Oriented Development (TOD) Database	2012	Point locations of TODs within each region

[24] LEHD data are not reported for New Hampshire.

Table 11. Built Environment Measures for Application: Definitions[25] [26]

Measure	Units	Source
Distance of Destination to CBD[27]	Miles	
Presence of TOD[28]	Binary	TOD Database
Residential		
Population Density	Residents per acre	Census 2010 SF1, P1
Employment		
Employment Density	Employees per acre	LEHD
Activity		
Activity Density (Population + Employment)	Employees and residents per acre	LEHD
Connectivity		
Total Intersection Density	Intersections per acre	TIGER
Four Approach (or more) Intersection Density	Intersections per acre	TIGER

[25] All items, unless otherwise noted, were calculated using GIS protocols set forth by D'sousa et al (2012).
[26]Area calculations for each AOI used to calculate densities include water area.
[27] Distance of Destination to Central Business District (CBD) is the Euclidian distance (miles) from the destination trip end of each trip to the CBD for the given region.
[28] Presence of TOD is a binary measure indicating the presences of a TOD within the AOI.

4.0 Results

This chapter provides an overview of the results from the three methodologies (see Section 3.3) used for calculating automobile mode shares in Section 4.1 and discusses the results found when verifying the three adjustment methodologies using independently collected vehicle trip generation data collected in accordance with ITE's *Trip Generation Handbook* in Section 4.2.

4.1 Mode Share and Vehicle Occupancy Model Results

Data were separated into nine different land use categories based on the process described in Section 3.2.1. For each of these nine land use categories, one mode share table, two automobile mode share regressions and one vehicle occupancy regression were derived according to the process described in Section 3.3, for a total of nine descriptive mode share tables, eighteen automobile mode share models and nine vehicle occupancy models. The Adjustment A mode share tables are located in APPENDIX F.

Overall, the benefit of the Adjustment A (descriptive mode share table) is the ability to easily calculate the average bike, walk and transit automobile mode shares. The data set could be further broken out into those trip ends located near and not near transit-oriented development, or segmented by the time of day. An example of the mode share tables can be seen in Table 12. This table shows the changes in aggregate vehicle, bike, transit and walk mode share for all trip ends at restaurant land uses observed in each of the three household travel surveys.

Table 12. Mode Shares across Activity Density: Restaurant Land Uses

	Activity Density (residents and employment per acre)						
	0-50	**50-100**	**100-150**	**150-200**	**200-250**	**250-300**	**300-350**
Vehicle	88%	53%	36%	25%	27%	30%	24%
Bike	1%	0%	3%	2%	2%	0%	5%
Transit	2%	9%	5%	7%	17%	15%	7%
Walk	9%	38%	56%	66%	54%	55%	64%
Trip Ends	15,900	647	299	281	155	274	42

The vehicle trip end mode shares do not evenly decline across the increasing activity density categories. Trip ends at activity densities greater than 200 people per acre were only observed in the Puget Sound data set. Trends observed above this level are therefore reflective of only one data set. Including an additional household travel survey from a region that contains greater activity densities may help smooth these trends.

Adjustment B and C binary logistic mode results are located in APPENDIX G and APPENDIX H, respectively. An example of the regression output for both Adjustment B and C is provided in Table 13 for the restaurant trip ends only. The direction of all the effects for the built environment variables were as expected. For example, as intersection density increases, the area-type becomes more urban and automobile mode shares decrease. In general, as the distance from the regional central business district increases, the automobile mode share increases, and when the trip end is located within a half-mile from a transit-oriented development where high-quality transit is present, the likelihood that an automobile is taken decreases. For all models in all land use categories, smaller samples were observed in highly urbanized locations than more suburban area-types.

Table 13. Adjustment B & C: Binary Logistic Regressions, Automobile Mode Share, Restaurant

				Adjustment B: Built environment metric with the best model performance		Adjustment C: Built environment metric with a strong model performance that is sensitive to land use policy	
	χ^2 (Likelihood Ratio Test)			3,318		2,992	
	Nagelkerke R^2			0.29		0.26	
	Sample Size (N)			17,561		17,561	
				B	**Sig.**	**B**	**Sig.**
Time of Day	AM Peak (7-9AM)	*		0.22	0.020	0.16	0.090
Time of Day	PM Peak (4-6PM)	*		0.23	0.000	0.22	0.000
Time of Day	Before 7AM, After 6PM	*		0.66	0.000	0.62	0.000
Time of Day	Mid-day (9AM-4PM)			(base)	-	(base)	-
Time of Day	Daily (calculated) [29]			*0.28*		*0.26*	
Date	Friday	*		0.16	0.010	0.19	0.000
Date	Weekend (Sa-Su)	*		0.36	0.050	0.30	0.080
Date	Weekday (M-Th)	*		(base)	-	(base)	-
Date	Winter (Nov. thru Feb.)	*		0.53	0.000	0.34	0.010
	Distance to CBD (miles)			0.02	0.000	0.04	0.000
	Presence of TOD	*		-0.55	0.000	-1.03	0.000
	Built environment metric with the best model performance		**Intersection Density**	-6.06	0.000	--	--
	Built environment metric with a strong model performance that is sensitive to land use policy		**Population Density**	--	--	-0.08	0.000
	(constant)			2.79	0.000	2.00	0.000

* Indicates dummy variable.

Overall, the regressions from Adjustment B, using the best built environment predictor to estimate vehicle mode share, explained a range of variation for each land use, from a pseudo-R^2 of 5% for single-family residential trip ends to 35% of variation for office trip ends (see Table 14 for the summary). The automobile mode share models for Adjustment C were selected for their contribution to land use policy sensitivity, not just their performance, and therefore the range of Nagelkerke R^2 range is slightly lower overall,

[29] For a discussion on the determination of the "Daily" coefficient, see APPENDIX E.

ranging from 4% to 35% of variation explained. The pseudo R^2 metrics for binary logistic models tend to be lower than the ordinary least squares R^2 metrics to which more people are familiar (Cohen, Cohen, West, & Aiken, 2003, p. 504). In the behavioral sciences, explanation of variance metrics above 10% "moderately" explain the variance observed in the dependent variable, the likelihood of taking an automobile for a given trip end.

Table 14. Adjustment B & C: Binary Logistic Regression, Summary of Results

		Adjustment B: Built environment metric with the best model performance		Adjustment C: Built environment metric with a strong model performance that is sensitive to land use policy	
Land Use Type	**Sample Size**	**Nagelkerke R^2**	**Built Environment Variable**	**Nagelkerke R^2**	**Built Environment Variable**
Restaurant	17,561	29%	Intersection Density	26%	Population Density
Retail	28,743	26%	Intersection Density	26%	Population Density
Service (non-restaurant)	26,104	14%	4-Approach Intersection Density	14%	Population Density
Office	10,912	35%	4-Approach Intersection Density	35%	Activity Density
Residential - General	84,517	10%	4-Approach Intersection Density	10%	Population Density
Multifamily	18,034	12%	4-Approach Intersection Density	11%	Population Density
Single-family	62,392	5%	4-Approach Intersection Density	4%	Population Density
Entertainment /Recreational	18,702	15%	4-Approach Intersection Density	15%	Population Density
All Land Uses	243,274	10%	4-Approach Intersection Density	14%	Population Density

For each of the three adjustment methods, a similar OLS linear regression predicting vehicle occupancy is applied. The linear regressions predicting vehicle occupancy rates are located in APPENDIX I, and Table 15 provides the results of the restaurant land use category vehicle occupancy rate regression.

Table 15. All Adjustment Methods: Ordinary Least Squares Regressions, Vehicle Occupancy, Restaurant Land Use

	Adjusted R^2		0.045		
	Sample Size (N)		68,547		
			B	**Beta**	**Sig.**
Time of Day	AM Peak (7-9AM)	*	-0.37	-0.08	0.000
Time of Day	PM Peak (4-6PM)	*	0.24	0.07	0.000
Time of Day	Before 7AM, After 6PM	*	0.37	0.15	0.000
Time of Day	Mid-day (9AM-4PM)		(base)	-	-
Time of Day	Daily (calculated) [30]		*0.15*	*0.06*	
Date	Friday	*	0.16	0.05	0.000
Date	Weekend (Sa-Su)	*	0.50	0.07	0.000
Date	Weekday (M-Th)	*	(base)	-	-
Date	Winter (Nov. thru Feb.)	*	0.25	0.04	0.000
	Distance to CBD (miles)		0.00	0.04	0.000
	Presence of TOD	*	-0.12	-0.03	0.006
	Activity Density		0.00	0.04	0.000
	(constant)		1.75		0.000

* Indicates dummy variable.
B: Unstandardized coefficient
Beta: Standardized coefficient

Overall, the performance of the vehicle occupancy models was low for all land use categories (see Table 16). Although all the included variables remain highly significant in explaining the variation, the effect size of the built environment measures remains very small. This indicated that vehicle occupancy rates vary significantly across context, but that the effect size of this variation is still very near zero.

[30] For a discussion on the determination of the "Daily" coefficient, see APPENDIX E.

Table 16. All Adjustments: Linear Regression Predicting Vehicle Occupancy

Land Use Type	Sample Size	Nagelkerke R^2
Restaurant	68,547	4.5%
Retail	22,896	3%
Service (non-restaurant)	25,280	3.7%
Office	8,705	1.1%
Residential - General	68,547	0.1%
Multifamily	12,209	2.5%
Single-family	52,943	0.6%
Entertainment /Recreational	14,639	6.6%
All Land Uses	197,426	1.1%

By constraining the model specification to data either (a) available within ITE's *Trip Generation Handbook*, such as the time of day or the day of week, or (b) built environment information readily available to the analyst, the low and moderate model performances for both automobile mode share and vehicle occupancy still provide predictors of automobile mode choice for establishment-level estimation without more robust individual-level information. To determine whether the model performances are sufficient in explaining variation in automobile mode choice and vehicle occupancy for an application in practice, the models were applied to establishment-level data to test the improvements of the mode share adjustments to ITE's *Trip Generation Handbook*.

4.2 Verification Results Discussion

This section discusses the results from the verification of each adjustment methods separated by land use category. Limited establishment-level data were available, and therefore, not every land use category was tested, and those that were tested did not always have an adequate sample size. Therefore, the analysis in this section cannot be called a “validation of the methodology”. Instead, we call this process a “verification of the methodology”. The sample sizes of the categories in these results should be considered when drawing conclusions, and further data collection and testing is required before this methodology be considered fully validated for the purpose of application in traffic impact analysis. The results were summarized in the following sections by the four land use categories available and studied: residential, office, restaurant and retail. Summaries of the quantitative results are shown in Table 17 and Table 18. For each ITE land use code, Figure 8 though Figure 19 were provided to show the differences between the estimation from ITE, Adjustment A, B, and C for each verification data point tested, as well as each urban-context adjustment land use type applied. These figures provide more information about whether ITE or any of the adjustment methods (A, B, or C for each land use type applied) over- or under-estimated vehicle trip end rates for the land uses analyzed. All data were plotted across activity densities, which highlight the range of urban area-types that were able to be tested in this analysis.

Table 17. Verification Results for Adjustment Methodologies (Table 1 of 2)

ITE's *Trip Generation Handbook* Land Use Code and Name		Urban Context Adjustment Land Use Type	Count	Normalized Root Mean Squared Error			
				Adjustment A	Adjustment B	Adjustment C	REFERENCE
				Mode Shares Across Activity Density	Regression: Best Predictor Variable	Regression: Best Policy Variable	ITE's *Trip Generation Handbook* Estimation
Residential							
222	High-Rise Apartments	**Multifamily**	2	53% *	317% *	**26%** *	1323%
		Residential	2	46% *	300% *	134% *	1323%
		All	2	173% *	283% *	156% *	1323%
223	Mid-Rise Apartments	**Multifamily**	15	27% *	26% *	28% *	32%
		Residential	15	26% *	27% *	29% *	32%
		All	15	**25%** *	27% *	33%	32%
230	Residential Condominiums / Townhouses	**Multifamily**	2	536%	492%	570%	**213%** •
		Residential	2	566%	509%	609%	**213%** •
		All	2	503%	517%	652%	**213%** •
232	High-Rise Residential Condominiums / Townhouses	**Multifamily**	2	60% *	65% *	50% *	412%
		Residential	2	56% *	51% *	**49%** *	412%
		All	2	109% *	91% *	88% *	412%
Office							
710	General Office Building	**Office**	8	56% *	68% *	63% *	109%
		All	8	50% *	**44%** *	63% *	109%

* Indicates an adjustment method that improves ITE's *Trip Generation Handbook* estimations.
• Indicates ITE's *Trip Generation Handbook* remains the best prediction method.
BOLD Indicates the lowest estimation method for each land use category.

Table 18. Verification Results for Adjustment Methodologies (Table 2 of 2)

ITE's *Trip Generation Handbook* Land Use Code and Name		Urban Context Adjustment Land Use Type	Count	Normalized Root Mean Squared Error: Adjustment A — Mode Shares Across Activity Density	Adjustment B — Regression: Best Predictor Variable	Adjustment C — Regression: Best Policy Variable	REFERENCE — ITE's *Trip Generation Handbook* Estimation
Retail							
820	Shopping Center	**Retail**	13	174% *	163% *	148% *	427%
		All	13	108% *	105% *	**85%** *	427%
850	Supermarket	**Retail**	14	56%	59%	62%	**26%** •
		All	14	71%	73%	76%	**26%** •
851	Convenience Market (Open 24-Hours)	**Retail**	39	37% *	27% *	30% *	78%
		All	39	23% *	**22%** *	23% *	78%
Restaurants (Service)							
925	Drinking Place	**Restaurant**	31	25% *	26% *	**19%** *	80%
		All	31	23% *	23% *	**19%** *	80%
931	Quality (Sit-Down) Restaurant	**Restaurant**	4	59%	57%	64%	**33%** •
		All	4	58%	55%	61%	**33%** •
932	High-Turnover (Sit-Down) Restaurant	**Restaurant**	59	**26%** *	28% *	27% *	35%
		All	59	27% *	27% *	27% *	35%
936	Coffee/Donut Shop without Drive-Through Window	**Restaurant**	4	193% *	129% *	59% *	345%
		All	4	195% *	101% *	**52%** *	345%
939	Bread/Donut/Bagel Shop without Drive-Through Window	**Restaurant**	2	646% *	427% *	297% *	1051%
		All	2	647% *	355% *	**271%** *	1051%

* Indicates an adjustment method that improves ITE's *Trip Generation Handbook* estimations.
• Indicates ITE's *Trip Generation Handbook* remains the best prediction method.
BOLD Indicates the lowest estimation method for each land use category.

Residential

For the residential-type land uses, three data sets were compiled considering only trips to multifamily-type land uses, trips only to general residential-type land uses and all trip ends in an aggregate data set. For each data set, three adjustment methods were developed: one considering simple mode share splits across activity density ranges (Adjustment A); a regression controlling for the built environment, for this category intersection density with four or more approaches was selected under the guiding principal of "best prediction" (Adjustment B), and; a regression controlling for the built environment when the policy sensitivity was taken into account, selecting population density as the built environment metric (Adjustment C). In general, the three adjustment methods (model shared across activity density, best predictor variable regression and best policy sensitive variable regression) perform differently for each land use. Any urban adjustment tends to improve the estimation of vehicle trip ends for high-rise apartments (LUC 222) and residential condominiums/townhouses (LUC 232). Mid-rise apartments (LUC 223) locations are estimated relatively well using ITE's *Trip Generation Handbook*. Improvements using urban context adjustments were less substantial for these land use establishments, compared with error observed when using ITE's *Trip Generation Handbook*. Adjustments to Residential Condominiums/Townhouses (LUC 230) degrade the accuracy of estimation for the two study sites included in the verification analysis. With only two locations analyzed for Residential Condominiums/Townhouses (LUC 230), the range of observed vehicle trip ends is limited (the same goes for LUC 222 and 230), which may inflate the NRSME metric. More locations are needed to confirm the need for an adjustment for these land uses.

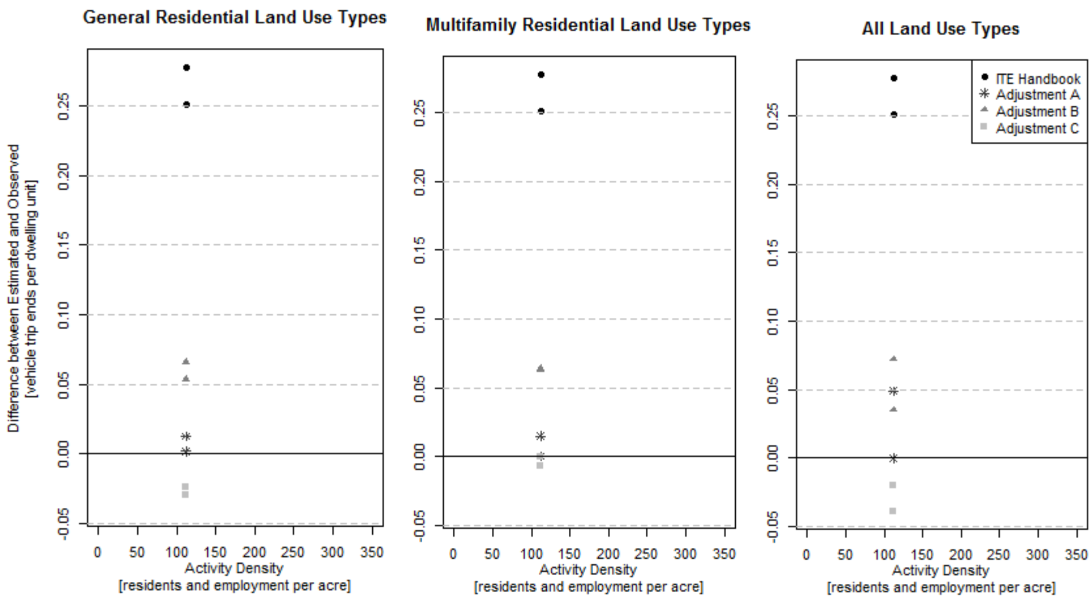

Figure 8. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 222: High-Rise Apartments

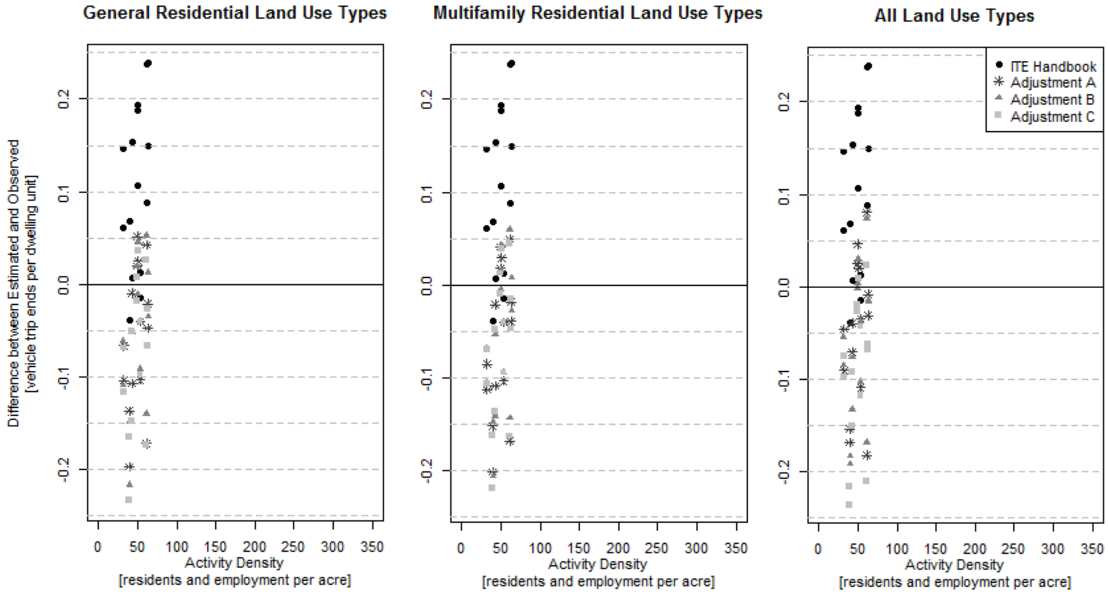

Figure 9. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 223: Mid-Rise Apartments

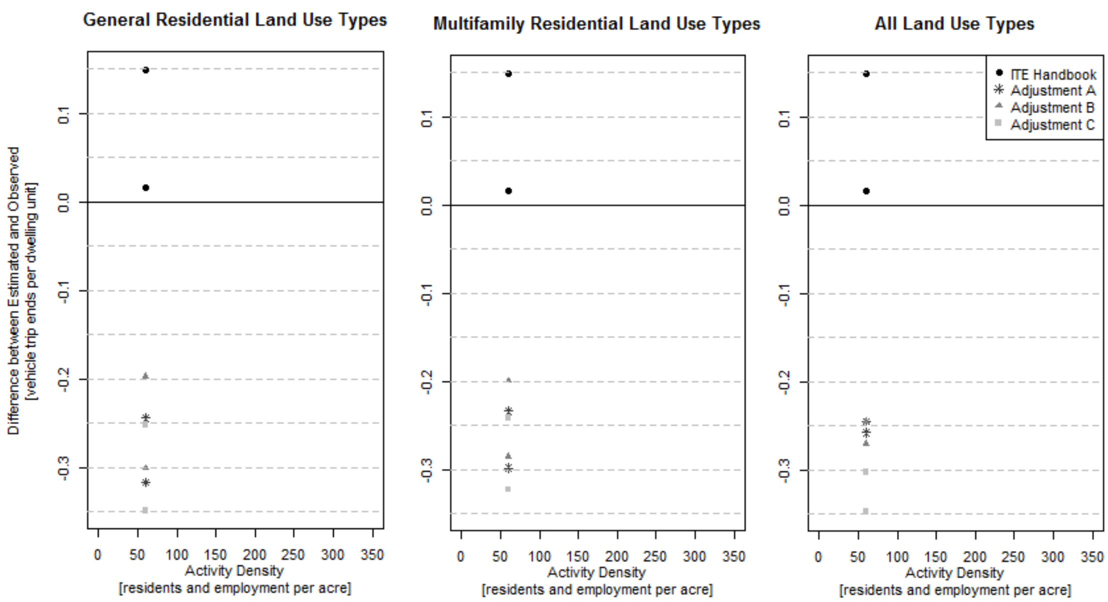

Figure 10. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 230: Residential Condominiums / Townhouses

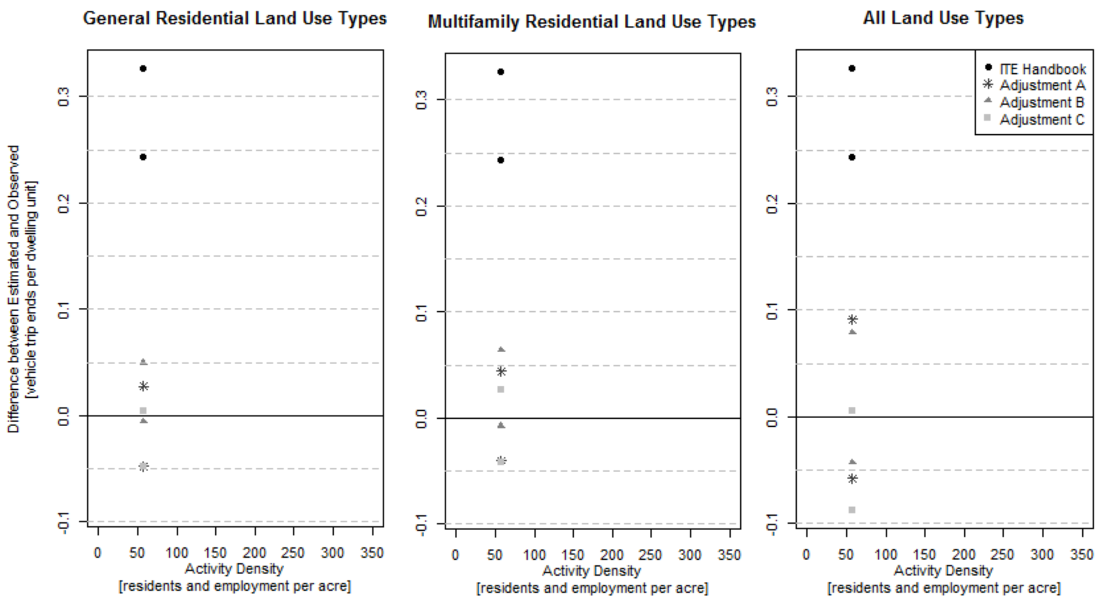

Figure 11. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 232: High-Rise Residential Condominiums / Townhouses

Office

For offices, two land use category data sets were used to develop adjustment methods, including: office-type land uses and all aggregate trip ends. Similar to residential land uses, three adjustment methods were developed for each data set. The built environment controlled for within Adjustment B (best predictor regression) was four-approach intersection density for both the office-type data set as well as the data set with all trip ends. For the regression with the best policy-sensitive variable (Adjustment C), activity density and population density were used as the primary control for the built environment for the office data set and the all trip ends data set, respectively. Once again, activity density was used for both data sets within Adjustment A, mode shares across activity density.

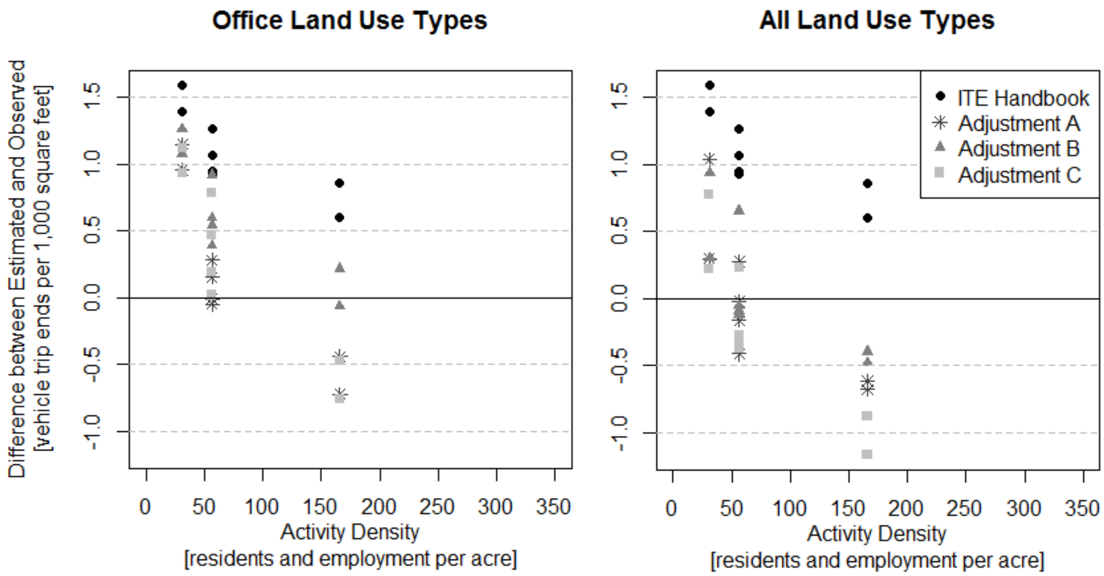

Figure 12. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 710: Office Building

In general, adjustments for urban context tend to improve the NRSME for all eight observations. The observed best performance was using the all trip ends data set and the Adjustment B, or the regression with the best predicting built environment measure. Adjustment A, the mode share table, also provided a probable adjustment.

Retail

Retail land uses were also estimated using land use data sets with retail-type trip ends and the all aggregate trip ends. For Adjustment B, the retail trip ends data set regression with the best predictor used intersection density, while the regression with the policy sensitive variable used population density (Adjustment C). In general, an adjustment with either the all trip ends data set or the retail-specific trip ends data set improved the estimation for both shopping centers (LUC 820) and convenience markets (LUC 851). There was greater error in shopping centers than the other two retail land uses, perhaps due to the variation possible in the type of retail establishments within development type.

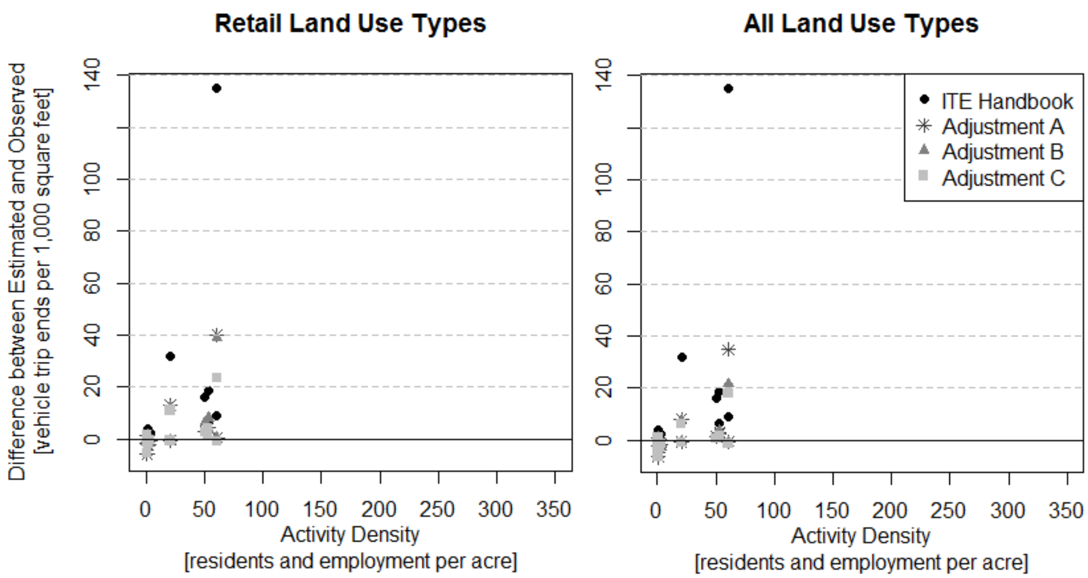

Figure 13. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 820: Shopping Center

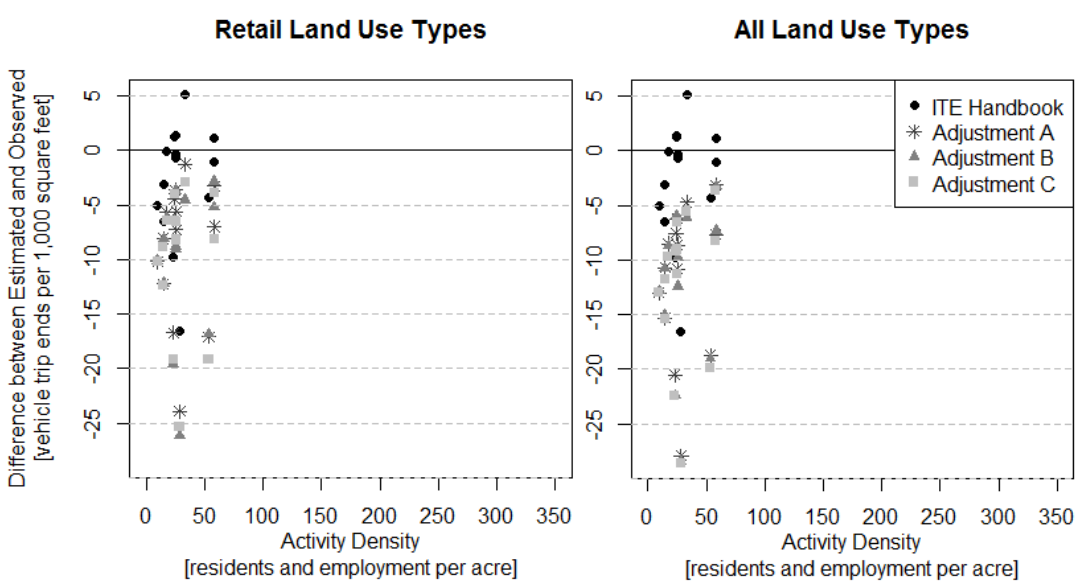

Figure 14. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 850: Supermarket

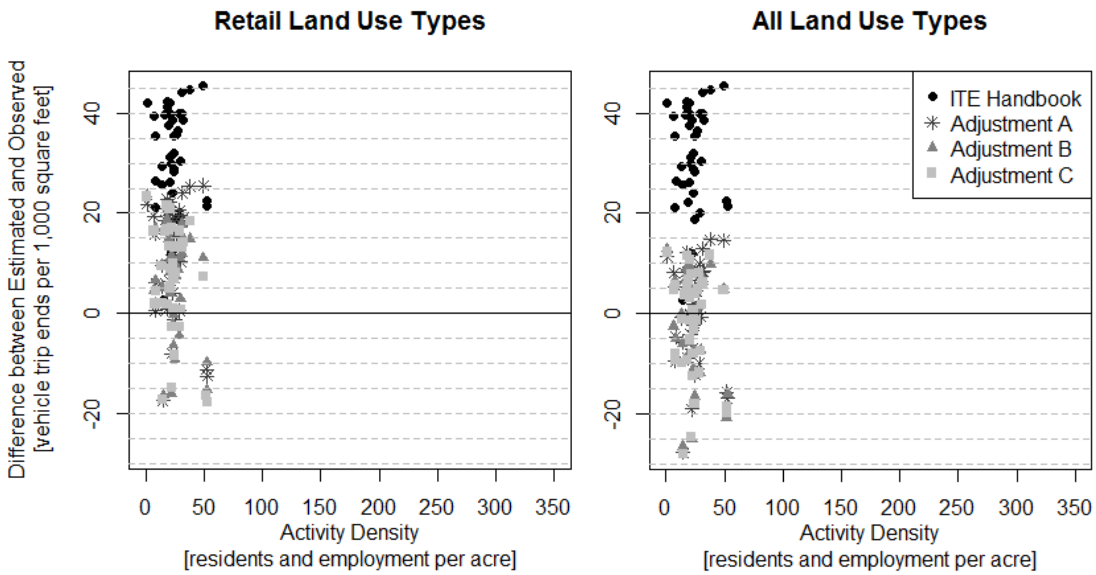

Figure 15. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 851: Convenience Market (Open 24-hours)

ITE's *Trip Generation Handbook* estimates supermarkets (LUC 850) relatively well compared with urban adjustment methods. Shopping centers often contain a variety of retail-type locations and convenience markets may attract trip makers picking up just a few things, instead of a car full of groceries. The retail trip end data set compiled may reflect more general retail that was not grocery-shopping specific. These results may reflect similarities between urban and suburban supermarkets based on the nature of the trip. Mode choice at general retail land uses may be more sensitive to urban form than grocery shopping.

Restaurants

Five land uses were observed within the restaurant land use category. Fewer observations were collected for quality (sit-down) restaurants (LUC 931), coffee/donut shops without drive-through windows (LUC 936) and bread/donut/bagel shops without drive-through windows (LUC 939); this may cause larger measurements for NRSME due to limitations in the range of observed vehicle trip end counts. In general, ITE's *Trip Generation Handbook* estimates quality (sit-down) restaurants (LUC 931) relatively well, both observations collected during winter months. High-turnover (sit-down) restaurants (LUC 932) were also estimated with a low amount of error using ITE's *Trip Generation Handbook*, although using an adjustment for urban contexts improved the relative error slightly using all three methods using both data sets. All urban adjustments improve the estimation of vehicular travel to drinking places (LUC 925), although using the regression with the best policy predictor (Adjustment C) has the lowest error rate for the large sample size.

The most substantial amount of error observed was for coffee/donut shops (LUC 936) and bread/donut/bagel shops (LUC 939), which may relate to the limited verification sample size, or to the relative newness of the land use as a category within ITE's *Trip Generation Handbook*. It is also plausible that the large error rates estimating these land use categories was due to a larger sensitivity to urban context than generally aggregated trips or overall restaurant type activities. While more observations at new developments may improve the overall understanding of travel to these land uses, identifying trip ends that travel to/from these extremely high-turnover restaurants may improve the ability to estimate the sensitivity to urban context.

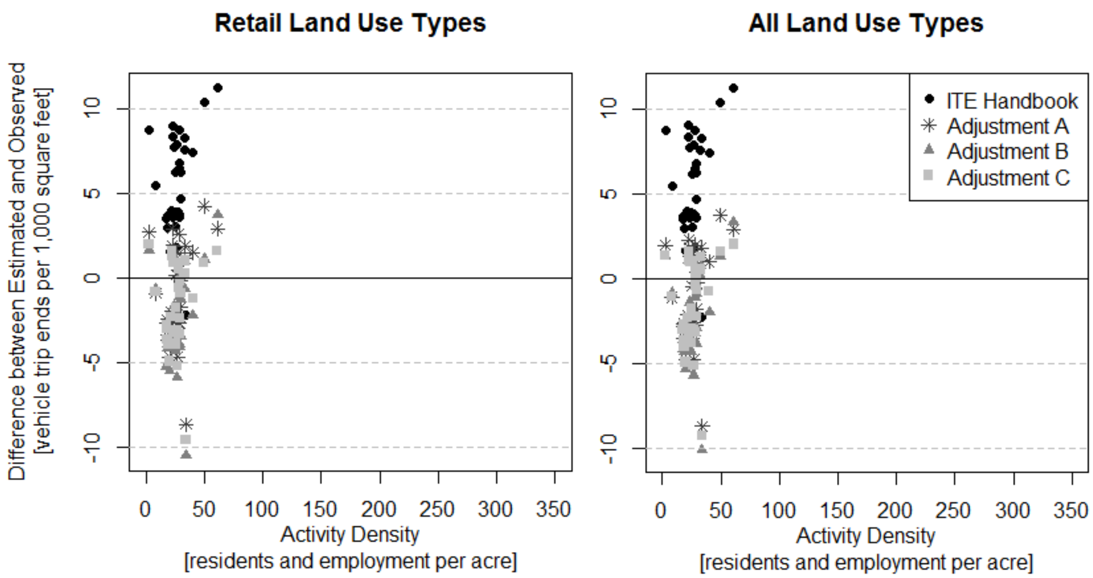

Figure 16. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 925: Drinking Places

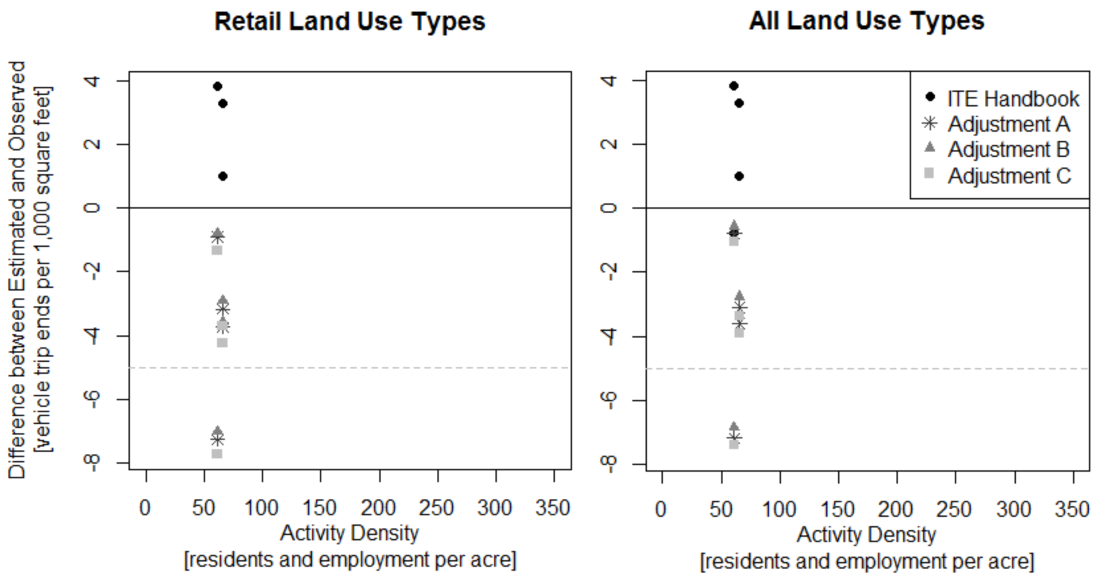

Figure 17. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 931: Quality (Sit-Down) Restaurants

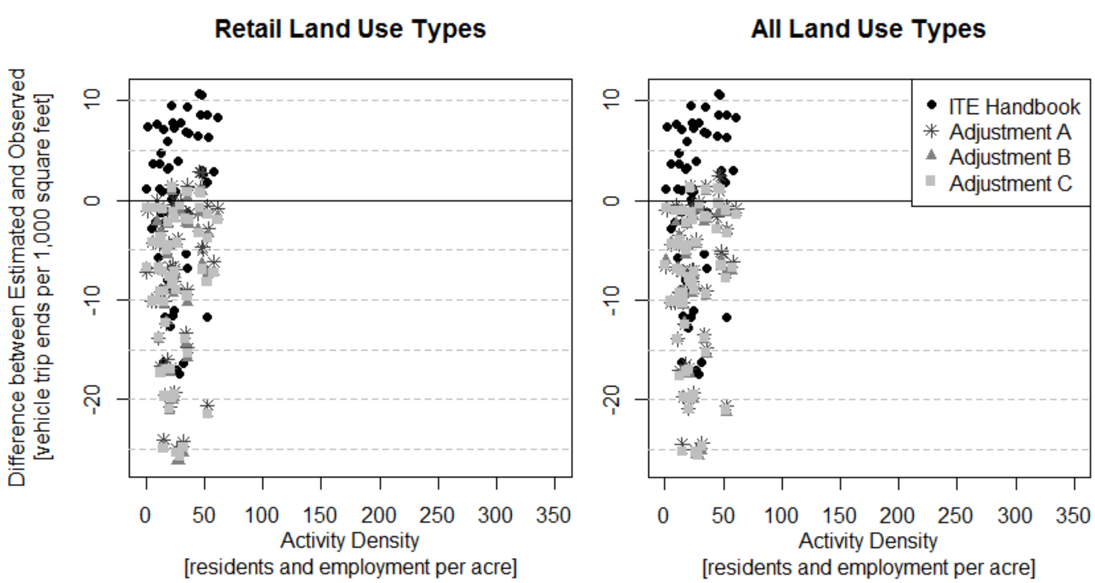

Figure 18. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 932: High-turnover (Sit-Down) Restaurants

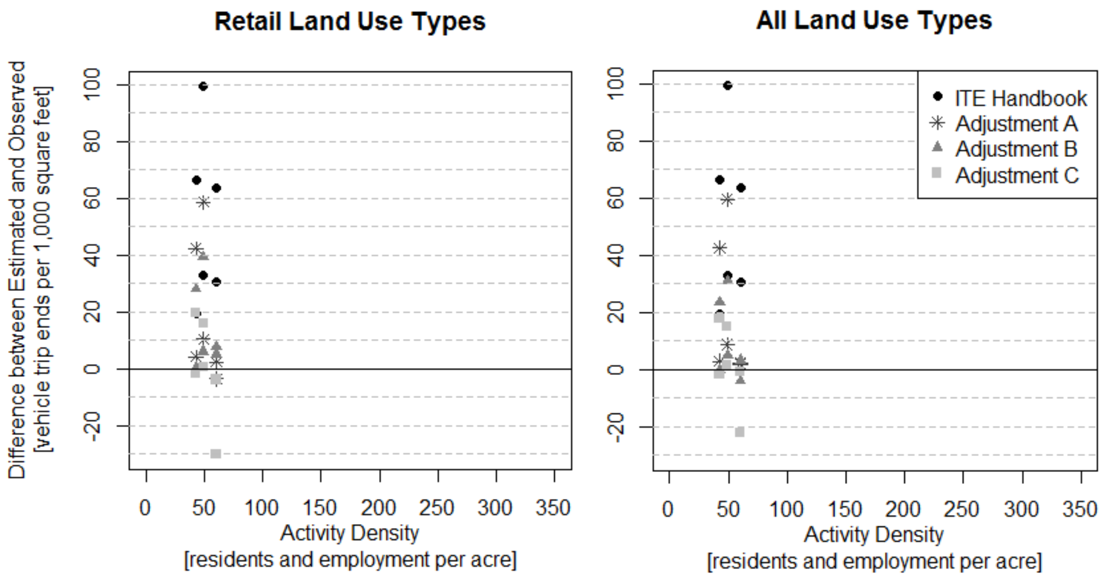

Figure 19. Verification: Estimated minus observed vehicle trip end rate - Land Use Code 936/939: Coffee/Donut-Bread/Donut/Bagel Shop without Drive-Through

5.0 Conclusions

This section discusses the findings from this study, outlines the limitations and makes recommendations for practice and future work. In this study we developed and tested three methods for adjusting ITE's *Trip Generation Handbook* estimates for developments located in different urban contexts. This work is concurrent with other studies with similar goals (Clifton, Currans, & Muhs, 2012; Schneider, Shafizadeh, & Handy, 2013; Daisa, et al., 2009) as the need for such an adjustment has long been called for in the literature (Lapham, 2001; Colorado/Wyoming ITE Section Technical Committee - Trip Generation, 1987; Hooper, 1989; Jeihani & Camilo, 2009). The three approaches make use of readily available household travel survey data for three metropolitan regions in the US: Baltimore, Maryland; Seattle, Washington, and; Portland, Oregon. These regions have a wide variety of urban environments, with differing transportation and land use characteristics. By basing these adjustment approaches on data from three divergent regions, we hope to eliminate the regional bias that may occur with data from one region alone and provide robust adjustment methodologies that can be broadly applied to communities throughout the United States.

Out of all of the land uses tested and verified in Section 4.2, ITE's *Trip Generation Handbook* appeared to have more accurate estimations for land uses that included residential condominiums/townhouses (LUC 230), supermarkets (LUC 850) and quality (sit-down) restaurants (LUC 931). Moderate or small improvements were observed when applying urban context adjustments to mid-rise apartments (LUC 223), high-turnover (sit-down) restaurants (LUC 932). The most substantial improvements occurred at high-rise apartments (LUC 222) and condominiums/townhouses (LUC 232), shopping centers (LUC 820), or coffee/donut (LUC 936) or bread/donut/bagel shops (LUC 939) without drive-through windows. Any of the three methods proposed to estimate automobile mode shares provides improvements to the *Handbook* rates for most infill developments in urban environments.

On average, all of the three methods developed and tested here perform better than ITE's Trip Generation Rates alone. The results demonstrate that urban context adjustments should be considered when using ITE Trip Generation rates for infill developments in densely populated areas with mixed use, smart growth sites, transit oriented developments and other locations with strong built environment supports for non-automobile modes.

Table 19. Overall Estimation Method Performance

UCA HTS Adjustment Methodology	Count	Normalized Root Mean Squared Error			
		Adjustment A	Adjustment B	Adjustment C	REFERENCE
		Mode Shares Across Activity Density	Regression: Best Predictor Variable	Regression: Best Policy Variable	ITE's *Trip Generation Handbook* Estimation
Multifamily	21	**23%** *	25% *	24% *	63%
Office	8	**56%** *	68% *	63% *	109%
Residential	21	**24%** *	25% *	26% *	63%
Restaurant	100	47% *	35% *	**25%** *	82%
Retail	66	77% *	72% *	**66%** *	190%
All	195	28% *	27% *	**22%** *	110%

* Indicates an adjustment method that improves ITE's *Trip Generation Handbook* estimations.

• Indicates ITE's *Trip Generation Handbook* remains the best prediction method.

BOLD Indicates the lowest estimation method for each land use category.

Of the three approaches, the simplest adjustment approach (Adjustment A) works just as well as the approaches derived using more complex models (see Table 19). This approach is easy to use in a variety of urban environments and suggests that simple adjustments that account for more multi-modal travel to urban destinations to the ITE methodology can have marked improvements. Additional development-level data collections representing more land uses, time periods and time of days are necessary to determine how ITE's *Handbook* performs in other circumstances, including assessing the transferability of the vehicle trip end rates or mode share reductions across regions.

This finding punctuates one the shortcomings of ITE Trip Generation Handbook, one of the most widely-used transportation references in use throughout the country. Its lack of sensitivity to urban context is just one of many issues that needs to be addressed. Other considerations include: the lack of guidance for estimating non-automobile trips, the need to account for person trips, the inability to include location information, the influence of site design, and the lack of a behavioral framework, to name a few. The current version of the Handbook is currently undergoing a revision and ITE is considering changes to the data collection procedures address these current failings. The findings from this study provide a stop-gap mechanism to deal with the urban context adjustment issue until an adequate amount of new data exist or an alternate approach is available.

However, this study is not without limitations. First, the use of trip purpose or activity type to approximate the land use type of the destination is subject to many assumptions about the nature of the establishment at the trip end. Some land use types are likely to be subject to more uncertainty than others, particularly those land uses that might attract a variety of trip purposes. For example, the trip purpose “go to a meeting” was considered a work-related activity and classified according to the trip-maker’s workplace industry type. It was possible, in the technological age of laptops and telecommunications, that this trip was actually a trip to a restaurant, coffee shop or park. Therefore, the data set used for each land use category provided only a sample of *potential* trip ends to occur at each land use category, not a sample of the universe of trip ends.

To improve the process of relating trip purposes to land uses, an archived spatial land use layer[31] for each regional travel survey may be compared with the coordinates of each trip end. This may enrich two items: (1) it may increase the confidence of applying trip ends into land use categories, and (2) it may provide an overall understanding of how accurate and successful was the non-mapping method. Work related to the spatial matching of activity patterns via GPS to land uses may provide useful algorithms for linking trip ends to likely land uses (Chen, Hongmian, Lawson, Bialostozky, & Muckell, 2010). The utility of household travel surveys for this purpose may be greatly enhanced as the amount and detailed of spatial information increases.

Another issue was there were an insufficient number of trip ends for some land use types that prohibited inclusion in this study. For example, trips to hotels, hospitals, recreational-specific sites and other establishments are often not captured in household travel surveys

[31] A land use layer provides, to the analyst’s best knowledge, the up-to-date use of land in the given area. Land use layers provide only long term plans for the land, and may not represent the current use.

due to the nature of the trips or the characteristics of the trip maker. In addition, the classification of HTS trip purposes required aggregation of land uses that may be distinctly different into general categories. For example, there may be some benefit from segmenting the Service (non-restaurant) category into more distinct land uses, such as "bank", "hair salon", or "print/copy shop".

In terms of the representation of urban context, this analysis employed only one measure of the built environment. This measure was selected based on its predictive power or land use policy-sensitivity in the planning practice. Another possibility to improve the representation of urban contexts is through composite measures of the built environment. Including multiple, built environment metrics in regression analysis is problematic due to the potential for correlation issues. Methods to distill built environment information into composite measures (i.e., factor and/or cluster analysis) may allow for representation of many measures of the built environment and how they work together to define the urban context (Clifton, Currans, Cutter, & Schneider, 2012; Cervero & Kockelman, 1997; Krizek K. J., 2003; Cao, Mokhtarian, & Handy, 2009). This, however, is challenging when we consider the widespread application of trip generation data and methods across the United States. Therefore future approaches may consider developing and testing these composite measures from a wide variety of places, rather than relying on just one region, in order to develop a set of universal context definitions. More research is needed to include additional measures describing the environment, testing the improvement of estimation results and performance in the application for establishment-level data.

In terms of other future work, the literature suggests that the relationship between the built environment and travel behavior changes significantly when controlling for socio-demographic characteristics of the trip-maker and travel characteristics of the trip itself (Ewing, DeAnna, & Li, 1996; Ewing & Cervero, 2010; Crane, 2000). ITE's *Trip Generation Handbook* methodology, initially developed in the 1960's, ignores the individual-level characteristics of the trip makers. Total vehicle trips are simply considered a function of the size of the establishment, whether measured in square footage, employees or seats. Subsequently it is not controlled for in trip generation analysis despite the fact that it is long understood that socio-demographics play a more important role in determining behavior and most regional travel models use them as the primary predictors of trip generation.

Overall, this study provides another methodology to accommodate the increasing demand for a more urban-sensitive framework to estimate travel demand at land uses. In part, this demand is due to changes in the goals of jurisdictions to grow more dense or diverse cities. Moreover, this growing interest in urban-sensitive trip generation methods reflects a promising desire to accommodate biking, walking and transit modes when planning for new developments and their impacts on the transportation network.

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APPENDIX A. ITE's *Trip Generation Handbook* Land Use Descriptions

Table A-1. ITE's *Trip Generation Handbook* Restaurant Land Use Descriptions[32]

Code	Land Use	Vehicle Occupancy Range (Persons/ Automobile)	Other Notes
925	Drinking Place	---	Food can be sold here, and possibly entertainment.
931	Quality Restaurant	1.78 (1.59-1.98)	For areas with outdoor seating number of seats may reflect estimates better than gross floor area (since outdoor areas are not included).
932	High-Turnover (Sit-Down) Restaurant	1.52 (1.39-1.69)	Not all restaurants have AM hours. Seats are also an available independent variable for estimating vehicle trips.
933	Fast-Food Restaurant without Drive-Through Window	---	
934	Fast-Food Restaurant with Drive-Through Window	---	ITE recommends using number of seats in the establishment as the independent variable.
935	Fast-Food Restaurant with Drive-Through Window	---	
936	Coffee/Donut Shop without Drive-Through Window	---	
937	Coffee/Donut Shop with Drive-Through Window	---	
938	Coffee/Donut Shop with Drive-Through Window and No Indoor Seating	---	
939	Bread/Donut/Bagel Shop without Drive-Through Window	---	
940	Bread/Donut/Bagel Shop with Drive-Through Window	---	Opens at 5/6AM; Closes at 11PM/12AM

--- Not available.

[32] Only the ITE's *Trip Generation* restaurant land use categories which are likely to appear in more urban contexts are listed in this table. No peak periods were provided for these land use. Hours of operation are noted on when applicable.

Table A-2. ITE's *Trip Generation Handbook* Service (Non-Restaurant) Land Use Descriptions[33]

Code	Land Use	AM Peak	PM Peak	Weekend Peak	Other Notes
911	Walk-in Bank	---	4-5:30PM	---	Low sample sizes available.
912	Drive-in Bank	vary 8AM-12PM	vary 12PM-6PM	9AM-1:30PM	May also service walk-in customers.
918	Hair Salon	---	---	---	Sample size of one.
920	Copy, Print and Express Ship Store	10:30-11:30AM	3:30-4:30PM	---	

--- Not available.

[33] Only the ITE's *Trip Generation* service land use categories which are likely to appear in more urban contexts and are not restaurants are listed in this table. No vehicle occupancy rates were provided.

Table A-3. ITE's *Trip Generation Handbook* Retail Land Use Descriptions[34]

Code	Land Use	AM Peak	PM Peak	Weekend Peak	Other Notes
813/815	Free-Standing Discount Superstore/Store[35]	vary 10AM-12PM	vary 12-6PM	vary 10AM-6PM	Weekend peak periods were midday. Superstores contain an additional grocery store.
814	Specialty Retail Center	---	---	---	A combination of several small land uses.
820	Shopping Center	varies	varies	varies	May contain non-merchandising land uses. Typically larger than land use 814.
823	Factory Outlet Center	---	---	---	Housing mainly factory outlet retail establishments, attracting patrons from a broader area.
850	Supermarket	---	---	---	
851/852	Convenience Market (24-hours)/(15-16 hours)	---	---	---	
853	Convenience Market with Gasoline Pumps	---	---	---	Peak periods generally coincide with the adjacent street.
854	Discount Supermarket	10AM-12PM	5-6PM	Afternoon	
861	Sporting Goods Superstore	---	---	12-2PM	Low sample sizes.
864	Toy/Children's Superstore	---	4-6PM	12-2PM	Low sample sizes.
865	Baby Superstore	---	---	---	Low sample sizes.
866	Pet Supply Superstore	---	---	12-2PM	Low sample sizes.
867	Office Supply Superstore	---	---	---	Low sample sizes.
868	Book Superstore	---	---	---	Low sample sizes.
872	Bed and Linen Superstore	---	---	2-3PM	Low sample sizes.
875	Department Store	11AM-12PM	vary 12:30-5PM	vary 1-5PM	Low sample sizes.
876	Apparel Store	---	---	---	Low sample sizes.
879	Arts and Crafts Store	---	---	---	Low sample sizes.
880/881	Pharmacy/Drugstore without/with Drive-Through Window	vary 10AM-12PM	vary 12-6PM	12-2PM	Low sample sizes.
896	Video Rental Store	---	---	---	Fridays generated more trips than other days, but samples for weekdays were aggregated anyway.

--- Not available.

[34] Only the ITE's *Trip Generation* retail land use categories which are likely to appear in more urban contexts are listed. Those with potential for larger purchases (hardware shops or nurseries) are not included.
[35] Only one study provided a vehicle occupancy rate of 1.46 persons per vehicle. No time of day was collected.

Table A-4. ITE's *Trip Generation Handbook* Office Land Use Descriptions[36]

Code	Land Use	Vehicle Occupancy Range (Persons/ Automobile)	AM Peak	PM Peak	Other Notes
710	General Office Building	---	Coincides with adjacent street facility.	Coincides with adjacent street facility.	Transit trip ends for observed data points are "nearly non-existent."
715	Single Tenant Office Building	1.1 (1.03-1.14)	Coincides with adjacent street facility.	Coincides with adjacent street facility.	
720	Medical-Dental Office	1.37 (1.32-1.44)			Outpatient care and diagnoses only.
730	Government Office Building	---	Coincides with adjacent street facility.	1-2PM	Low sample size.
731	State Motor Vehicles Department	1.38 (1.30-1.48)	Peak hours are midday: 10AM-4PM		
732	US Post Office	1.14	9-10AM	3-4PM	

--- Not available.

[36] Only the ITE's *Trip Generation* office land use categories which are likely to appear in more urban contexts are listed in this table. Office park style land uses are not described here.

Table A-5. ITE's *Trip Generation Handbook* Residential Land Use Descriptions[37]

Code	Land Use	Other Notes
210	Single-Family Detached Housing	A greater variation exists in this residential land use category. The number of trips within developments varies with pricing, size and distance to the regional central business district.
220	Apartment	The number of trips within developments varies with pricing, size and distance to the regional central business district.
221	Low-Rise Apartment	Apartments with one or two levels.
222	High-Rise Apartment	Apartments with more than ten levels, most likely with elevators.
223	Mid-Rise Apartment	Apartments with three to ten levels.
224	Rental Townhouse	A minimum of two attached units per building structure. Sample size of one.
230	Residential Condominium/Townhouse	Owned units with at least two owned units per building structure. These may be low- or high- rise structures. Vehicles owned and persons were also strong predictors.
231	Low-Rise Residential Condominium/Townhouse	Owned units with at least two owned units per building structure. A minimum of two attached units per building structure, at one to two floors tall.
232	High-Rise Residential Condominium/Townhouse	Owned units with at least two owned units per building structure. A minimum of two attached units per building structure, at three or more floors tall.
233	Luxury Condominium	This building structure includes "luxury facilities or services".

--- Not available.

[37] Only the ITE's *Trip Generation* residential land use categories which are likely to appear in more urban contexts are listed in this table. Group style living quarters should be considered a special generator and are not included in this analysis. Peak hours for all land uses (except Luxury Condominium) are reported to typically coincide with adjacent street facilities. The vehicle occupancy or non-automobile travel information was not included in any description.

APPENDIX B. Final HTS/Land Use Crosswalk, by Land Use

Table B-1. Restaurant Category- Trip Purposes

CODE	DESCRIPTION
	Trip Purposes
1007	Eat out
1012	Social
2017	Eat meal outside of home
3080	Meals
3081	Social event
3082	Get/eat meal
3083	Coffee/ice cream/snacks
	Work-Related Trip Purposes
1003	Work
2003	Work/job
2004	All other activities at work
2011	Work/Business related
3010	Work
3011	Go to work
3012	Return to work
3013	Attend business meeting/trip
3014	Other work related
3104	Meeting (unspecified)
3106	Looking for a job/Job interview

Table B-2. Restaurant Category- Work Industry Types

CODE	DESCRIPTION
2509	Accommodation or food services
1021	Restaurant/Fast Food/Bar & Grill (Unknown)
1038	Restaurant/Fast Food/Bar & Grill (Enclosed Mall)
1039	Restaurant/Fast Food/Bar & Grill (Standalone or Strip Mall)
1071	Bakery

Table B-3. Service Category - Trip Purposes

CODE	DESCRIPTION
	Trip Purposes
2015	Household errands (Bank, Dry Cleaning, etc.)
3063	User personal services: grooming/haircut/nails
2016	Personal business (Visit government office, attorney, accountant)
3061	Use professional services: attorney/accountant
1008	Personal business
3060	Family Personal Business/Obligations
3042	Buy services (video rentals, dry cleaner, post office)
	Work-Related Trip Purposes
1003	Work
2003	Work/job
2004	All other activities at work
2011	Work/Business related
3010	Work
3011	Go to work
3012	Return to work
3013	Attend business meeting/trip
3014	Other work related
3104	Meeting (unspecified)
3106	Looking for a job/Job interview

Table B-4. Service Category - Work Industry Types

CODE	DESCRIPTION
1003	Bank/Financial Institution (Unknown)
1004	Barber/Beauty/Nail Salon (Unknown)
1026	Bank/Financial Institution (Enclosed Mall)
1027	Bank/Financial Institution (Standalone or Strip Mall)
1028	Barber/Beauty/Nail Salon (Enclosed Mall)
1029	Barber/Beauty/Nail Salon (Standalone or Strip Mall)
1046	Animal Care/Control (Veterinary/Boarding/Grooming/Supplies)
1058	Photo studio
1069	Tattoo parlor
1075	Tanning Salon
3001	Sales or service

Table B-5. Retail Category - Trip Purposes

CODE	DESCRIPTION
	Trip Purpose
1009	Everyday shopping
2013	Routine Shopping (Groceries, Clothing, Convenience Store, HH Maintenance)
3040	Shopping errands
3041	Buy goods (groceries, clothing, hardware store)
	Work-Related Trip Purposes
1003	Work
2003	Work/job
2004	All other activities at work
2011	Work/Business related
3010	Work
3011	Go to work
3012	Return to work
3013	Attend business meeting/trip
3014	Other work related
3104	Meeting (unspecified)
3106	Looking for a job/Job interview

Table B-6. Retail Category - Work Industry Types

CODE	DESCRIPTION
1007	Convenience/Drug Store (Unknown)
1011	Grocery
1032	Convenience/Drug Store (Enclosed Mall)
1033	Convenience/Drug Store (Standalone or Strip Mall)
1073	Public market/Outdoor market/Fruit stand
1005	Bookstore/Library/Newsstand (Unknown)
1030	Bookstore/Library/Newsstand (Enclosed Mall)
1031	Bookstore/Library/Newsstand (Standalone or Strip Mall)
1043	Retail (Retail Shops/Unspecified Sales)
1053	Art gallery/studio
1062	Video store
1072	Music store/Shop
1093	Design/Clothing/Graphics/Arts/Crafts/Pottery
2004	Retail Trade

Table B-7. Office Category- Trip Purposes[38]

CODE	DESCRIPTION
	Work-Related Trip Purposes
1003	Work
2003	Work/job
2004	All other activities at work
2011	Work/Business related
3010	Work
3011	Go to work
3012	Return to work
3013	Attend business meeting/trip
3014	Other work related
3104	Meeting (unspecified)
3106	Looking for a job/Job interview

[38] Codes given in each trip purpose table relate to the trip purpose codes provided by the HTS. 1000-series codes correspond with the Puget Sound Regional Council HTS [code: ACT1 + 1000]; 2000-series codes correspond with the Oregon Household Activity Survey [code: TPURP + 2000]; 3000-series codes correspond with the National Household Travel Survey Add-Odd Survey for Baltimore Maryland [code: WHYTRP + 3000].

Table B-8. Office Category- Work Industry Types[39]

CODE	DESCRIPTION
1018	Office Building
1077	Computers/Software
1082	Architecture
1083	Insurance/Health insurance
1084	Marketing/Market Research/Public Relations/Advertising
1085	Consulting services
1086	Engineering
1088	Legal/Law
1089	Real Estate/Property Management
1092	Counseling
1094	Accounting/Bookkeeping/CPA
1095	Newspaper/Media/Publishing/Writer/Editor
1096	Professional Services
1097	Communications
1100	Technology/Electronics
1101	Telecommunication/Phone
1102	Management
1103	Research
1104	Collections/Collection Agency
1106	Technical
1107	Union
2006	Government
2501	Finance and insurance
2502	Real estate, rental or leasing
2503	Professional, scientific, or technical services
3002	Clerical or administrative support
3004	Professional, managerial, or technical
1010	Government/Municipal/City Offices/Library/Fire Station/ Post Office
1015	Medical Facility/Hospital

[39] Codes given in each workplace industry type table relate to the workplace industry codes provided by the HTS. 1000-series codes correspond with the Puget Sound Regional Council HTS [code: W1IND + 1000]; 2000-series codes correspond with the Oregon Household Activity Survey (OHAS) [code: INDUS + 2000]; 2500-series codes correspond a more detailed description of "service" industries (INDUS = 5) for OHAS workplace industry types [code: if INDUS = 5, INDUS5 + 2500]; 3000-series codes correspond with National Household Travel Survey Add-Odd Survey for Baltimore Maryland [code: OCCCAT + 3000].

Table B-9. Residential Category - Trip Purposes

CODE	DESCRIPTION
	Home-Related Trip Purposes
1001	Home - Paid work
1002	Home - Other
2001	Working at Home
2002	All other at home activities
3001	Home
	Work-Related Trip Purposes
1003	Work
2003	Work/job
2004	All other activities at work
2011	Work/Business related
3010	Work
3011	Go to work
3012	Return to work
3013	Attend business meeting/trip
3014	Other work related
3104	Meeting (unspecified)
3106	Looking for a job/Job interview

Table B-10. Residential Category- Home Structure and Work Industry Types, by Category[40]

CODE	DESCRIPTION	CATEGORY
1001	Residential (Work Industry)	Residential
1001	Detached single house	Single-Family
1002	Duplex	Multi-Family
1003	Triplex or Quad-plex	Multi-Family
1004	Row-house, townhouse	Multi-Family
1005	Apartment, condominium	Multi-Family
1006	Mobile home or trailer	Residential
1042	Senior Care (Assisted Living/Retirement Communities/Nursing) (Work Industry)	Residential
2001	Single family unit	Single-Family
2002	Duplex	Multi-Family
2003	Building with 3 or more apartments	Multi-Family
2022	Visit friends/relatives	Residential
3001	Detached single house	Single-Family
3002	Duplex, triplex	Multi-Family
3003	Row-house, townhouse	Multi-Family
3004	Apartment, condominium	Multi-Family
3007	Semi-attached/Semi-detached house	Multi-Family
3008	Quad-plex	Multi-Family
3053	Visit friends/relatives	Residential

[40] Codes given in each residential structure type table relate to the home place codes provided by the HTS. 1000-series codes correspond with the Puget Sound Regional Council HTS [code: CHMTYPE + 1000]; 2000-series codes correspond with the Oregon Household Activity Survey (OHAS) [code: RESTY + 2000]; 3000-series codes correspond with National Household Travel Survey Add-Odd Survey for Baltimore Maryland [code: HOMETYPE + 3000].

Table B-11. Entertainment/Recreational Category - Trip Purposes

CODE	DESCRIPTION
	Trip Purposes
1013	Recreation - Participate
1014	Recreation - Watch
2020	Outdoor recreation/entertainment
2021	Indoor recreation/entertainment
3050	Social/recreational
3051	Go to gym, exercise, play sports
3052	Rest or relaxation/vacation
3054	Go out/hand out (entertainment, theater, sports event)
3055	Visit public place (historical site, museum, park)
	Work-Related Trip Purposes
1003	Work
2003	Work/job
2004	All other activities at work
2011	Work/Business related
3010	Work
3011	Go to work
3012	Return to work
3013	Attend business meeting/trip
3014	Other work related
3104	Meeting (unspecified)
3106	Looking for a job/Job interview

Table B-12. Service Category - Work Industry Types

CODE	DESCRIPTION
1013	Indoor Recreation - gym/health club, skating rink (unknown)
1016	Movie Theater/Theatre/Concert Venue/Sports Arena (Unknown)
1017	Museum/Zoo/Historic Site
1019	Outdoor Recreation - Park, Athletic Field, Beach
1034	Indoor Recreation (Enclosed Mall)
1035	Indoor Recreation (Standalone or Strip Mall)
1036	Movie Theater/Theatre/Concert Venue/Sports Arena (Enclosed)
1037	Movie Theater/Theatre/Concert Venue/Sports Arena (Standalone)
1087	Entertainment
2508	Arts, entertainment or recreation

APPENDIX C. Summary Statistics for Trip End Data by Land Use

Table C-1. Summary Statistics of HTS Trip End Data Set: Restaurant Trip Ends

		Trip Ends	Percent of Total	
Total		17622	100%	
OHAS		2298	13%	
PSRC		12720	72%	
Baltimore		2604	15%	
		Average	**Standard Deviation**	**Sample Size[41]**
Built Environment (defined within a 1/2 mile)				
Activity Density	Persons per acre	25.6	48.4	
Employment Density	Employment per acre	16.8	44.0	
Intersection Density	Intersections per acre	0.22	0.15	
Percent of Intersections, 4 or more approaches	Percent of intersections with 4 or more approaches	37%		
Percent Retail Employment	Percent of employment in the retail service	14%		
Distance to the CBD	Miles to the MPO CBD	12.6	11.9	
Near a TOD	Percent near a TOD	12%		
Household Characteristics				
Size	Count	2.7	1.3	
Vehicle ownership	Persons per vehicle	2.1	1.0	
Drivers	Count	2.0	0.8	
Income	Percent with Income below $50,000	25%		
	Percent with Income above $100,000	27%		
Workers	Count	1.4	0.9	
Trip-maker Characteristics				
Age	Years	44	21	
Sex	Percent Female	55%		
Travel Characteristics				
Travel Distance (mi)	Average/SD	5.5	8.2	
Vehicle Occupancy	Average/SD	1.98	1.19	15,168
Vehicle Mode Share	Percent	83%		17,598
Walk Mode Share	Percent	13%		17,598
Transit Mode Share	Percent	3%		17,598
Bike Mode Share	Percent	1%		17,598
Time or Date				
AM Peak Period (7-9AM)	Percent	6%		17,621
PM Peak Period (4-6PM)	Percent	13%		17,621
Midday Period (9AM-4PM)	Percent	45%		17,621
Date				
Weekend (Saturday, Sunday)	Percent	2%		17,562
Friday	Percent	16%		17,562
Winter (Nov. thru Feb.)	Percent	4%		17,562

[41] If different from the total sample. This pertains to the rest of the tables in this appendix.

Table C-2. Summary Statistics of HTS Trip End Data Set: Service (Non-Restaurant) Trip Ends

		Trip Ends	Percent of Total	
Total		26,126	100%	
OHAS		2,195	8%	
PSRC		19,799	76%	
Baltimore		4,132	16%	
		Average	**Standard Deviation**	**Sample Size**
Built Environment (defined within a 1/2 mile)				
Activity Density	Persons per acre	20.3	39.2	
Employment Density	Employment per acre	12.4	35.0	
Intersection Density	Intersections per acre	0.20	0.14	
Percent of Intersections with 4 or more approaches	Percent of intersections with 4 or more approaches	35%		
Percent Retail Employment	Percent of employment in the retail service	14%		
Distance to the CBD	Miles to the MPO CBD	13.4	11.1	
Near a TOD	Percent near a TOD	9%		
Household Characteristics				
Size	Count	2.7	1.4	
Vehicle ownership	Persons per vehicle	2.1	1.1	
Drivers	Count	1.9	0.7	
Income	Percent with Income below $50,000	30%		
	Percent with Income above $100,000	22%		
Workers	Count	1.3	0.9	
Trip-maker Characteristics				
Age	Years	45	22	
Sex	Percent Female	55%		
Travel Characteristics				
Travel Distance (mi)	Average/SD	6.0	8.8	
Vehicle Occupancy	Average/SD	1.65	0.96	23,677
Vehicle Mode Share	Percent	88%		26,080
Walk Mode Share	Percent	7%		26,080
Transit Mode Share	Percent	4%		26,080
Bike Mode Share	Percent	1%		26,080
Time or Date				
AM Peak Period (7-9AM)	Percent	8%		26,123
PM Peak Period (4-6PM)	Percent	17%		26,123
Midday Period (9AM-4PM)	Percent	58%		26,123
Date				
Weekend (Saturday, Sunday)	Percent	1%		26,107
Friday	Percent	14%		26,107
Winter (Nov. thru Feb.)	Percent	4%		26,107

Table C-3. Summary Statistics of HTS Trip End Data Set: Retail Trip Ends

		Trip Ends	Percent of Total	
Total		28,781	100%	
OHAS		3,632	13%	
PSRC		17,152	60%	
Baltimore		7,997	28%	
		Average	**Standard Deviation**	**Sample Size**
Built Environment (defined within a 1/2 mile)				
Activity Density	Persons per acre	18.0	33.0	
Employment Density	Employment per acre	10.5	29.5	
Intersection Density	Intersections per acre	0.18	0.14	
Percent of Intersections with 4 or more approaches	Percent of intersections with 4 or more approaches	35%		
Percent Retail Employment	Percent of employment in the retail service	17%		
Distance to the CBD	Miles to the MPO CBD	12.7	9.8	
Near a TOD	Percent near a TOD	9%		
Household Characteristics				
Size	Count	2.6	1.3	
Vehicle ownership	Persons per vehicle	2.0	1.1	
Drivers	Count	1.9	0.8	
Income	Percent with Income below $50,000	31%		
	Percent with Income above $100,000	23%		
Workers	Count	1.3	0.9	
Trip-maker Characteristics				
Age	Years	49	18	
Sex	Percent Female	57%		
Travel Characteristics				
Travel Distance (mi)	Average/SD	5.64	7.87	
Vehicle Occupancy	Average/SD	1.52	0.85	26,620
Vehicle Mode Share	Percent	88%		28,765
Walk Mode Share	Percent	8%		28,765
Transit Mode Share	Percent	3%		28,765
Bike Mode Share	Percent	1%		28,765
Time or Date				
AM Peak Period (7-9AM)	Percent	5%		28,764
PM Peak Period (4-6PM)	Percent	19%		28,764
Midday Period (9AM-4PM)	Percent	55%		28,764
Date				
Weekend (Saturday, Sunday)	Percent	4%		28,760
Friday	Percent	15%		28,760
Winter (Nov. thru Feb.)	Percent	7%		28,760

Table C-4. Summary Statistics of HTS Trip End Data Set: Office Trip Ends

		Trip Ends	Percent of Total	
Total		10,924	100%	
OHAS		1,928	18%	
PSRC		4,738	43%	
Baltimore		4,258	39%	
		Average	**Standard Deviation**	**Sample Size**
Built Environment (defined within a 1/2 mile)				
Activity Density	Persons per acre	40.0	61.4	
Employment Density	Employment per acre	30.8	56.5	
Intersection Density	Intersections per acre	0.25	0.19	
Percent of Intersections with 4 or more approaches	Percent of intersections with 4 or more approaches	39%		
Percent Retail Employment	Percent of employment in the retail service	11%		
Distance to the CBD	Miles to the MPO CBD	10.7	11.2	
Near a TOD	Percent near a TOD	24%		
Household Characteristics				
Size	Count	2.5	1.2	
Vehicle ownership	Persons per vehicle	2.1	1.1	
Drivers	Count	1.9	0.7	
Income	Percent with Income below $50,000	23%		
	Percent with Income above $100,000	29%		
Workers	Count	1.8	0.7	
Trip-maker Characteristics				
Age	Years	46	12	
Sex	Percent Female	57%		
Travel Characteristics				
Travel Distance (mi)	Average/SD	9.4	12.3	
Vehicle Occupancy	Average/SD	1.18	0.61	9,529
Vehicle Mode Share	Percent	80%		10,920
Walk Mode Share	Percent	12%		10,920
Transit Mode Share	Percent	7%		10,920
Bike Mode Share	Percent	2%		10,920
Time or Date				
AM Peak Period (7-9AM)	Percent	24%		10,919
PM Peak Period (4-6PM)	Percent	21%		10,919
Midday Period (9AM-4PM)	Percent	40%		10,919
Date				
Weekend (Saturday, Sunday)	Percent	1%		10,917
Friday	Percent	15%		10,917
Winter (Nov. thru Feb.)	Percent	10%		10,917

Table C-5. Summary Statistics of HTS Trip End Data Set: Multi-family Residential Trip Ends

		Trip Ends	Percent of Total	
Total		18,078	100%	
OHAS		1,562	9%	
PSRC		6,844	38%	
Baltimore		9,672	54%	
		Average	**Standard Deviation**	**Sample Size**
Built Environment (defined within a 1/2 mile)				
Activity Density	Persons per acre	27.2	32.7	
Employment Density	Employment per acre	12.7	28.1	
Intersection Density	Intersections per acre	0.30	0.18	
Percent of Intersections with 4 or more approaches	Percent of intersections with 4 or more approaches	41%		
Percent Retail Employment	Percent of employment in the retail service	12%		
Distance to the CBD	Miles to the MPO CBD	8.2	8.6	
Near a TOD	Percent near a TOD	20%		
Household Characteristics				
Size	Count	2.3	1.4	
Vehicle ownership	Persons per vehicle	1.3	0.9	
Drivers	Count	1.5	0.8	
Income	Percent with Income below $50,000	56%		
	Percent with Income above $100,000	8%		
Workers	Count	1.2	0.8	
Trip-maker Characteristics				
Age	Years	43	21	
Sex	Percent Female	56%		
Travel Characteristics				
Travel Distance (mi)	Average/SD	7.3	18.7	
Vehicle Occupancy	Average/SD	1.51	0.93	15,477
Vehicle Mode Share	Percent	68%		18,057
Walk Mode Share	Percent	19%		18,057
Transit Mode Share	Percent	12%		18,057
Bike Mode Share	Percent	1%		18,057
Time or Date				
AM Peak Period (7-9AM)	Percent	16%		18,063
PM Peak Period (4-6PM)	Percent	16%		18,063
Midday Period (9AM-4PM)	Percent	36%		18,063
Date				
Weekend (Saturday, Sunday)	Percent	6%		18,049
Friday	Percent	16%		18,049
Winter (Nov. thru Feb.)	Percent	11%		18,049

Table C-6. Summary Statistics of HTS Trip End Data Set: Single-family Residential Trip Ends

		Trip Ends	Percent of Total	
Total		62,499	100%	
OHAS		11,257	18%	
PSRC		40,286	64%	
Baltimore		10,956	18%	
		Average	**Standard Deviation**	**Sample Size**
Built Environment (defined within a 1/2 mile)				
Activity Density	Persons per acre	8.4	7.1	
Employment Density	Employment per acre	2.1	3.4	
Intersection Density	Intersections per acre	0.2	0.1	
Percent of Intersections with 4 or more approaches	Percent of intersections with 4 or more approaches	27%		
Percent Retail Employment	Percent of employment in the retail service	12%		
Distance to the CBD	Miles to the MPO CBD	13.9	9.4	
Near a TOD	Percent near a TOD	2%		
Household Characteristics				
Size	Count	3.1	1.3	
Vehicle ownership	Persons per vehicle	2.3	1.0	
Drivers	Count	2.1	0.7	
Income	Percent with Income below $50,000	19%		
	Percent with Income above $100,000	31%		
Workers	Count	1.6	0.9	
Trip-maker Characteristics				
Age	Years	43	20	
Sex	Percent Female	53%		
Travel Characteristics				
Travel Distance (mi)	Average/SD	7.8	22.3	
Vehicle Occupancy	Average/SD	1.67	1.03	55,188
Vehicle Mode Share	Percent	85%		62,459
Walk Mode Share	Percent	7%		62,459
Transit Mode Share	Percent	6%		62,459
Bike Mode Share	Percent	2%		62,459
Time or Date				
AM Peak Period (7-9AM)	Percent	17%		62,490
PM Peak Period (4-6PM)	Percent	17%		62,490
Midday Period (9AM-4PM)	Percent	35%		62,490
Date				
Weekend (Saturday, Sunday)	Percent	2%		62,401
Friday	Percent	13%		62,401
Winter (Nov. thru Feb.)	Percent	5%		62,401

Table C-7. Summary Statistics of HTS Trip End Data Set: General Residential Trip Ends

		Trip Ends	Percent of Total	
Total		84,674	100%	
OHAS		13,911	16%	
PSRC		48,028	57%	
Baltimore		22,735	27%	
		Average	**Standard Deviation**	**Sample Size**
Built Environment (defined within a 1/2 mile)				
Activity Density	Persons per acre	12.7	18.7	
Employment Density	Employment per acre	4.6	14.6	
Intersection Density	Intersections per acre	0.20	0.14	
Percent of Intersections with 4 or more approaches	Percent of intersections with 4 or more approaches	30%		
Percent Retail Employment	Percent of employment in the retail service	12%		
Distance to the CBD	Miles to the MPO CBD	12.7	9.8	
Near a TOD	Percent near a TOD	6%		
Household Characteristics				
Size	Count	2.9	1.4	
Vehicle ownership	Persons per vehicle	2.1	1.1	
Drivers	Count	2.0	0.8	
Income	Percent with Income below $50,000	28%		
	Percent with Income above $100,000	26%		
Workers	Count	1.5	0.9	
Trip-maker Characteristics				
Age	Years	43	20	
Sex	Percent Female	54%		
Travel Characteristics				
Travel Distance (mi)	Average/SD	7.7	21.3	
Vehicle Occupancy	Average/SD	1.64	1.02	74,454
Vehicle Mode Share	Percent	81%		84,605
Walk Mode Share	Percent	10%		84,605
Transit Mode Share	Percent	7%		84,605
Bike Mode Share	Percent	1%		84,605
Time or Date				
AM Peak Period (7-9AM)	Percent	17%		84,649
PM Peak Period (4-6PM)	Percent	17%		84,649
Midday Period (9AM-4PM)	Percent	36%		84,649
Date				
Weekend (Saturday, Sunday)	Percent	3%		84,546
Friday	Percent	14%		84,546
Winter (Nov. thru Feb.)	Percent	7%		84,546

Table C-8. Summary Statistics of HTS Trip End Data Set: Entertainment/Recreation Trip Ends

		Trip Ends	Percent of Total	
Total		18,749	100%	
OHAS		2,403	13%	
PSRC		13,198	70%	
Baltimore		3,148	17%	
		Average	**Standard Deviation**	**Sample Size**
Built Environment (defined within a 1/2 mile)				
Activity Density	Persons per acre	29.1	54.3	
Employment Density	Employment per acre	20.2	48.9	
Intersection Density	Intersections per acre	0.21	0.15	
Percent of Intersections with 4 or more approaches	Percent of intersections with 4 or more approaches	37%		
Percent Retail Employment	Percent of employment in the retail service	12%		
Distance to the CBD	Miles to the MPO CBD	11.9	11.0	
Near a TOD	Percent near a TOD	13%		
Household Characteristics				
Size	Count	2.9	1.3	
Vehicle ownership	Persons per vehicle	2.1	1.0	
Drivers	Count	2.0	0.7	
Income	Percent with Income below $50,000	22%		
	Percent with Income above $100,000	30%		
Workers	Count	1.5	0.8	
Trip-maker Characteristics				
Age	Years	41.6	20.5	
Sex	Percent Female	55%		
Travel Characteristics				
Travel Distance (mi)	Average/SD	6.9	9.3	
Vehicle Occupancy	Average/SD	1.80	1.19	16,108
Vehicle Mode Share	Percent	79%		18,714
Walk Mode Share	Percent	14%		18,714
Transit Mode Share	Percent	6%		18,714
Bike Mode Share	Percent	2%		18,714
Time or Date				
AM Peak Period (7-9AM)	Percent	11%		18,746
PM Peak Period (4-6PM)	Percent	19%		18,746
Midday Period (9AM-4PM)	Percent	37%		18,746
Date				
Weekend (Saturday, Sunday)	Percent	3%		18,705
Friday	Percent	13%		18,705
Winter (Nov. thru Feb.)	Percent	3%		18,705

APPENDIX D. Summary of Built Environment Statistics: Verification Data

Table D-1. Summary of Built Environment Statistics: Verification Data Set: Average Values

	Within 1/2 mile of Transit-Oriented Development	Distance to the CBD (miles)	Activity Density	Population Density	Intersection Density	4-Approach Intersection Density	Percent 4-Approach Intersections of Total
222: High-Rise Apartments	100%	0.9	112	56	0.42	0.24	58%
223: Mid-Rise Apartments	87%	10	49	24	0.31	0.21	68%
230: Residential Condominiums / Townhouses	100%	0.2	60	30	0.29	0.23	79%
232: High-Rise Residential Condominiums / Townhouses	100%	0.3	57	29	0.28	0.21	74%
710: General Office Building	50%	5.8	77	39	0.26	0.16	59%
820: Shopping Center	54%	34.6	25	13	0.21	0.13	42%
850: Supermarket	50%	4	29	15	0.31	0.17	50%
851: Convenience Market (Open 24-Hours)	46%	5.3	23	12	0.32	0.18	48%
925: Drinking Place	23%	3	27	13	0.39	0.26	62%
931: Quality (Sit-Down) Restaurant	100%	0.6	64	32	0.38	0.15	39%
932: High-Turnover (Sit-Down) Restaurant	36%	5.7	26	13	0.34	0.21	52%
936: Coffee/Donut Shop without Drive-Through Window	100%	5	55	27	0.31	0.23	75%
939: Bread/Donut/Bagel Shop without Drive-Through Window	100%	8.8	43	21	0.36	0.26	72%
Total Observations	48%	7.1	33	16	0.33	0.2	55%

Table D-2. Summary of Built Environment Statistics: Verification Data Set: Minimum Values

	Within 1/2 mile of Transit-Oriented Development	Distance to the CBD (miles)	Activity Density	Population Density	Intersection Density	4-Approach Intersection Density	Percent 4-Approach Intersections of Total
222: High-Rise Apartments	100%	0.9	112	56	0.42	0.24	58%
223: Mid-Rise Apartments	0%	8.8	32	16	0.22	0.1	37%
230: Residential Condominiums / Townhouses	100%	0.2	60	30	0.29	0.23	79%
232: High-Rise Residential Condominiums / Townhouses	100%	0.3	57	29	0.28	0.21	74%
710: General Office Building	0%	0.2	31	15	0.18	0.09	43%
820: Shopping Center	0%	6.4	0	0	0.03	0	0%
850: Supermarket	0%	0.2	10	5	0.12	0.02	18%
851: Convenience Market (Open 24-Hours)	0%	0.3	1	0	0.01	0	0%
925: Drinking Place	0%	0.3	3	1	0.09	0.01	11%
931: Quality (Sit-Down) Restaurant	100%	0.6	61	31	0.38	0.15	39%
932: High-Turnover (Sit-Down) Restaurant	0%	0.1	0	0	0.03	0	0%
936: Coffee/Donut Shop without Drive-Through Window	100%	0.2	49	25	0.29	0.23	72%
939: Bread/Donut/Bagel Shop without Drive-Through Window	100%	8.8	43	21	0.36	0.26	72%
Total Observations	0%	0.1	0	0	0.01	0	0%

Table D-3. Summary of Built Environment Statistics: Verification Data Set: Maximum Values

	Within 1/2 mile of Transit-Oriented Development	Distance to the CBD (miles)	Activity Density	Population Density	Intersection Density	4-Approach Intersection Density	Percent 4-Approach Intersections of Total
222: High-Rise Apartments	100%	0.9	112	56	0.42	0.24	58%
223: Mid-Rise Apartments	100%	13.8	63	32	0.36	0.27	79%
230: Residential Condominiums / Townhouses	100%	0.2	60	30	0.29	0.23	79%
232: High-Rise Residential Condominiums / Townhouses	100%	0.3	57	29	0.28	0.21	74%
710: General Office Building	100%	12.4	166	83	0.38	0.26	72%
820: Shopping Center	100%	115.6	61	30	0.51	0.4	77%
850: Supermarket	100%	11.7	58	29	0.49	0.3	80%
851: Convenience Market (Open 24-Hours)	100%	20.6	53	26	0.63	0.54	85%
925: Drinking Place	100%	9.5	61	31	0.62	0.53	85%
931: Quality (Sit-Down) Restaurant	100%	0.6	66	33	0.39	0.16	40%
932: High-Turnover (Sit-Down) Restaurant	100%	115.4	61	31	0.63	0.55	87%
936: Coffee/Donut Shop without Drive-Through Window	100%	9.7	60	30	0.33	0.24	79%
939: Bread/Donut/Bagel Shop without Drive-Through Window	100%	8.8	43	21	0.36	0.26	72%
Total Observations	100%	115.6	166	83	0.63	0.55	87%

APPENDIX E. Distributions of Trip Ends by Time of Day for "Daily" Coefficients Calculations within Regressions

The time-of-day dummy variables applied within the model represent AM peak period, midday peak periods, PM peak period or all other times of the day. A coefficient for daily average mode shares cannot be derived when dummy variables are included for each disaggregate time period, since each coefficient represents the relationship between time-of-day and the likelihood an automobile mode choice is made. The sample, however, provides a distribution of observations by time of day. For example, the AM Peak period (7-9AM), Midday (base variable, 9AM-4PM), PM Peak period (4-6PM) and the rest of the day (before 7AM and after 6PM) account for 10%, 41%, 23% and 26% of the observed Restaurant land use sample, respectively. A "daily" mode share coefficient may be estimated by taking the distribution of trip ends by time of day and creating a weighted coefficient for "daily" estimates based on the observed time of day frequencies and coefficients, which would be $\beta_{daily} = 0.29$ for this example.

Table E-1. Distributions of Trip Ends by Time of Day

Trip Ends Data Set	Distribution of Person Trip Ends				Distribution of Vehicle Trip Ends			
	AM Peak 7AM – 9AM	Mid-day 9AM – 4PM	PM Peak 4PM – 6PM	Before 7AM, After 6PM	AM Peak 7AM – 9AM	Mid-day 9AM – 4PM	PM Peak 4PM – 6PM	Before 7AM, After 6PM
Restaurant	6%	45%	13%	36%	6%	37%	13%	43%
Service (Non-Restaurant)	8%	58%	17%	17%	8%	18%	17%	58%
Retail	5%	55%	19%	21%	5%	21%	19%	55%
Office	24%	40%	21%	15%	24%	16%	21%	39%
Multifamily Residential	16%	36%	16%	32%	15%	33%	35%	17%
Single-Family Residential	17%	35%	17%	30%	17%	31%	17%	35%
General Residential	17%	36%	17%	31%	15%	33%	17%	35%
Entertainment/ Recreation	11%	37%	19%	33%	10%	34%	37%	19%
All Trip Ends	15%	43%	17%	25%	14%	26%	17%	43%

APPENDIX F. Adjustment A: Tables of Mode Shares by Activity Density

Table F-1. Mode Shares across Activity Density: Restaurant Land Uses

	Activity Density (residents and employment per acre)						
	0-50	50-100	100-150	150-200	200-250	250-300	300-350
Vehicle	88%	53%	36%	25%	27%	30%	24%
Bike	1%	0%	3%	2%	2%	0%	5%
Transit	2%	9%	5%	7%	17%	15%	7%
Walk	9%	38%	56%	66%	54%	55%	64%
Trip Ends	15,900	647	299	281	155	274	42

Table F-2. Mode Shares across Activity Density: Service (Non-Restaurant) Land Uses

	Activity Density (residents and employment per acre)						
	0-50	50-100	100-150	150-200	200-250	250-300	300-350
Vehicle	90%	72%	56%	48%	58%	26%	0%
Bike	1%	1%	3%	2%	0%	0%	0%
Transit	3%	10%	16%	20%	22%	24%	75%
Walk	6%	18%	25%	30%	19%	50%	25%
Trip Ends	24,332	710	310	289	219	208	12

Table F-3. Mode Shares across Activity Density: Retail Land Uses

	Activity Density (residents and employment per acre)						
	0-50	50-100	100-150	150-200	200-250	250-300	300-350
Vehicle	91%	52%	32%	34%	36%	25%	83%
Bike	1%	2%	4%	1%	0%	0%	0%
Transit	2%	10%	13%	26%	33%	20%	0%
Walk	7%	37%	51%	39%	32%	55%	17%
Trip Ends	27,299	730	156	214	206	148	12

Table F-4. Mode Shares across Activity Density: Office Land Uses

	Activity Density (residents and employment per acre)						
	0-50	**50-100**	**100-150**	**150-200**	**200-250**	**250-300**	**300-350**
Vehicle	89%	56%	46%	36%	60%	32%	25%
Bike	1%	5%	3%	3%	0%	2%	0%
Transit	4%	17%	8%	14%	29%	40%	75%
Walk	6%	22%	42%	46%	12%	25%	0%
Trip Ends	8,566	900	464	648	42	276	24

Table F-5. Mode Shares across Activity Density: Multi-Family Residential Land Uses

	Activity Density (residents and employment per acre)						
	0-50	**50-100**	**100-150**	**150-200**	**200-250**	**250-300**	**300-350**
Vehicle	71%	47%	32%	30%	35%	60%	15%
Bike	1%	1%	1%	3%	0%	0%	0%
Transit	10%	20%	21%	22%	9%	30%	0%
Walk	17%	32%	46%	45%	56%	10%	85%
Trip Ends	15,959	1,497	336	130	79	30	26

Table F-6. Mode Shares across Activity Density: Single-Family Residential Land Uses

	Activity Density (residents and employment per acre)						
	0-50	**50-100**	**100-150**	**150-200**	**200-250**	**250-300**	**300-350**
Vehicle	85%	66%	69%	---	---	---	---
Bike	2%	0%	0%	---	---	---	---
Transit	6%	11%	0%	---	---	---	---
Walk	7%	23%	31%	---	---	---	---
Trip Ends	62,289	157	13	---	---	---	---

Table F-7. Mode Shares across Activity Density: General Residential Land Uses

	Activity Density (residents and employment per acre)						
	0-50	50-100	100-150	150-200	200-250	250-300	300-350
Vehicle	82%	48%	34%	34%	35%	52%	15%
Bike	1%	1%	1%	3%	0%	0%	0%
Transit	7%	19%	20%	21%	9%	38%	0%
Walk	9%	31%	45%	43%	56%	10%	85%
Trip Ends	82,217	1,726	369	146	79	42	26

Table F-8. Mode Shares across Activity Density: Entertainment/Recreational Land Uses

	Activity Density (residents and employment per acre)						
	0-50	50-100	100-150	150-200	200-250	250-300	300-350
Vehicle	83%	57%	47%	56%	36%	37%	15%
Bike	2%	1%	4%	2%	2%	2%	15%
Transit	3%	12%	28%	15%	38%	38%	46%
Walk	12%	30%	21%	28%	24%	23%	23%
Trip Ends	16,474	689	580	224	359	362	26

Table F-9. Mode Shares across Activity Density: All Land Uses

	Activity Density (residents and employment per acre)						
	0-50	50-100	100-150	150-200	200-250	250-300	300-350
Vehicle	84%	55%	41%	33%	44%	37%	25%
Bike	1%	2%	3%	2%	1%	1%	3%
Transit	6%	15%	19%	23%	28%	30%	34%
Walk	9%	28%	38%	42%	28%	32%	38%
Trip Ends	226,178	7,359	3,418	2,964	1,398	1,878	192

APPENDIX G. Adjustment B: Binary Logistic Regressions, Automobile Mode Share, Built Environment with Best Predictive Power

Table G-1. Adjustment B: Binary Logistic Regressions, Automobile Mode Share, Built Environment with Best Predictive Power, Table 1 of 2

			Restaurant		Service (Non-Restaurant)		Retail		Office	
	χ^2 (Likelihood Ratio Test)		3,318		2,180		4,203		2,741	
	Nagelkerke R^2		0.29		0.15		0.26		0.35	
	Sample Size (N)		17,561		26,104		28,743		10,912	
			B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Time of Day	AM Peak (7-9AM)	*	0.22	0.020	-0.35	0.000	-0.39	0.000	0.22	0.000
	PM Peak (4-6PM)	*	0.23	0.000	0.02	0.670	0.09	0.090	0.25	0.000
	Before 7AM, After 6PM	*	0.66	0.000	0.20	0.000	0.10	0.050	0.45	0.000
	Mid-day (9AM-4PM)		(base)	-	(base)	-	(base)	-	(base)	-
	Daily (calculated) **		*0.28*		*0.00*		*0.02*		*0.17*	
Date	Friday	*	0.16	0.010	-0.06	0.270	0.02	0.750	0.04	0.610
	Weekend (Sa-Su)	*	0.36	0.050	0.37	0.100	0.01	0.930	-0.01	0.970
	Weekday (M-Th)	*	(base)	-	(base)	-	(base)	-	(base)	-
	Winter (Nov. thru Feb.)	*	0.53	0.000	0.53	0.000	0.21	0.020	0.22	0.040
	Distance to CBD (miles)		0.02	0.000	0.02	0.000	0.04	0.000	0.12	0.000
	Presence of TOD	*	-0.55	0.000	-0.32	0.000	-0.33	0.000	-0.35	0.000
	Built Environment Variable with the Best Prediction		**Intersection Density**		**4-Approach Intersection Density**		**Intersection Density**		**4-Way Intersection Density**	
			-6.06	0.000	-5.77	0.000	-5.56	0.000	-0.03	0.000
	(constant)		2.79	0.000	2.42	0.000	2.91	0.000	1.74	0.000

* Indicates dummy variable.

** For a discussion on the determination of the “Daily” coefficient, see APPENDIX E.

Table G-2. Adjustment B: Binary Logistic Regressions, Automobile Mode Share, Built Environment with Best Predictive Power, Table 2 of 2

			Residential						Entertainment/ Recreation		All Trip Ends	
			Multifamily		Single Family		General					
	χ^2 **(Likelihood Ratio Test)**		1,637		1,791		5,537		1,950		25,077	
	Nagelkerke R^2		0.12		0.05		0.10		0.15		0.16	
	Sample Size (N)		18,034		62,392		84,517		18,702		243,274	
			B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Time of Day	AM Peak (7-9AM)	*	-0.05	0.340	-0.28	0.000	-0.19	0.000	-0.11	0.070	-0.27	0.000
	PM Peak (4-6PM)	*	0.16	0.000	0.14	0.000	0.15	0.000	0.09	0.100	0.18	0.000
	Before 7AM, After 6PM	*	0.20	0.000	0.18	0.000	0.19	0.000	0.24	0.000	0.27	0.000
	Mid-day (9AM-4PM)		(base)	-	(base)	-	(base)	-	(base)	-	(base)	-
	Daily (calculated) **		*0.08*		*0.03*		*0.05*		*0.09*		*0.06*	
Date	Friday	*	0.14	0.000	0.05	0.180	0.06	0.040	-0.09	0.080	0.04	0.010
	Weekend (Sa-Su)	*	0.77	0.000	0.22	0.030	0.46	0.000	-0.21	0.070	0.32	0.000
	Weekday (M-Th)	*	(base)	-	(base)	-	(base)	-	(base)	-	(base)	-
	Winter (Nov. thru Feb.)	*	0.24	0.000	0.28	0.000	0.17	0.000	-0.61	0.000	0.13	0.000
	Distance to CBD (miles)		0.01	0.000	0.01	0.000	0.01	0.000	0.03	0.000	0.02	0.000
	Presence of TOD	*	-0.11	0.020	0.01	0.860	-0.24	0.000	-0.07	0.250	-0.46	0.000
	Built Environment Variable with the Best Prediction		**4-Way Intersection Density**		**4-Way Intersection Density**		**4-Way Intersection Density**		**4-Way Intersection Density**		**4-Way Intersection Density**	
			-4.32	0.000	-4.39	0.000	-5.03	0.000	-4.68	0.000	-4.80	0.000
	(constant)		1.20	0.000	1.84	0.000	1.73	0.000	1.53	0.000	1.78	0.000

* Indicates dummy variable.

** For a discussion on the determination of the "Daily" coefficient, see APPENDIX E.

APPENDIX H. Adjustment C: Binary Logistic Regressions, Automobile Mode Share, Built Environment with Policy Sensitivity

Table H-1. Adjustment C: Binary Logistic Regressions, Automobile Mode Share, Built Environment with Policy Sensitivity, Table 1 of 2

			Restaurant		**Service (Non-Restaurant)**		**Retail**		**Office**	
	χ^2 (Likelihood Ratio Test)		2,992		1,967		4,101		2,710	
	Nagelkerke R^2		0.26		0.14		0.26		0.35	
	Sample Size (N)		17,561		26,104		28,743		10,912	
			B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Time of Day	AM Peak (7-9AM)	*	0.16	0.090	-0.39	0.000	-0.36	0.000	0.27	0.000
	PM Peak (4-6PM)	*	0.22	0.000	0.02	0.750	0.06	0.240	0.29	0.000
	Before 7AM, After 6PM	*	0.62	0.000	0.19	0.000	0.13	0.010	0.52	0.000
	Mid-day (9AM-4PM)		(base)	-	(base)	-	(base)	-	(base)	-
	Daily (calculated) **		*0.26*		0.00		*0.02*		0.20	
Date	Friday	*	0.19	0.000	-0.03	0.630	0.01	0.870	0.06	0.410
	Weekend (Sa-Su)	*	0.30	0.080	0.40	0.080	0.09	0.400	0.04	0.920
	Weekday (M-Th)	*	(base)	-	(base)	-	(base)	-	(base)	-
	Winter (Nov. thru Feb.)	*	0.34	0.010	0.57	0.000	0.24	0.010	0.44	0.000
	Distance to CBD (miles)		0.04	0.000	0.02	0.000	0.05	0.000	0.13	0.000
	Presence of TOD	*	-1.03	0.000	-0.81	0.000	-0.73	0.000	-0.12	0.130
	Built Environment Variable With Policy Sensitivity		**Population Density**		**Population Density**		**Population Density**		**Activity Density**	
			-0.08	0.000	-0.06	0.000	-0.09	0.000	-0.01	0.000
	(constant)		2.00	0.000	2.38	0.000	2.48	0.000	0.70	0.000

* Indicates dummy variable.

** For a discussion on the determination of the "Daily" coefficient, see APPENDIX E.

Table H-2. Adjustment C: Binary Logistic Regressions, Automobile Mode Share, Built Environment with Policy Sensitivity, Table 2 of 2

			Residential						Entertainment/ Recreation		All Trip Ends	
			Multifamily		Single Family		General					
	χ^2 (Likelihood Ratio Test)		1,480		1,573		5,311		1,888		22,721	
	Nagelkerke R^2		0.11		0.04		0.10		0.15		0.14	
	Sample Size (N)		18,034		62,392		84,521		18,702		243,278	
			B	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**	**B**	**Sig.**
Time of Day	AM Peak (7-9AM)	*	-0.05	0.350	-0.28	0.000	-0.20	0.000	-0.10	0.120	-0.29	0.000
	PM Peak (4-6PM)	*	0.16	0.000	0.13	0.000	0.15	0.000	0.10	0.050	0.16	0.000
	Before 7AM, After 6PM	*	0.21	0.000	0.17	0.000	0.20	0.000	0.25	0.000	0.27	0.000
	Mid-day (9AM-4PM)		(base)	-	(base)	-	(base)	-	(base)	-	(base)	-
	Daily (calculated) **		*0.09*		*0.02*		*0.06*		*0.09*		*0.05*	
Date	Friday	*	0.15	0.000	0.07	0.040	0.09	0.000	-0.10	0.080	0.07	0.000
	Weekend (Sa-Su)	*	0.78	0.000	0.22	0.030	0.55	0.000	-0.16	0.150	0.42	0.000
	Weekday (M-Th)	*	(base)	-	(base)	-	(base)	-	(base)	-	(base)	-
	Winter (Nov. thru Feb.)	*	0.30	0.000	0.32	0.000	0.27	0.000	-0.54	0.000	0.23	0.000
	Distance to CBD (miles)		0.02	0.000	0.01	0.000	0.01	0.000	0.03	0.000	0.03	0.000
	Presence of TOD	*	-0.32	0.000	-0.03	0.730	-0.35	0.000	-0.43	0.000	-0.86	0.000
	Built Environment Variable With Policy Sensitivity		**Population Density**		**Population Density**		**Population Density**		**Population Density**		**Population Density**	
			-0.04	0.000	-0.06	0.000	-0.06	0.000	-0.06	0.000	-0.05	0.000
	(constant)		1.16	0.000	1.97	0.000	1.83	0.000	1.60	0.000	1.75	0.000

* Indicates dummy variable.

** For a discussion on the determination of the "Daily" coefficient, see APPENDIX E.

APPENDIX I. All Adjustment Methods: Linear Regressions, Vehicle Occupancy

Table I-1. All Adjustment Methods: Ordinary Least Squares Regressions, Vehicle Occupancy, Table 1 of 2

			Restaurant			Service (Non-Restaurant)			Retail			Office		
	Adjusted R^2		0.045			0.03			0.037			0.011		
	Sample Size (N)		68,547			22,896			25,280			8,705		
			B	**Beta**	**Sig.**	**B**	**Beta**	**Sig.**	**B**	**Beta**	**Sig.**	**B**	**Beta**	**Sig.**
Time of Day	AM Peak (7-9AM)	*	-0.37	-0.08	0.000	0.03	0.01	0.174	-0.26	-0.07	0.000	-0.05	-0.03	0.004
	PM Peak (4-6PM)	*	0.24	0.07	0.000	0.15	0.06	0.000	0.03	0.02	0.023	-0.06	-0.04	0.001
	Before 7AM, After 6PM	*	0.37	0.15	0.000	0.37	0.15	0.000	0.18	0.08	0.000	-0.04	-0.02	0.039
	Mid-day (9AM-4PM)		(base)	-	-	(base)	-	-	(base)	-	-	(base)	-	-
	Daily (calculated) **		*0.15*	*0.06*		*0.10*	*0.04*		*0.03*	*0.02*		*-0.03*	*-0.02*	
Date	Friday	*	0.16	0.05	0.000	0.02	0.01	0.196	0.12	0.05	0.000	-0.01	-0.01	0.662
	Weekend (Sa-Su)	*	0.50	0.07	0.000	0.17	0.02	0.009	0.59	0.13	0.000	0.20	0.03	0.012
	Weekday (M-Th)	*	(base)	-	-	(base)	-	-	(base)	-	-	(base)	-	-
	Winter (Nov. thru Feb.)	*	0.25	0.04	0.000	-0.24	-0.05	0.000	0.16	0.05	0.000	0.08	0.04	0.000
	Distance to CBD (miles)		0.00	0.04	0.000	0.01	0.05	0.000	0.01	0.05	0.000	0.00	-0.01	0.640
	Presence of TOD	*	-0.12	-0.03	0.006	-0.09	-0.02	0.004	0.03	0.01	0.176	0.04	0.02	0.109
	Activity Density		0.00	0.04	0.000	0.00	-0.03	0.000	0.00	0.00	0.770	0.00	0.08	0.000
	(constant)		1.75		0.000	1.53		0.000	1.40		0.000	1.18		0.000

* Indicates dummy variable.

** For a discussion on the determination of the "Daily" coefficient, see APPENDIX E.

B: Unstandardized coefficient

Beta: Standardized coefficient

Table I-2. All Adjustment Methods: Ordinary Least Squares Regressions, Vehicle Occupancy, Table 2 of 2

			Residential									Entertainment/ Recreation			All Trip Ends		
			Multifamily			Single-Family			General								
	Adjusted R^2		0.025			0.006			0.01			0.066			0.011		
	Sample Size (N)		12,209			52,973			68,547			14,639			197,426		
			B	**Beta**	**Sig.**	**B**	**Beta**	**Sig.**	**B**	**Beta**	**Sig.**	**B**	**Beta**	**Sig.**	**B**	**Beta**	**Sig.**
Time of Day	AM Peak (7-9AM)	*	-0.07	-0.03	0.008	0.11	0.04	0.000	0.08	0.03	0.000	0.02	0.01	0.026	-0.47	-0.12	0.000
Time of Day	PM Peak (4-6PM)	*	0.03	0.01	0.333	0.10	0.04	0.000	0.09	0.03	0.000	0.08	0.03	0.000	0.33	0.11	0.000
Time of Day	Before 7AM, After 6PM	*	0.08	0.04	0.000	0.06	0.03	0.000	0.08	0.04	0.000	0.15	0.06	0.000	0.26	0.10	0.000
Time of Day	Mid-day (9AM-4PM)		(base)	-	-	(base)	-	-	(base)	-	-	(base)	-	-	(base)	-	-
Time of Day	Daily (calculated) **		*0.02*	*0.01*		*0.05*	*0.02*		*0.05*	*0.02*		*0.11*	*0.03*		*0.06*	*0.04*	
Date	Friday	*	0.08	0.03	0.002	0.05	0.02	0.000	0.05	0.02	0.000	0.06	0.02	0.000	0.22	0.06	0.000
Date	Weekend (Sa-Su)	*	0.54	0.14	0.000	0.45	0.06	0.000	0.52	0.09	0.000	0.47	0.07	0.000	1.05	0.14	0.000
Date	Weekday (M-Th)	*	(base)	-	-	(base)	-	-	(base)	-	-	(base)	-	-	(base)	-	-
Date	Winter (Nov. thru Feb.)	*	0.09	0.03	0.001	0.09	0.02	0.000	0.08	0.02	0.000	-0.01	0.00	0.402	0.07	0.01	0.194
	Distance to CBD (miles)		0.01	0.05	0.000	0.00	0.01	0.215	0.00	0.02	0.000	0.00	0.04	0.000	0.00	0.04	0.000
	Presence of TOD	*	-0.04	-0.02	0.132	-0.02	0.00	0.560	-0.01	0.00	0.602	-0.10	-0.03	0.000	0.10	0.02	0.020
	Activity Density		0.00	0.00	0.880	0.00	0.00	0.483	0.00	-0.01	0.002	0.00	-0.01	0.072	0.00	-0.04	0.000
	(constant)		1.51		0.000	1.61		0.000	1.60		0.000	1.65		0.000	1.66		0.000

* Indicates dummy variable.

** For a discussion on the determination of the "Daily" coefficient, see APPENDIX E.

B: Unstandardized coefficient

Beta: Standardized coefficient