600 NE Grand Ave.
Portland, OR 97232-2736
503-797-1700
503-797-1804 TDD
503-797-1797 fax

Metro | Agenda

Meeting: Metro Technical Advisory Committee: **SEMINAR**

Date: Wednesday, June 6, 2012

Time: 10 a.m. – 12 p.m.

Place: Metro Regional Center, council chamber

Time	Agenda Item	Action Requested	Presenter(s)	Materials
10:00 a.m.	**ANNOUNCEMENTS**	None	John Williams, Chair	None
10:10 a.m.	**Contextual Influences on Trip Generation (OTREC 2011 report)** *Objective: Present & discuss research findings*	Information / Discussion	Miranda Bateschell (Metro), Kelly Clifton, Kristi Currans, Chris Muhs (PSU)	In packet
12:00 p.m.	**ADJOURN**			

MTAC meets on the 1st & 3rd Wednesday of the month. **The next meeting is scheduled for June 20, 2012.**

For agenda and schedule information, call Alexandra Roberts Eldridge at 503-797-1839, email: Alexandra.Eldridge@oregonmetro.gov. To check on closure or cancellations during inclement weather, please call 503-797-1700#.

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Portland, OR 97232-2736
503-797-1700
503-797-1804 TDD
503-797-1797 fax

Metro | *Memo*

Date: Wednesday, May 30, 2012

To: Metro Technical Advisory Committee members

From: Miranda Bateschell, Senior Land Use Planner

Cc: John Williams

Re: **Contextual Influences on Trip Generation OTREC report**

Background

During the development of the first volume of Metro's Community Investment Toolkit: Financial Incentives, partners from our local communities expressed interest in innovative System Development Charge fee schedules that were more reflective of the reduced impacts of sustainable development. A few examples were provided in that volume of the toolkit. However, it quickly became clear there was an interest in additional information on this topic.

As a result, Metro worked with Galardi Consulting to provide model approaches and recommendations in the report "Promoting Vibrant Communities with System Development Charges." This report highlighted research findings that showed infrastructure cost variations due to location, impact as a result of varying development patterns, and green design. It also outlined methods for better connecting the real costs associated with serving different developments with the SDC fees collected to cover these costs. The report provided numerous case studies that reflect the different costs within one jurisdiction through the use of variable SDC rates. After the publication of this report, several communities considered or adopted trip generation adjustments to ITE rates within specific areas, particularly town and regional centers. Many of which had questions about determining the most accurate reduction rate.

OTREC Project Findings

In an effort to provide better local trip generation data and guide transportation improvement decisions, Metro partnered with several local cities, ODOT, and PSU on an OTREC grant project. The project collected local data (using multi-modal counts and establishment surveys) on a few specific land uses to develop trip generation rates sensitive to demographic, land use and transportation contexts. The research team compared these new trip rates to ITE rates and developed a methodology for adjusting ITE rates to reflect the local context. The research accounts for how the built environment (e.g., both land use and transportation) influences travel behavior (number of trips, trip length, mode choice).

This is extremely important in determining the impact of different development types on the transportation system to: 1) avoid over-planning the system for the surrounding land uses; (2) suggest strategies and investment priorities to encourage more compact, mixed-use areas with more transportation choices and 3) avoid creating regulatory and/or financial barriers to compact form envisioned by local, regional and statewide plans (i.e. uniform TSDCs can result in lower impact development paying the same rates, and thus subsidizing development with higher impact costs to the transportation system).

Please review the attached report from this OTREC grant project. At the June 6 seminar, the principal investigator from PSU will present the study’s research methodology and findings. The presentation will also highlight examples of applying the findings locally. There will also be plenty of time for discussion.

CONTEXTUAL INFLUENCES ON TRIP GENERATION

Final Report

OTREC 2011-407

by

Dr. Kelly J. Clifton (PI)
Portland State University

for

Oregon Transportation Research
and Education Consortium (OTREC)
P.O. Box 751
Portland, OR 97207

May 2012

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

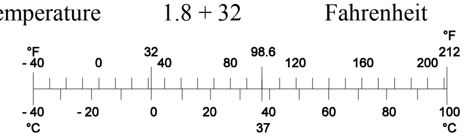
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

(4-7-94 jbp)

ACKNOWLEDGEMENTS

This project was sponsored by a grant from the Oregon Transportation Research and Education Consortium (OTREC) with assistance from:

- Metro
- Talia Jacobson, ODOT
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CONTEXTUAL INFLUENCES ON TRIP GENERATION

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This study examines the ways in which urban context affects vehicle trip generation rates across a variety of land uses. An establishment intercept travel survey was administered at 78 establishments in the Portland, Oregon region during the summer of 2011. Data were collected from high-turnover (sit-down) restaurants (Mexican and pizza), 24-hour convenience markets, and drinking places. Combined with person trip counts, vehicle trip counts, and built environment data, a method to adjust ITE vehicle trip rates to reflect a local community's context has been developed.

Results from this study reveal a trend: for all land uses tested here, vehicle trip rates decrease as neighborhood types become more urban. Comparisons between ITE Trip Generation vehicle trip rates and vehicle trip rates from this study indicate a need for a local adjustment for both convenience markets (open 24-hours) and drinking places. High-turnover (sit-down) restaurants are consistently predicted by the ITE methodology, but based on our findings we recommend a vehicle trip rate adjustment to better match locally observed travel patterns.

A model to adjust ITE's trip generation rate for urban contexts was developed in this study. The key measure representing urban context is the average Urban Living Infrastructure (ULI) score from the Metro Context Tool within a ½ mile buffer around establishments. ULI is a measure representing the density of retail and service establishments serving daily needs and is highly correlated with other built environment measures such as lot coverage, density, and accessibility to transit. The model developed here has a good statistical fit and ease of use in an evaluation of new development. The approach is also useful in guiding plans as we have related the ULI measure to other planning relevant built environment measures.

The study findings are limited in a number of ways. The three land uses examined and the relatively small sample size limit the number of factors that could be accounted for in our statistical analysis. In addition, data collection was limited to the weekday evening peak hour of the facility for each of the three land uses. The findings are localized and may not have broad applicability beyond the Portland region. Work planned for the immediate future includes: validation of the method using data collected from additional sites in Portland and elsewhere and analysis of site level attributes including parking, building orientation, pedestrian and bicycle infrastructure and other design features.

1.0 INTRODUCTION

There is national interest in building data that expand upon the existing Institute of Transportation Engineers (ITE) trip generation rates to include sites located in a multi-modal context. Often criticized for their shortcomings, Institute of Transportation Engineers (ITE) Trip Generation (TG) rates were developed beginning in the 1960s and focused on single-use, vehicle-oriented in suburban sites in the United States. ITE TG rates were meant to provide engineers with off-the-shelf estimates for basic land uses and simple contexts to bypass expensive data collection costs (Institute of Transportation Engineers 2008, Gard 2007, Steiner 1998). Despite this intention, the ITE TG handbook is commonly applied erroneously to more urban contexts. For these applications, ITE recommends that local rates be established via data collection for any non-suburban, paid-parking area with limited transit service or pedestrian access: “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).

Measuring local trip rates and calculating the impact of urban form on vehicle trip rates are expensive and intensive processes. Many local jurisdictions ignore warnings on the limited applications in the ITE TG Handbook and apply generic rates to inappropriate contexts, like high density areas with low actual vehicle trip rates (Nelson\Nygaard Consulting Associates 2005, Lerner-Lam, et al. 1992, Badoe 2000, Fleet and Sosslau 1976). ITE acknowledges the limitations of the TG dataset as they relate to availability of transit, non-motorized transportation facilities, mixed land uses, and density. While the impacts of transit are discussed in the appendix of the ITE TG Handbook, the section begins with a disclaimer stating any information provided “is strictly for informational purposes... [and] provides no recommended practices, procedures, or guidelines.” The ITE TG Handbook also recognizes the impact of pedestrian and bicycle infrastructure on reducing estimated vehicle trips, but the Handbook does not provide site-trip generation data upon which reduction factors are based (Institute of Transportation Engineers 2004). Efforts are underway by ITE to address those issues, but methodology and data will not likely be available soon. In the meantime, local governments burdened with long-range planning obligations are struggling with ITE rate applications in urban contexts with infill, mixed use, and Transit-Oriented Developments (TODs) (Rizavi and Yeung 2010, Nelson\Nygaard Consulting Associates 2005).

Despite evidence that a more compact urban form, access to transit and a greater mix of uses generates fewer and shorter vehicle trips, local governments are often compelled to use current ITE trip generation rates to evaluate transportation impacts and calculate transportation system development charges (TSDCs). This is due to: a) the expense of collecting local data, b) lack of alternative sources of information, c) the strong industry bias toward using ITE published rates and d) the absence of a consistent, empirically tested methodology for adjusting those rates for development occurring in different land use and transportation contexts.

When analysts ignore the impacts of transit, pedestrian infrastructure, bicycle facilities, and urban settings on vehicle trip generation, vehicle trips are overestimated. High vehicle trip estimates increase the amount of vehicle-oriented development, necessitating other automobile priority measures. More vehicle use, greater capacity, abundant parking supply, faster travel times, and fewer automobile alternatives are all related to overestimating vehicle trip rates.

Further, growth of new development is often stunted from high impact fees associated with overestimating vehicle trips.

Compounding these challenges, cities in Oregon are required to demonstrate that planning and zoning changes will not degrade the performance of state-owned transportation facilities compared to the levels of service documented in the Regional Transportation Plan under the Oregon Transportation Planning Rule, section -0060, and Oregon Highway Plan, Policy 1.F.6. These requirements can conflict with the region's 2040 Growth Concept, which calls for development of mixed-use centers and corridors to support jobs and freight reliability, protect farms and forests, create vibrant downtowns and main streets, and leverage transportation investments such as high capacity transit. Thus, there are gaps in the understanding about how best to evaluate, mitigate and plan for growth under these conditions.

This research project aims to address this issue and develop a method to adjust ITE's trip generation rates to better reflect the relationship between land use, transportation and travel demand for specific land use types located in various urban settings. The project collected local data (using counts and establishment surveys) on a few specific land uses (restaurants, 24-hour convenience markets, and drinking places) to develop trip generation rates that are sensitive to demographic, land use and transportation contexts. These new trip rates were compared to the ITE rates for the same land use category and establishment size and a methodology for adjusting the ITE rates was developed.

The benefits to providing methods for reducing vehicle trips include:

- Decreases need for extensive roadway construction improvements near TODs,
- Improves ability for local governments to appropriately adjust requirements for trip generation for development,
- Right sizes construction costs and impact development fees to builders and developers,
- Facilitates infill and mixed-use development, leading to increased commerce and density, and
- Provides better assessments of progress toward greenhouse gas targets by making more realistic estimates of the contribution of land use change.

The remainder of this report is organized as follows. A literature review summarizes the current state of the knowledge with respect to the role of context on trip generation. Then, the data used in this study and the methods used to collect them are described. Next, we document the methodology developed to adjust ITE's trip generation rate for urban context and discuss the application of the approach in a planning context. Finally, the report concludes with a discussion of the implications of our study findings for planning and policy, the study limitations, and suggestions for future work. Supporting documentation is provided in the Appendices.

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 briefly reviews the breadth of literature on the relationship between travel behavior and the built environment.

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 2-1, identify the large error range of results found from the variety of studies. To compare the error in ITE trip generation estimation, Equation 2-1is used. A negative rate indicates estimated vehicle trip counts being larger than those observed in the study.

Equation 2-1. ITE Trip Rate Error Equation

The greatest range of error in ITE estimation of vehicle trips occurs in Central Business District/Urban Core/Downtown areas. However, one retail shop studied in Oakland, California had an observed AM peak trip count of 13 vehicle trips and an ITE estimated trip count of 11 vehicle trips. Provided this establishment is an outlier, Mixed-Use Developments then show the greatest range of variation in error in estimation. Prediction of vehicle trip generation rates are by far the most complex when a dense, variety of land uses are accessible within one development. For these sites, although ITE provides a methodology to handle the interaction of land uses, it has not been shown to be the most effective method available to estimate vehicle trip generation to mixed use sites (Lee, et al. 2011), as discussed later in section 2.2.2. Retail and residential type 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.

Table 2-1. Summary of ITE Trip Rate Error Findings Collected from the Literature Review[1]

	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 also provided in this table for those studies which counted person trips and calculated those persons taking a vehicle. The Central Business District/Urban Core/Downtown area provides the largest range of automobile mode share. However, even those sites studied in Suburban Activity Centers and Corridors contain as small as 54% automobile mode share.

2.2 APPLICATIONS IN PRACTICE

ITE Trip Generation Report and Handbook are a commonly referenced and utilized practical guideline. 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

[1] Sources include (Samdahl 2010, National Research Council (U.S.) 1990, Fehr & Peers 2008, Schneider 2011, Lee, et al. 2011, Kimley-Horn and Associates, Inc. 2009 June 15, Cervero and Arrington 2008, Cervero 1993, JHK and Associates 1987, Dill 2008, Lapham 2001, Colorado/Wyoming ITE Section Technical Committee - Trip Generation 1987, Jeihani and Camilo 2009, Sperry 2010)

which require traffic impact studies of some type often provide guidelines on how to approach local adjustments for sites with mixed-uses, presence of transit, bicycle or pedestrian amenities available, or transportation demand management practices in place.

2.2.1 Existing Local Adjustments to ITE Trip Generation

This section details a review of 23 jurisdictional guidelines for local adjustment from around the United States and Canada. These sites range 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.

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.[2]
- 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 (New York City, New York; San Francisco, California; San Diego, California; Montgomery County, Maryland; Mississauga, Ontario, Canada; Southern New Hampshire).
- 11 jurisdictions provide some guidance of what conditions require a traffic impact study. Conditions are based on minimum vehicle trip thresholds, land use plan requirements, or stipulations associated with development near roadway facilities with congestion and/or access problems. Decisions on the depth required of the impact analysis typically occur on a case-by-case basis.

Table 2-3 shows the minimum vehicle trip thresholds requiring a Traffic Impact Study (TIS). In the ten jurisdictions shown, there is very large variation in thresholds requiring a TIS. To interpret the TIS requirements in Table 2-3, we have used the ITE rate for the number of vehicles to calculate the corresponding square foot building area. This information is shown in Table 2-4. The wide variation in building sizes that according to ITE generate certain numbers of vehicle trips suggest that using ITE is not an entirely reliable method.

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

Table 2-2. Summary of Traffic Impact Study Guidelines for 23 Jurisdictions[3]

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.

Pass-by Adjustments

- 19 of 23: Allow some pass-by adjustments.
- 3 of 19: Provide a sample of acceptable pass-by reduction rates by land use.
- 4 of 19: Accept ITE Trip Generation Pass-by methods and rates as being acceptable.
- 2 of 19: Provide maximum pass-by rates limitations for specific land uses or applicable to trips generation estimates for development.
- 5 of 19: Provide maximum limitations for pass-by adjustments based on percent of adjacent street, peak hour traffic. Four of these allowed 10% of adjacent street traffic as a maximum; one allowed 2%.
- 2 of 19: Restrict pass-by applications to specific land uses (retail-type).

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).

[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, Charlotte Department of Transportation 2006, City of Pasadena 2005 August 24, Georgia Regional Tranpsortation Authority 2002, Southern New Hampshire Planning Commission 2010, San Francisco Planning Department 2002, City of Bend 2009, San Diego Municipal Code 2003, City of San Diego 1998, Virginia Department of Transportaiton 2010, City of Rockville 2011, City of Los Angeles Department of Transportation 2010, City of Mississauga 2008, New York City 2010, San Francisco Planning Department 2002, State of Flordia Department of Community Affairs 2006, City of Salem 1995, City of Bellingham 2012, City of Bellingham 2012)

Table 2-3. 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 7, footnote 3.
*Also provides thresholds for transit trips and pedestrian/bike trips generated as basis of required transit and pedestrian/bicycle impact studies.

Table 2-4. Building Square Footage Required to Meet Trip Generation Thresholds

A	Approximate Sq. Ft. Floor Area to Generate Vehicles in Column (A)*				
Peak Hour Volumes of Adjacent Street (vehicles)	Drinking Place (ITE LU 925)	High-Turnover (Sit-Down) Restaurant (ITE LU 932)	Convenience Market (Open 24-Hours) (ITE LU 851)	Supermarket (ITE LU 850)	Coffee/Donut Shop without Drive-Through Window (ITE LU 936)
10	880	900	190	950	250
50	440	4,480	950	4,760	1,230
75	6,610	6,730	1,430	7,140	1,840
100	8,820	8,970	1,910	9,520	2,450
Weekday Daily Total Volume (vehicles)					
70	-	550	100	690	-
500	-	3,930	680	4,890	-
1,000	-	7,870	1,360	9,780	-
2,500	-	19,660	3,390	24,450	-

* Square footage of gross floor area is calculated using average ITE Trip Generation rates.

2.2.2 Other Current Studies and Approaches

The MXD model (Fehr & Peers) and the 4D model (Environmental Protection Agency - EPA) are two models that 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 TG Report rates and a 32% error using ITE TG Report rates and reductions (Walters 2009, September 30). The INDEX model with 4D enhancements (EPA) reported a 12% error compared with collected in areas of infill development (Hagler Bailly Services, Inc. and Criterion Planners/Engineers 1999).

URBEMIS is a similar model to 4D and MXD used for calculating air quality impacts of projects like new developments. It is a national model based on urban density, sidewalk connectivity, land use mix, and travel demand management (Nelson\Nygaard Consulting Associates 2005). URBEMIS allows credits, or trip reductions, for specific land uses but is not very useful for reducing vehicle impact fees or parking requirments for site development

The National Cooperative Highway Research Program (NCHRP) is currently funding two projects related to understanding the differences in travel behavior from these environmental differences. Neither study has officially been published, but general methodologies have been presented.

NCHRP 8-66, "Trip-Generation Rates for Transportation Impact Analyses of Infill Developments", defines reductions based on context for sites that allow or encourage infill development. In this study, a reduction method based on observed survey data is being developed to reduce ITE requirements.

NCHRP 8-51, "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 (Bochner 2010). Using this method, one researcher claims the trips generated are more accurate: the method results in about 13-percent error, down from 35 to 59-percent error from ITE methods. (Sperry 2010). The method here only pertains to mixed-use developments, and therefore cannot be utilized or applied to the study in this report.

2.3 DEFINING CONTEXT

The ITE Trip Generation Data Form has a box for "Location within Area" where one has the opportunity to check a box for the area type, or context, of the study site location (Institute of Transportation Engineers 2004). Options are "CBD," "Urban (non-CBD)," "Suburban CBD," "Suburban (non-CBD)," "Rural," and "Freeway Interchange Area – Rural," which suggests that ITE would consider context type when developing or applying vehicle trip generation methods. But, this information is not available from ITE nor is it mentioned in trip generation methods. Research has evaluated travel behavior associated with these sorts of area types and with individual built environment measures. The following sections review studies on these topics.

2.3.1 Area Types

This section explores travel behavior as it relates to area types as defined by local planning agencies of individual research studies.

2.3.1.1 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 reductions in the number of vehicle trips generated at establishments. Factors such as dense employment and residential populations, high accessibility to transit and 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.

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 (Schneider 2011).

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 and Zupan 1996).

Employment and population density in CBDs is related to transit ridership and reducing vehicle trips. High-density residential and workplace areas in locations of high-quality transit opportunities (lower service headways) increase the likelihood of taking transit. Researchers found that increasing employment density within a CBD by six times results in daily transit boardings increasing by over 4.5 times (Seskin, Cervero and Zupan 1996).

Effects of the built environment in downtown areas also appear to have influences on non-work travel behavior. A study Philadelphia compared three vehicle-oriented grocery stores with three pedestrian-oriented grocery stores. While holding density, land-use mix, street network connectivity, and sidewalk coverage constant, researchers varied availability of parking lot sizes and setbacks to the store entrance. They found the automobile-oriented grocery stores had on average 21% of respondents that always drove to the site, while the pedestrian-oriented grocery stores had 6.2% of respondents that they always drove (Maley and Weinberger 2010).

2.3.1.2 Transit-Oriented Development

Transit-Oriented Developments (TODs) or Transit-Oriented Areas (TOAs) are one of the more researched areas. By definition, TODs include a transit center or station with high density and mix of residential and employment land uses radiating from a quarter to a half mile out. These areas are developed in an effort to increase the amount of transit and active (bike and pedestrian) travel in concentrated areas. The research identifying impacts of TOD design is inconclusive on the best combination of the built environment, such as land use mix, density and pedestrian amenities, to maximize vehicle trip reductions. The literature on TOD-type areas 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.

Portland, Oregon has had much success in obtaining higher transit-ridership and vehicle trip reductions. One study attributes much of the success to the placement of TODs on corridors already developed for regional travel like a “necklace of pearls”. The study concludes that traffic impact studies may overestimate the vehicle impact of TOD residential locations in locations close to rail by nearly 50-percent. In this study, Portland represented only a portion of the surveyed sites, and appears to have the lowest vehicle trip generation rates, nearing 40-percent below the ITE manual for residential sites located near light rail stations. This reduction in vehicle trips generated increases in the study sample as the density of dwelling units per acre increases in the development area (Cervero and Arrington 2008).

Travel behavior is relatively inelastic within a quarter mile from a transit station when comparing environmental characteristics like mixed land uses, traffic calming, pedestrian amenities, and density (Cervero and Arrington 2008). This suggests that mode choice remains relatively constant less than a quarter mile from a transit center or station even when other built environment factors change. It has been found that TOD implementation on regional and corridor levels may decrease residential vehicle trips an average of 44% compared to ITE Trip Generation estimates (Cervero and Arrington 2008). Proximity to light, heavy and commuter rail transit stations in Washington, DC, Portland, San Francisco, and New Jersey were studied at ranges from a quarter to a half mile. Within these buffers, the number of dwelling units ranged from 100-900, while the range of calculated trip reductions ranged between 30% and 60%. The range of reductions in this study reflected proximity to transit, household density, and transit type all reducing the vehicle trips generated at these locations (Cervero and Arrington 2008).

Additionally, Transit-Adjacent Developments (TAD), those developments that have a lack of pedestrian amenities and tend to have greater vehicle-oriented design characteristics, show a smaller reduction in vehicle mode shares compared with TOD locations. While TOD-type developments appear to service transit-users, the combination of mixed land uses, densities and pedestrian amenities increase the likelihood of other non-automobile modes in addition to transit.

For example, a dissertation examined factors of commuting around fixed-rail transit stations in Maryland, Florida, Oregon, California and New Jersey. The split of access modes for the two stations are shown in Table 2-5 and are distinctly different (Renne 2005).

Table 2-5. TOD and TAD Study Mode Shares

Access Mode	TOD (Berkeley)	TAD (Fremont)
Automobile	7.4-percent	62.0-percent
Carpool	0.9-percent	6.3-percent
Walk	59.3-percent	7.8-percent
Bike	4.6-percent	1.0-percent
Transit	18.6-percent	10.2-percent

Source: Renne 2005

The higher driving rates for access mode at the Fremont station may be due to its park-n-ride design, priority for parking provision over infill development, pedestrian infrastructure, and density. Despite the differences in development in these two areas, the author noted Berkeley as having a higher share of transit commuting, walking, cycling, and households with one or no cars. Housing density near the Berkeley station is high. The author also notes a 740% increase in residential density and 990% increase in transit commuting trips from 1970 to 2000. Density around TODs is critical to their success. A 73-percent decline in walking and cycling around

Fremont station suggests park-n-ride type facilities may overwhelm other pedestrian features that make the area easier to access by active travel modes (Renne 2005).

Another Portland study performed two surveys at specified TOD locations and found the commuting transit mode share near MAX stations declined significantly when walk access time exceeded 30 minutes for work or school trips (Dill 2008), showing increased importance of pedestrian accessibilities. Additionally, another study in California found that roughly one fifth of trips within a TOD to retail locations are taken by transit, while one tenth of total trips are walking (Lund, Cervero and Willson 2004).

In the study of TODs in Portland, Oregon, overall transit commuting shares ranged from approximately 6 to 22% in 2000, while other alternative modes of transportation in TODs of the region ranged from 4 to 37%. The growth of transit commuting mode share in the compared TODs averaged 32% over 30 years. All TODs had a higher non-automobile mode share than surrounding areas (Renne 2005).

High-quality transit service also impacts most choice in TOD-type areas. In Portland, TriMet worked to improve off-peak bus service within more dense or TOD-like corridors, increasing the non-work trips by transit. Between 1999 and 2003, TriMet increased service frequency of 10 bus lines to less than 15 minutes, increasing overall ridership by 9-percent. In addition to an 8-percent increase in weekday ridership, ridership increased by 14 and 21% for Saturday and Sunday. Frequent bus service accounts for about half of the weekly hours ridden and trips taken. The same report suggests that headways of 10 minutes are ideal and positively correlated with ridership on transit. Other factors impacting transit ridership include the extensiveness of the transit network and parking costs (Cervero and Arrington 2008).

Moreover, a large influencer of mode share relates to the trip purpose. A travel survey conducted by mail in Portland, found that less than 25% of respondents used transit once a week or more for non-work trips in good weather. The further from the downtown area the TOD was located, the lower the non-commute share of transit ridership (Dill 2008). In a San Francisco Bay Area study, the likelihood that transit will be taken for a non-chained trip versus a chained trip is 24.5% versus 4.2%. In locations near BART where there was a greater density and land-use mix, there is reflected an even greater demand for non-work chained trips (Lund, Cervero and Willson 2004).

2.3.1.3 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. No part of this definition includes access to transit for mixed-use developments (Institute of Transportation Engineers 2004). 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 rates for four residential, mixed-use developments along the MAX corridor in Portland, Oregon, were found to have a 2 to 20% internal capture rate to or from retail locations during the PM peak hour. Daily rates include a 4 to 28% internal capture of trips to retail locations within these developments. The same study also found that when all pedestrian and transit trips are included in the trip generation of the residential sites along MAX transit corridors, the rates generated are still lower than the provided ITE TG Rates (Lapham 2001).

The internal capture which occurs from infill development is also an area of more recent research. Infill may occur in any urban areas and increases densities and accessibilities, potentially affecting travel behavior. A large study in California, surveying 13 residential, office and retail infill locations observed differences in vehicle trip generation between -99% to 30% compared to ITE Trip Generation estimations. Those sites that observed positive percent differences (generating greater trip rates than provided by ITE) include retail or grocery store locations and mid-rise residential condominiums (Kimley-Horn and Associates, Inc. 2009 June 15). Relationships between this variation in trip generation rates and the built environment are not addressed in the current state of the research. However, the data collected from this study was analyzed using currently available methods in a study from UC Davis. From this study, no current methodology was identified as a clear "winner" for estimating vehicle trip generation at smart growth locations due to the complexity of interactions between the built environment and travel choices (Lee, et al. 2011).

2.3.1.4 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 2-1 shows the actual vehicle trips seen in developed suburban city centers range from 5 to 37% below ITE estimates. Medium-density suburban locations, for example, near transit corridors with lower single-family housing percentages and smaller parcel sizes 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).

Although suburban type neighborhoods often have a reputation for vehicle oriented design, some researchers found in some suburban areas the ability to transition into TOD neighborhoods easily, helping to reduce vehicle travel. In a study in Toronto, Canada, increasing transit accessibility and utilizing the medium density of the neighborhood (developed between 1986 to 2001), the automobile-driver share of morning peak period trips dropped from 43 to 37%, while transit and non-motorized modes rose from 50 to 54% and 3 to 5%, respectively. In this example, changes in accessibility and encouraging density around transit stops further the vehicle trips taken (Crowley, Shalaby and Zarei 2009).

2.3.2 Built Environment

While the last section focused on studies which have classified the study sites into already known contexts, an alternative way to define the area-type is by using disaggregate measures of the built and transportation environment. For the purpose of this study, contextual factors researched and discussed include macro-scale measures. While micro-scale measures, such as presence of tree shade and pedestrian barriers to the roadway, may influence the decision to take a specific route, it is the macro-scale variations, such as intersection density and land use mix, which facilitate the ability to take an alternative mode instead of an automobile. This section introduces built environment attributes that are shown in the literature to have an 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 and Kockelman 1997, Ewing and Cervero 2001), and therefore are placed into these categories in this section.

2.3.2.1 Density

Employment and residential density both influence mode choice. One study suggests the main benefit to greater densities is to make destinations closer to origins, although the authors do not see the significance in an increase in transit usage when residential density increases (Lund, Cervero and Willson 2004). Another study found relevance in the employment and residential density. Some research suggests that by doubling the residential density, the 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). 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 and Cervero 2001).

2.3.2.2 Diversity (Land Use Mix)

Diversity, or land use mix, may be measured in a variety of ways. Simple measures include percent of commercial land use to total land, or percent single-family detached dwellings to total dwellings. More complex measures include measures of entropy, gravity or dissimilarity (D'sousa, et al. 2012). For transit, 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 and Zupan 1996). In vehicle trip generation studies, areas with mixed uses tend to have greater reductions in vehicle trip generations. For example, Fehr & Peers conducted a trip generation study in Sacramento and 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 TG was possible even at low densities when mixed land uses are present (Samdahl 2010).

Another study focusing on non-motorized trips 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 tend to be correlated with additional observed reductions in motorized discretionary travel (Guo, Bhat and Copperman 2007). In a synthesis of influences on the built environment in 2001, the aggregate (linear) elasticity of diversity or mix and vehicle trips is -0.03, suggesting that as diversity increases by 10%, the number of vehicle trips decreases by 3% (Ewing and Cervero 2001).

2.3.2.3 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 or pedestrian facilities. As the distance from transit increases, the ridership or demand of transit decreases. In addition, the handbook suggests that distance to rail generates different demand from distance to bus. The ITE TG Report provides information suggesting rate reductions between 2.5 to 10-percent for locations within a quarter mile of bus transit corridors. For locations within a quarter mile of light rail transit or near transit centers, the range of reductions increases to 5 to 20-percent. Higher levels of reductions are allowed with greater values of floor area ratios (i.e. property intensity correlated with activity densities) or greater mixed land use (Institute of Transportation Engineers 2004).

A San Francisco Bay Area study surveyed more than 1,000 large employment sites to examine possible connections between commuter's use of rail and location near stations. This study found a greater correlation between transit use and proximity to stations for work sites located within a quarter mile of a transit station, and decreasing correlations for sites located within a quarter to a half mile and more beyond stations. The greatest commuter use of rail was from stations located in downtown areas such as Oakland, Berkeley and San Jose (Dill 2003). In a 2004 study, the defining measure of distance to transit includes the proximity measure of a quarter to a third mile near a transit station, or a half mile for areas with extensive pedestrian-friendly facilities, to best capture travel behavior around the site. In the same study, the authors suggests that station headways under 15 minutes or rail headways of 20-50 minutes are enough to impact the vehicle ridership of transit station areas (Lund, Cervero and Willson 2004).

A meta-study conducted by Ewing and Cervero (2010) suggested that the proximity to transit was relatively inelastic, although slightly negative reducing vehicle trips, related to vehicle trips, but positively elastic relating to walking and transit usage. In addition, they found that there is a correlation between the destination accessibility (jobs within one mile) for automobile with a positive correlation toward walking. The slight negative correlation of job accessibility for transit (within 30 minutes) and vehicle and walking usage may reflect an inelastic correlation.

2.3.2.4 Design

The design of an area may be reflected by many different factors, but the type of built environment often correlates with pedestrian or bicycling use as well as transit attractiveness. In NCHRP Report Number 16 on transit and urban form, the authors found that suburban neighborhoods tend to have more automotive shares for non-work trips than "historic" neighborhoods, most likely due to the mix of land uses and density available from their built block types. Additionally, there is a modest negative correlation between transit ridership and the average block size (in acres) within one-mile of either the home-end or non-home-end of a trip. This means that as blocks increase in size, there is a decrease in the likelihood that a station area resident rides transit. In addition, the relationship between transit ridership and the amount of one- and two-side sidewalks are modestly positive. This suggests that transit usage is more attractive when more pedestrian amenities are available. The same study suggests that the number of "conflict points" on a pedestrian route surrounding a transit station is negatively correlated to accessing transit by foot (Seskin, Cervero and Zupan 1996). Additional factors which have positive impacts on the walkability of neighborhoods include the presence of Street Trees, Street Lights, Street Furniture (Lund, Cervero and Willson 2004). These impacts are small compared with the distance to transit stations, density or diversity of land uses.

An additional measure of design is intersection density or block size, characteristics that often reflect the street network. For example, the density and network connectivity of bikeway and pedestrian facilities within a mile of a traveler's residence appears to have a statistical significant and positive effect on the number of non-motorized trips taken (Guo, Bhat and Copperman 2007). Moreover, the relative location of both employment and residential land uses with respect to transit stations used by many jurisdictions was summarized as varying between a quarter to half mile in distance, a distance that "most people" would walk to work. Another factor of connectivity for destination access, therefore, is the proportion of total intersections that have more than four-way access which relates to pedestrian connectivity. The higher the street connectivity, the higher the likelihood residents near the station will take transit. The same survey showed the home-end correlation being negative with vehicle trips, suggesting either a unique characteristic of the neighborhood surveyed or that residents which live within walking distance of a rail station lacking street connectivity does not deter in transit ridership, supporting the strength of the variable for proximity to transit in overpowering other built environment characteristics (Lund, Cervero and Willson 2004). In a synthesis of influences on the built environment, the aggregate (linear) elasticity of design, such as street network density, and vehicle trips is -0.05, suggesting that as design increases by 10%, the number of vehicle trips decreases by 5% (Ewing and Cervero 2001).

2.3.2.5 Other Factors

2.3.2.5.1 Parking

The ability to park at the destination end of a trip taken is often a key player in selecting a mode choice. For example, there is a significant difference in transit ridership when the destination is located in an area with limited or paid parking compared with free parking (Cervero 2007). In another study, when studying transit, fewer than one out of twenty residents located near transit areas take transit to work if they can park for free at work; if free parking is not available, the transit-commuting share jumps to nearly 45 percent (Lund, Cervero and Willson 2004). While parking is discussed in this study as being a potential player in defining the built environment, parking generation rates and supply is not the focus of this study and remains an important area of future research.

2.3.2.5.2 Socio-economic Characteristics, Attitudes and Self-Selection

The literature also suggests that the built environment does not necessarily have the greatest correlations with reductions in vehicle trips generated. When controlling for socio-economic characteristics, the built environment, although often significant, has less explanatory power than demographic type information (Ewing and Cervero 2010). In fact a more significant player in explaining travel behavior tends to be attitudes, instead of the built environment and socio-economic characteristics (Kitamura, Mokhtarian and Laidet 1995).

Additionally the self-selection of individuals to travel choices also plays a key role in more accurate estimation of vehicle travel behavior. For example, reduced vehicle trips in TOD areas is often thought to come in part from the self-selection of residents, the mix of retail and residential land uses allowing for increased trip-chaining and reduced need for vehicle trips due to facilities provided (Cervero and Arrington 2008). Another study suggests that self-selection characteristics of a pedestrian may have a higher impact on actual pedestrian mode splits (Lund, Cervero and Willson 2004).

Traditional data collected using ITE Trip Generation methods do not, however, include information relating to socioeconomic characteristics, attitudes or self-selection. Although these factors appear to be significant in the literature, the application of information and results pertaining to analysis considering these factors would remain difficult in comparing or adjusting to ITE Trip Generation methods, and therefore, are not the focus of this study.

2.3.2.5.3 Destination (Trip Type and Length)

The "destination" can be defined as the trip type taken, such as work or non-work trips, and the trip length. Both of these descriptions relate more closely to the type of land use being studied, the demographics of the surrounding area, and willingness to travel by various modes. A survey of public and private organizations in Oregon provided rates expected from improvements in alternative transportation systems. The vehicle trip reductions provided for pedestrian and cycling trips are 2 to 10% for home-based work trips and home-based other trips and 2 to 5% for non-home-based other trips less than 0.5 miles. For trips between 0.5-2.5 miles in length only 2 to 5% of reductions for cycling would be allowed for all trip types, and for trips between 2.5-5 miles, 0 to 2% of reductions for cycling would be allowed for home-based trips. In this survey, pedestrian and bicycling reductions act independently to reduce vehicle trips (Clark 1997).

For non-work trips, the TOD neighborhood type has the highest ability to capture non-automobile modes of transportation due to the density and land use mix. Rail (5.3%), walk (3.9%), bus (2.9%), and bicycle and taxi (tied at 0.4%) are the most important non-automobile modes within a TOD for non-work trips (Lund, Cervero and Willson 2004). Once work commute sections are within one-quarter mile of a rail station, factors like mixed land uses, traffic calming, pedestrian amenities, and even density seem to matter little. These features are more likely to affect the non-work short trips (Cervero and Arrington 2008).

2.4 SUMMARY

There does not appear to be any land use in which ITE Trip Generation rates and methodologies predict with a consistent level of accuracy. It is clear that developments in central business district, urban core and downtown areas tend to have the greatest variation in automobile mode share and the most substantial range of error when compared with ITE rate estimates. Mixed-use areas with very high levels of internal capture are also problematic in applying ITE methods. TODs are also difficult places to apply ITE methods and little information about the impact of specific land uses in these areas is understood. Despite that locations from ITE datasets are typically suburban and vehicle-oriented, developments in suburban centers and corridors have been shown to have inaccurate estimates using ITE rates and methods.

Some of the error between ITE estimates and observed data may be due to small sample sizes within ITE's estimates, requiring average rates to be used despite many vehicle trip generation relationships being non-linear. Error may also be due to variations in socioeconomic characteristics. There are no current methodologies for estimation or adjustment to ITE rates which account for socioeconomic characteristic variations in traffic impact assessment, mainly due to the lack of information about patrons of establishments. As a result, the built and transportation environment remain the standard for attempting to account for variation in ITE Trip Generation rates.

There has recently been a lot of activity investigating methodologies to more accurately estimate trip generation. There is no one methodology that works best for all cases and all methods have challenges in implementation. Lee et al (2011) provides an evaluation of the most current methodologies: ITE Mixed-Use, EPA MXD model, NCHRP 8-51, MTC Survey, and URBEMIS. Of these five methods, both the EPA MXD method and the URBEMIS method provide a greater level of sensitivity to changes in the built environment. But, they require far greater data needs, making it difficult to modify or supply the models with information modifying them to represent local behavior. Methods such as MTC Survey have not been evaluated in places beyond California.

Guidelines in trip generation estimation provided by jurisdictions in the United States often list ITE rates and methodologies as being the primary or secondary method approved for application in estimation. Many of the same jurisdictions also provide guidelines on suggested methods of adjustment to ITE using fixed rates or mode shares to adjust estimated rates. Of the few that allow documented mode share information to be applied for trip rate adjustments, only one also requests documentation on vehicle occupancy, a key factor in adjusting person trips by alternative modes (transit, bike, and walk) to and from vehicles. Few jurisdictions have compiled local trip generation studies to develop local rates and/or adjustments. Those that do provide local rates tend to vary their rates by district-based or area-based boundaries.

These district-based rates are location specific and difficult to relate to external areas such as the Portland region. Identifying the built and transportation environment variables which significantly explain the most variation in observed vehicle trip generation is important in predicting travel behavior. Built environment measures typically studied tend to be highly-correlated with each other, making it difficult to incorporate more than one variable in a regression alone. Advanced statistical techniques like factor and cluster analysis overcome this and allow many variables to be incorporated into identifying indices of composite measures or groupings of similar areas, but they require more observations (at the establishment level) to be able to be correctly applied and in some ways are subjective.

Therefore, the focus of this study is to identify those built and transportation environment measures which explain the most variation in vehicle trips generated at establishments in the local contexts of the Portland, Oregon region to provide a parsimonious local adjustment to ITE Trip Generation rates and methodologies.

3.0 DATA & METHODS

This chapter presents the study design, data collection processes, and sample used to develop an adjustment method to ITE vehicle trip rates based on area type. The chapter is organized as follows:

1. Survey site selection, establishment types, and definitions of area types
2. Survey instrument design and sample description
3. Count data collection methods and sample description
4. Built environment data methods

Data collected from this study are then compared to ITE Trip Generation Manual information to form the basis of a method to adjust ITE rates locally.

3.1 SITE SELECTION & ESTABLISHMENT TYPES

To analyze trip generation at different types of urban environments, establishments were included in the study based on characteristics of their surrounding built environment. Environmental variables were analyzed[4] to ensure that selected sites represented the entire spectrum of the urban landscape found in the Portland metropolitan region. Five unique classifications resulted. They are described in the following area type terms:

- Central Business District neighborhoods (near downtown Portland)
- Urban Core neighborhoods (e.g. inner Northeast and Southeast Portland neighborhoods)
- Neighborhood and Regional Centers (similar to Regional Centers defined by Metro)
- Suburban Town Centers and Corridors (typically areas farther from the Central Business District but more densely developed than suburban residential areas)
- Suburban Areas (the least densely developed areas)

Individual establishments found in places throughout the region that represented the five different area types were recruited to participate in the study. Greater numbers of establishments were sought in more urban area types (Central Business District, Urban Core, Neighborhood/Regional Centers) as we hypothesize that these are likely to have greater non-motorized and transit trips. We anticipate that establishments in more automobile-oriented area types (Suburban Town Centers, Suburban Areas) have higher automobile mode shares and trip rates similar to those found in the ITE manual. Agreement with ITE rates requires fewer observations (a smaller sample size) to support statistical analyses.

Given the resource limitations for this study, only a few ITE land use types are examined. Land uses chosen for the study include a) Land Use 932: High-Turnover (Sit-Down) Restaurants (pizza and Mexican restaurants were used in this study), b) Land Use 851: Convenience Markets

[4] K-means clustering analysis was performed with the stats package of R on built environment measures to classifiy area type. Variables in the cluster analysis included intersection density, population density, employment density, block size and floor-area ratio.

(Open 24-Hours) without gas stations and c) Land Use 925: Drinking Places. These land use types were chosen because they are found throughout the region in all area types and are common in areas where vehicle trip overestimation is most problematic: urban infill, mixed-use, and TODs.

Most establishments in the study belong to regionally owned and operated franchises. Local establishments are overrepresented in the sample because they were more willing to participate than national corporate franchises. This potentially creates limitations in the study: establishments were generally smaller (most under 3,000 sq. ft. gross floor area) and may cater to a more local cultural demographic. Table 3-1 summarizes the number of establishments that participated in the study. Figure 3-1 shows the spatial distribution of the 78 survey establishments throughout the Portland region and illustrates how area types change from more urban to more suburban as distance from the Central Business District increases.

Table 3-1. Establishments Surveyed by Area and Land Use Type

Area Type	# Restaurant Locations	# Convenience Locations	# Bar Locations	Total
Central Business District	12	4	3	19
Urban Core Neighborhoods	10	5	6	21
Neighborhood and Regional Centers	6	6	4	16
Suburban Town Centers	5	7	0	12
Suburban Areas	6	4	0	10
Total	39	26	13	78

3.2 SURVEY DATA

This section details the methods used for survey data collection and provides a description of the survey sample.

3.2.1 Survey Instruments

Data were collected in 2011 from June through early October. Because of the relatively small sample size, we controlled for weather by only collecting data on days with favorable conditions. Data collection events occurred from 5:00PM to 7:00PM on Mondays, Tuesdays, Wednesdays, and Thursdays, as they are considered "typical" travel days. The 5:00PM to 7:00PM time window was chosen to overlap with ITE's Trip Generation weekday, peak hour (4:00PM to 6:00PM) as well as the peak hour of generators for some land uses. According to many store managers, most restaurants do not experience much customer traffic during the 4:00PM to 5:00PM hour.

Information collected at each location included: (1) customer intercept surveys, including socio-demographic status and travel information; (2) counts of persons entering and leaving the establishments and of automobiles leaving (where possible); (3) establishment information, including site-specific attributes such as gross square footage, number of employees, parking capacity, and other site design characteristics; and (4) archived information about the built environment.

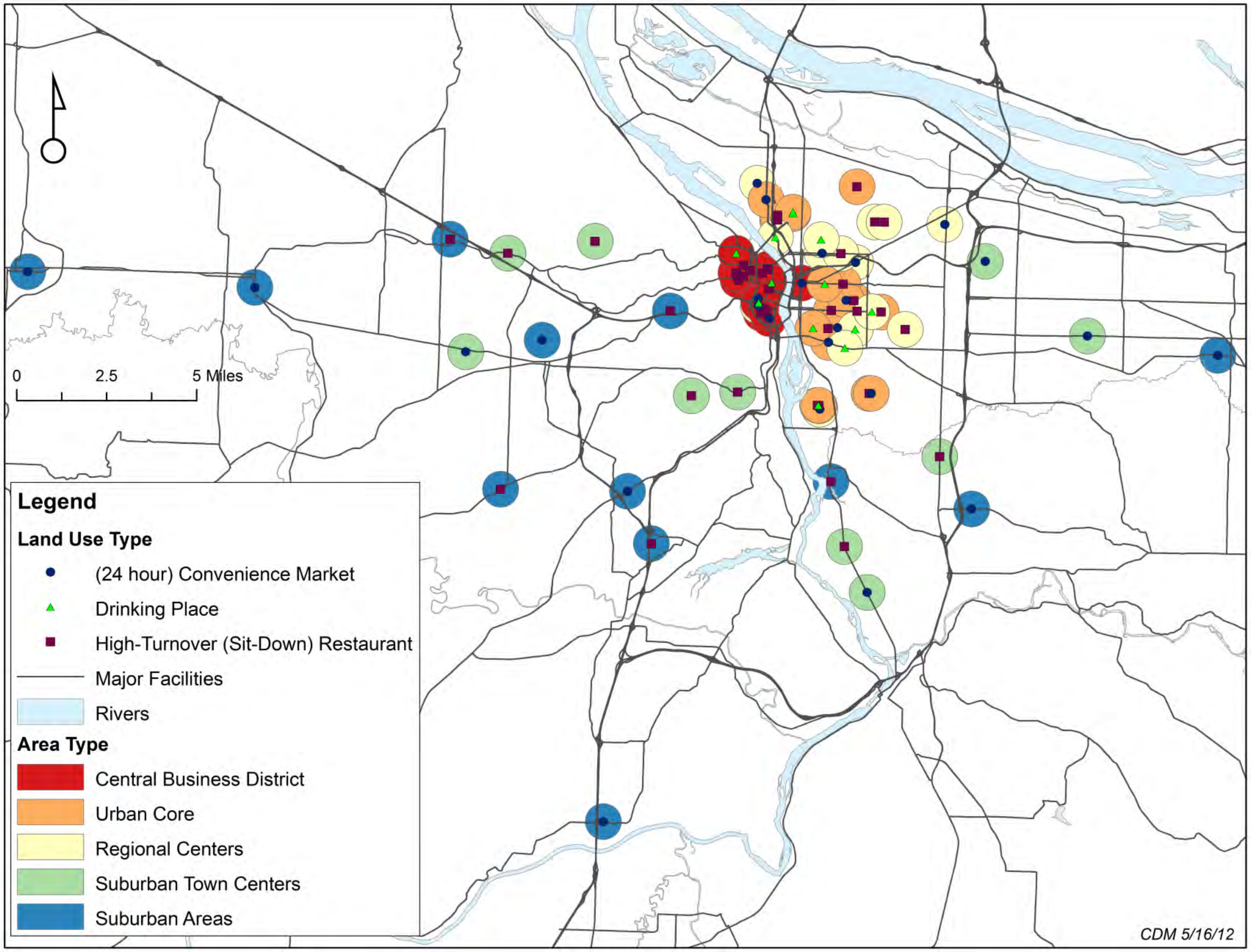


Figure 3-1. Locations of Survey Establishments

3.2.1.1 Customer intercept survey

The surveys were administered by intercepting customers as they leave the establishment. Two survey options were offered to customers: (1) a five-minute survey administered via handheld computer tablets, and (2) a shortened version of just four questions. The five-minute survey collected information on demographics, travel mode(s), consumer spending behavior, attitudes towards transportation modes, the trip to and from the establishment, and map locations of home and work. Appendix A contains a paper version of the five-minute survey instrument.

The short survey was offered as an alternative to customers refusing the five minute survey. It does not collect as much detailed information, but it does help obtain a larger sample. This survey collected four pieces of information: mode of travel, amount spent on that trip, frequency of visits to the establishment, and the respondent's home location. Gender was recorded by the survey administrator. See Appendix B for the short survey instrument.

3.2.1.2 Establishment information

Site-level characteristics were collected during field data collection events. These characteristics include vehicle parking spaces, parking configuration, and site amenities for pedestrians and cyclists. Building square footage was collected from business managers at the establishments and through Google Earth.

3.2.2 Sample Description

An average of 24.2 surveys was collected at each establishment, for a total of 1884 surveys (697 long surveys and 1187 short). The overall response rate was 52% for all surveys. More detail on sample size is provided in Table 3-2.

Table 3-2. Survey Sample Size

Land Use	Establishments (N)	Long Surveys (N)	Short Surveys (N)	Response Rates		Total
				Long Survey	Short and Long Survey	
Drinking places	13	107	108	30%	50%	215
Convenience	26	281	710	14%	61%	991
Restaurants	39	309	369	24%	52%	678
Total	78	697	1187	19%	52%	1884

Table 3-3 shows the demographic information of long survey respondents. In addition, the sample demographic characteristics are compared to US Census data for the Portland metro area. Household income, vehicle ownership, and household size are closely aligned with Census information. Men and younger people were slightly overrepresented in our sample.

Table 3-3. Survey Demographics Compared to U.S. Census Data

Variable	Survey observed*	2010 Census (Oregon)
Median household income per year	$50,000 - $99,000	$48,457
Average household income per year	$50,000 - $99,000	$62,964
Median Age	25-34	38
Male respondents	56.80%	49.50%
Average # vehicles per household	1.60	1.80
Average # bicycles per household	1.70	N/A
Average # transit passes per household	0.50	N/A
Average # adults per household	2.20	N/A
Average # children per household	0.25	N/A
Average household Size	2.45	2.50
Physical limitations	6.90%	13.00%

*Note: demographic data from long survey only. N = 697

3.2.2.1 Mode share

Table 3-4 shows automobile mode share is consistently higher in suburban areas than in more urban settings. Automobile mode share decreases as locations become more urban. Note that no drinking places were surveyed in suburban locations.

Table 3-4. Automobile Mode Share

Area Type	Drinking Place	24-hour Convenience Store	High Turnover (Sit-Down) Restaurant
Central Business District	26%	34%	35%
Urban Core	46%	51%	64%
Regional Centers	52%	60%	70%
Suburban Town Centers	N/A	70%	85%
Suburban Areas	N/A	72%	86%

Table 3-5 shows mode shares in more detail. Higher proportions of walking and bicycling occur at establishments in the Central Business District, Urban Core, and Regional Center area types than in suburban area types. Transit mode shares are highest in the Central Business District, but there is not as consistent a trend in transit mode shares between urban to suburban area types as there are trends with other travel modes. Non-automobile mode shares appear highest in the areas of the region that offer the most variety of convenient travel choices.

Table 3-5. Percent Mode Shares by Area Type and Land Use

Area Type & Land Use	Automobile Mode Share	Walk Mode Share	Bicycle Mode Share	Transit Mode Share
Convenience	58%	27%	7%	6%
Central Business District	34%	49%	10%	10%
Urban Core	52%	31%	9%	6%
Regional Centers	60%	26%	7%	5%
Suburban Town Centers	70%	18%	3%	7%
Suburban Areas	72%	14%	8%	3%
High-turnover Restaurant	63%	22%	8%	6%
Central Business District	35%	42%	7%	16%
Urban Core	65%	20%	13%	2%
Regional Centers	70%	24%	6%	1%
Suburban Town Centers	85%	6%	1%	6%
Suburban Areas	86%	5%	0%	8%
Drinking Place	43%	27%	22%	7%
Central Business District	26%	40%	19%	15%
Urban Core	46%	20%	25%	8%
Regional Centers	52%	30%	18%	1%
Suburban Town Centers*	N/A	N/A	N/A	N/A
Suburban Areas*	N/A	N/A	N/A	N/A
Overall	58%	25%	9%	7%
Central Business District	34%	43%	9%	14%
Urban Core	57%	23%	15%	5%
Regional Centers	61%	26%	10%	3%
Suburban Town Centers	79%	11%	2%	7%
Suburban Areas	78%	10%	5%	5%

*Drinking places were not surveyed in suburban area types

Figure 3-2 shows the resulting automobile mode share for all establishments surveyed in a spatial context. As shown, automobile mode shares are generally lower in establishments closer to the city center. There is variation in automobile mode share in the inner east side of Portland where area type varies between Urban Center and Neighborhood/Regional Center. For a more detailed map of mode shares of survey establishments, see Appendix D.

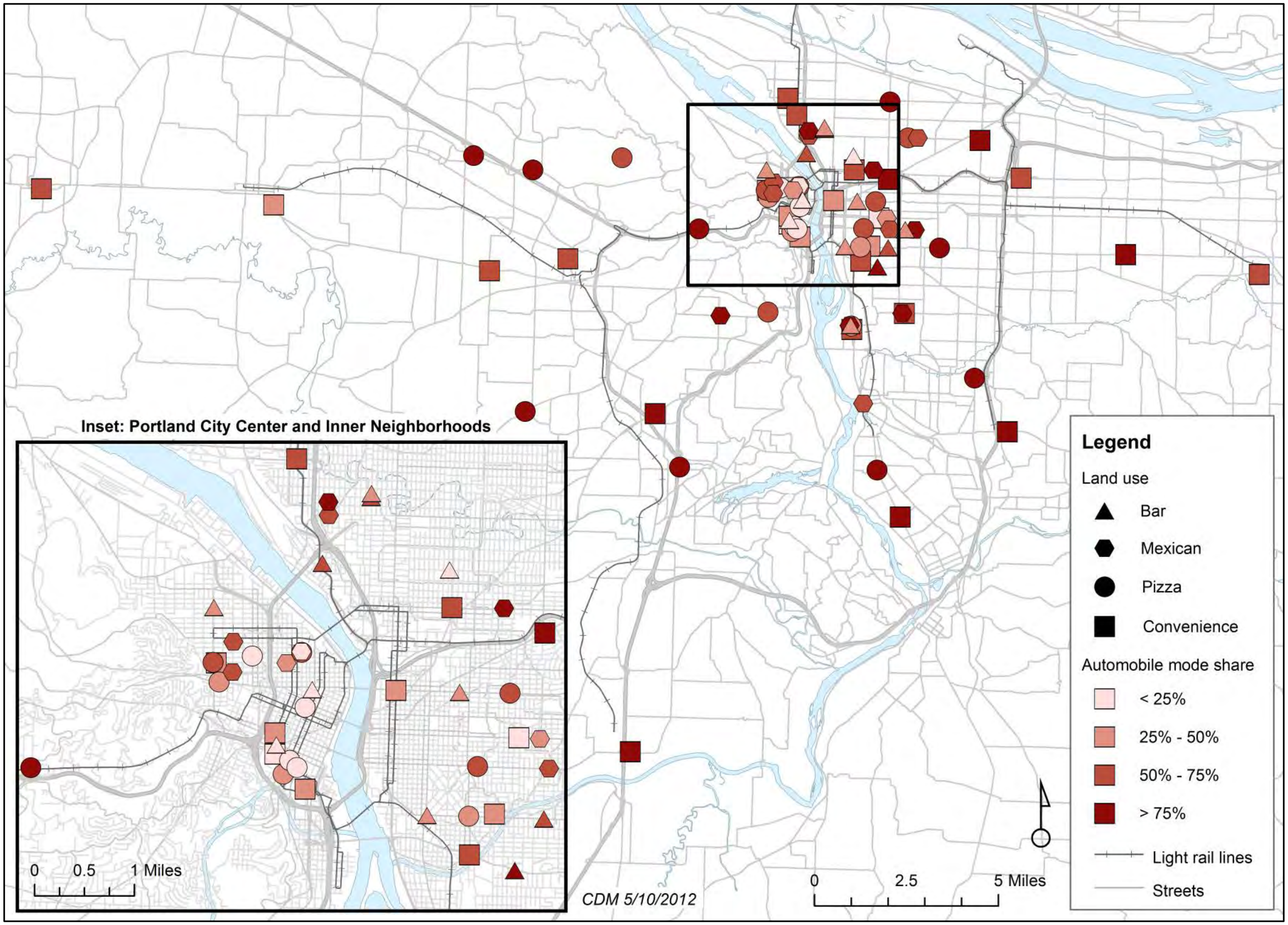
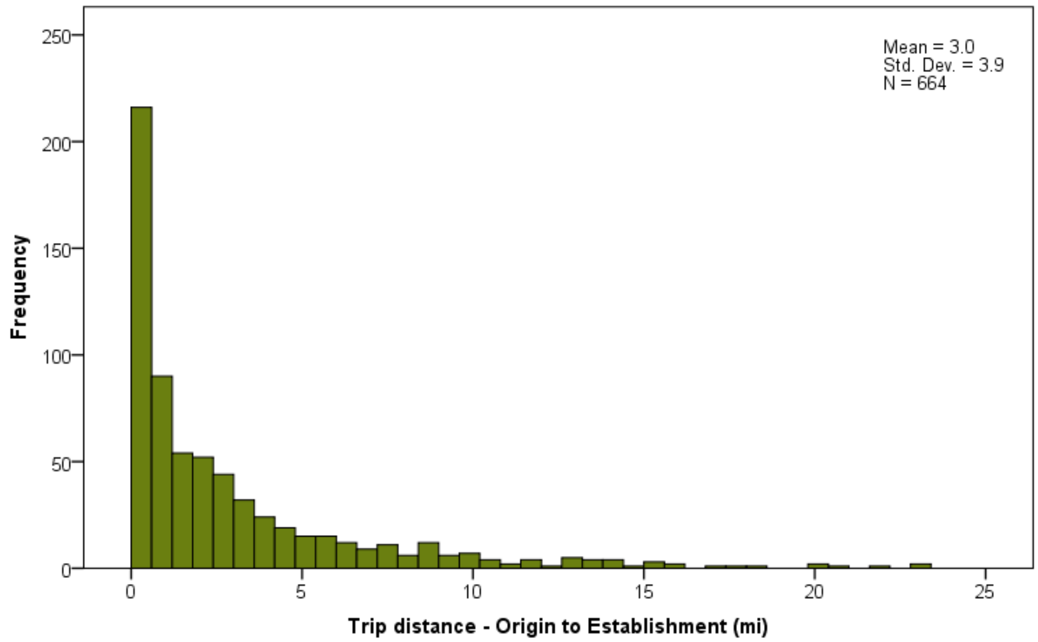


Figure 3-2. Automobile Mode Share of Survey Establishments

3.2.2.2 *Trip length distribution*



Note: trip distance to establishment only available for long survey responses

Figure 3-3. Trip Lengths, Origin to Establishment

In Figure 3-3, the trip length distribution (network distance) of origin to establishment trips is shown from long survey data. Most trips were less than five miles in length. Average trip lengths by mode and area type are provided in Table 3-6. There is no consistent pattern for trip length as area type changes from urban to suburban.

Table 3-6. Average Trip Length Distribution by Area Type (miles)

Area Type	Vehicle		Rail	Bus	Bike	Walk	All	N
	Driver	Passenger						
Central Business District	4.9	4.2	10.6	3.8	2.2	0.6	2.5	163
Urban Core	4.2	2.4	1.7	4.6	2.7	0.9	3.0	227
Regional Centers	2.9	3.0	3.1	3.0	2.2	0.7	2.1	158
Suburban Town Centers	5.7	1.7	8.9	9.0	0.9	0.5	5.1	77
Suburban Area	4.7	3.5	9.2	4.2	1.3	0.5	3.9	72
All	4.3	2.7	10.0	5.0	2.4	0.8	3.0	697
N	305	49	23	26	75	203	681	

Note: N for travel mode is less than N for area type due to respondents that chose “Other mode”, skipped, or opted out of the question.

3.2.2.1 *Vehicle occupancy*

Table 3-7 shows the average observed vehicle occupancy from long survey responses tabulated by land use and area type. Convenience stores had the lowest vehicle occupancy and high-turnover restaurants had the highest. There appears to be little variation in vehicle occupancy across area types.

Table 3-7. Average Vehicle Occupancy from Long Survey

Area Type	Drinking Place	24-hour Convenience Store	High Turnover (Sit-Down) Restaurant
Central Business District	1.5	1.0	1.8
Urban Core	1.5	1.1	1.8
Regional Centers	1.8	1.3	1.8
Suburban Town Centers	N/A	1.2	1.5
Suburban Areas	N/A	1.1	1.8

3.2.2.2 OHAS Comparison

Vehicle occupancy and automobile mode share data collected from the survey are compared to data from another regional survey of travel behavior, the Oregon Household Activity Survey (OHAS). Table 3-8 and Table 3-9 show that automobile mode shares and vehicle occupancies observed in this study are lower than those observed in OHAS data.

Adjustment for potential survey bias was not applied to the survey sample. OHAS data are collected at the households of participants, unlike data from this study that are collected at establishments.

Table 3-8. OHAS Comparison: Automobile Mode Share

Land Use	TGS Survey	Oregon Household Travel Survey Data (OHAS, 2011)[5]
Convenience Market (Open 24-Hours)	58.5%	84.8%
High-Turnover (Sit-down) Restaurant	62.9%	79.0%
Drinking Place	43.3%	79.0%

Table 3-9. OHAS Comparison: Vehicle Occupancy

Land Use	PSU Survey	Oregon Household Travel Survey Data (OHAS, 2011)[5]
Convenience Market (Open 24-Hours)	1.2	1.6
High-Turnover (Sit-down) Restaurant	1.8	2.0
Drinking Place	1.6	2.0

[5] OHAS Trip purpose comparing Convenience Market (Open 24-hours) includes "Routine Shopping (Groceries, Clothing, Convenience Store, Household Maintenance)". OHAS trip purpose comparing High-Turnover (Sit-down) Restaurants and Drinking Places is aggregated by "Eat Meal Outside of Home" trip purposes.

3.3 COUNT DATA

This section details the methods used to collect person trip counts and vehicle trip counts from establishments. It also describes the resulting trip count data.

3.3.1 Method

Surveyors counted persons entering and exiting the establishment at every entrance to the store. The number and gender of people refusing to participate in the survey was recorded in order to later calculate response rate and bias in the survey data. Counts of vehicles and bicycles exiting the site were recorded when feasible (typically when the site had parking adjacent to the store entrance). Vehicles and bicycles were only counted when exiting because many establishments were in shopping centers and mixed-use developments. Counting vehicles entering a mixed-use development site could potentially introduce error from counting vehicles that went to non-survey establishments. By counting vehicles and bicycles exiting, we ensure that these trips came to the site before leaving.

3.3.2 Sample description

3.3.2.1 Trip counts and establishment type

Observed person trips exiting establishments varied across establishment types. In Figure 3-4 we see that convenience stores had the highest person trip rates of any particular land use type. We can also see that customer traffic appears to be greater during the 6-7 PM hour than customer traffic during the 5-6 PM hour for all land uses except convenience stores.

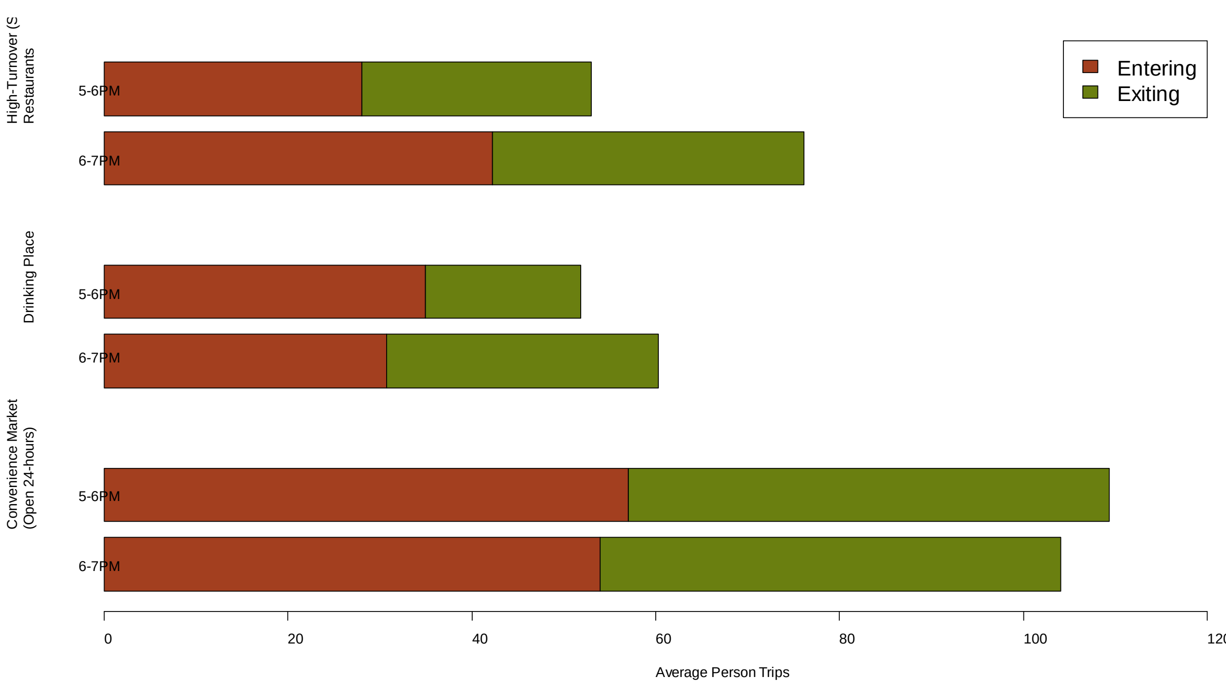


Figure 3-4. Observed Person Trips by Establishment Type

Figure 3-5 shows the mean observed vehicle trips exiting different establishment types. Vehicle trips do not appear to vary substantially between the 5-6 PM and 6-7 PM hours. We see that convenience stores have the most observed vehicle trips on average. Exiting vehicle trip counts were obtained for just 44 of the 78 establishments studied. Many study sites, especially those in urbanized neighborhoods, contained on-street and complex parking situations and did not allow vehicle counts to be obtained during data collection.

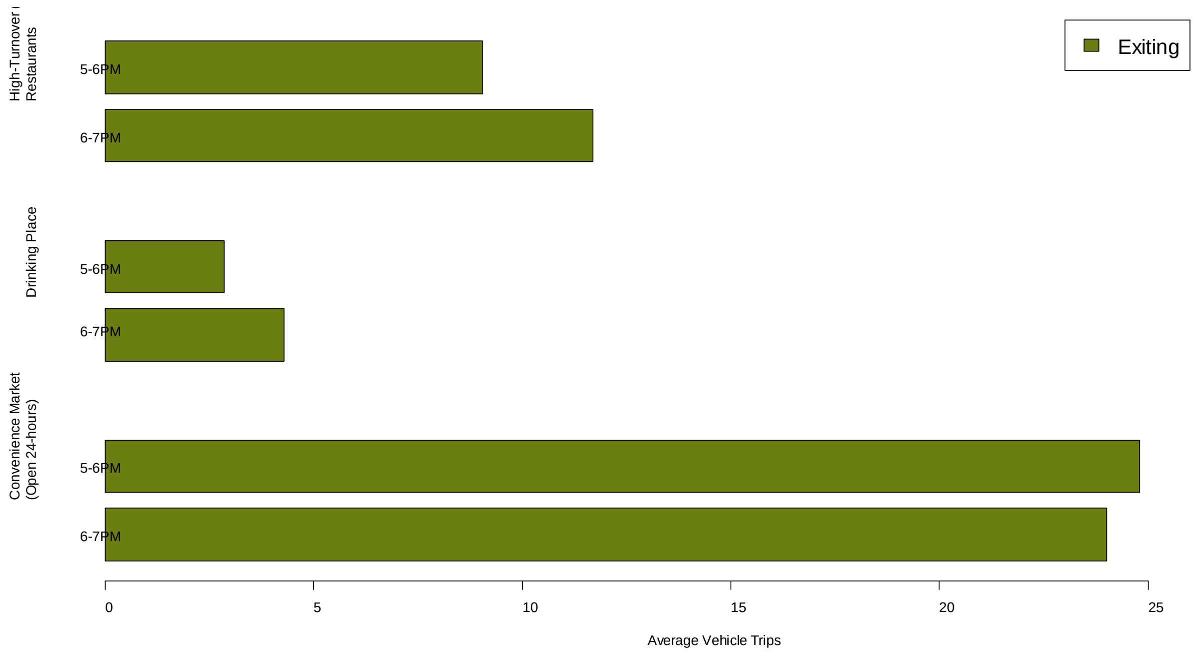


Figure 3-5. Observed Vehicle Counts by Establishment Type

Table 3-10 shows a summary of person and vehicle trips aggregated to land use. The survey locations were on average not very big (most between 1800 and 3200 square feet in area). Convenience stores had the most customer traffic during the 5:00 – 7:00 PM hour.

Table 3-10. Observed Person and Vehicle Trip Counts by Land Use Type

ITE Land Use		Convenience Market (Open-24 Hours)		Drinking Place		High-Turnover (Sit-Down) Restaurant	
ITE Land Use Code		851		925		932	
Sample Size (N)		26		13		39	
		Mean	*Std. Dev.*	Mean	*Std. Dev.*	Mean	*Std. Dev.*
Average Gross Floor Area of Establishment (Sq. Ft.)		2529	*278*	3197	*2881*	1747	*871*
Person Trips	Enter	57.0	*29.6*	35.0	*15.3*	28.1	*18.2*
	Exit	52.3	*29.2*	16.8	*5.6*	24.9	*12.0*
Vehicle Trips	Exit	48.8	*21.4*	7.1	*9.4*	20.8	*18.9*

3.4 BUILT ENVIRONMENT DATA

Built environment information was gathered from archived data sources in order to support our analysis of context. This information was collected within a ½ mile radius (Euclidean distance) from each establishment point, hereby referred to as the establishment buffer. The measures that were included in this study are described below in more detail.

3.4.1 Metro Context Tool

The Context Tool, developed by Metro, is a set of GIS raster indices[6] of built environment dimensions including: bicycle access, people per acre (population and employment density), transit access, urban living infrastructure (ULI), sidewalk density, and block size. Each individual raster index, or indicator, is a component of the larger Context Tool. Only the Context Tool ULI Indicator is used in the analysis presented here. Other built environment measures used in this study are described in the next section.

ULI serves as a measure of the density and diversity of retail and service destinations. Figure 3-6 illustrates the Context Tool ULI Indicator across the Metro region. The measure is based on the different retail and service land uses that accommodate everyday non-work living needs[7]. The ULI Indicator increases as the number of these business types nearby increases. The highest ULI values are in places like downtown Portland, where many different retail and service establishments exist in close proximity.

The Context Tool ULI Indicator is developed by calculating the densities of retail and service businesses within a ¼-mile of each raster cell and then classifying them into a one through five index. Classification is performed using Jenks' natural breaks algorithm, a method typically used to display data on chloropleth maps. The method finds actual breaks in the data instead of using an arbitrary classification scheme like equal intervals. The range of observations comprising each index value varies as a result.

Figure 3-7 provides an example. Business densities around establishments, the underlying calculation of ULI, are plotted against vehicle trip rates at establishments. The ULI of survey establishments is shown in the shaded background of the plot. This chart illustrates an increased range in business density as the ULI score increases. Only two establishments have a ULI of 5 and are located in the central business district of Portland. Many locations have ULI values of 2, 3, and 4. Figure 3-6 also provides an example: very few areas in the Metro region besides downtown Portland have ULI values of 5 and the majority of the region has a ULI of 1. Most areas with ULI values 2, 3, and 4 are located along major corridors and town centers.

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[6] Rasters are calculated using Kernel Density Tool (1/4 mile distance) in Spatial Analyst Toolbox in ArcGIS 10.

[7] Business types in the ULI Context Tool (and corresponding NAICS 2007 codes) are the following: retail bakeries (311811), breweries (312120), nursery/garden/farm supply stores (444220), supermarkets and other grocery (except convenience) stores (445110), other specialty food stores (445299), beer/wine/liquor stores (445310), men's clothing stores—men's, women's, children and infants, family (448110, 448120, 448130, 448140), sporting goods stores (45110), bookstores (451211), department stores (except discount department stores) –but only including large supermarket-type department stores (452111), gift/novelty/souvenir stores (453220), motion picture theaters (except drive-ins) (512131), child day care services (624410), fitness/recreational sports centers (713940), drinking places (722410), full-service restaurants (722110), limited-service restaurants (722211), cafeterias/grill buffets/buffets (722212), snack and nonalcoholic beverage bars (722213), and dry cleaning and laundry services (except coin-operated) (812320).

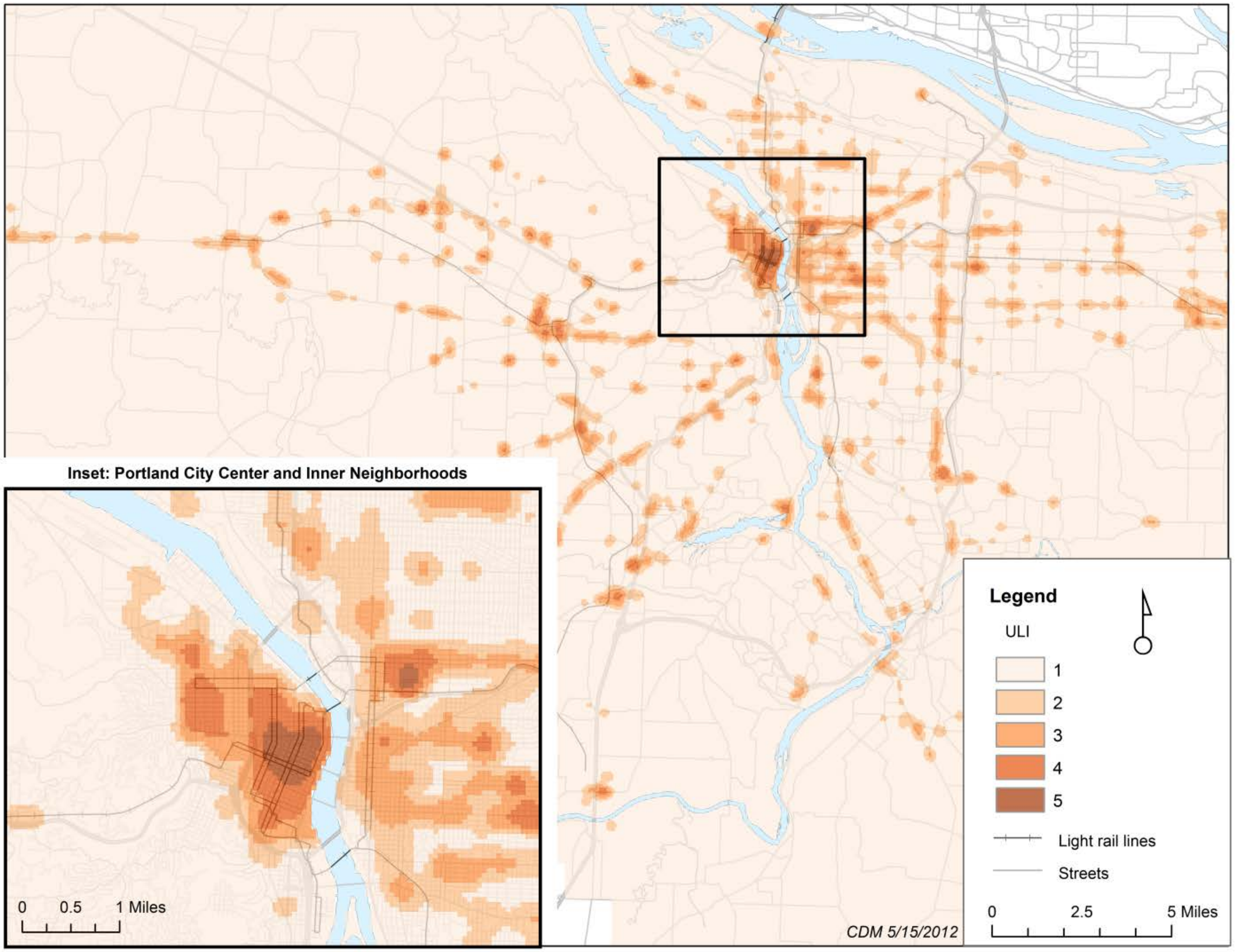

Figure 3-6. Urban Living Infrastructure Context Tool

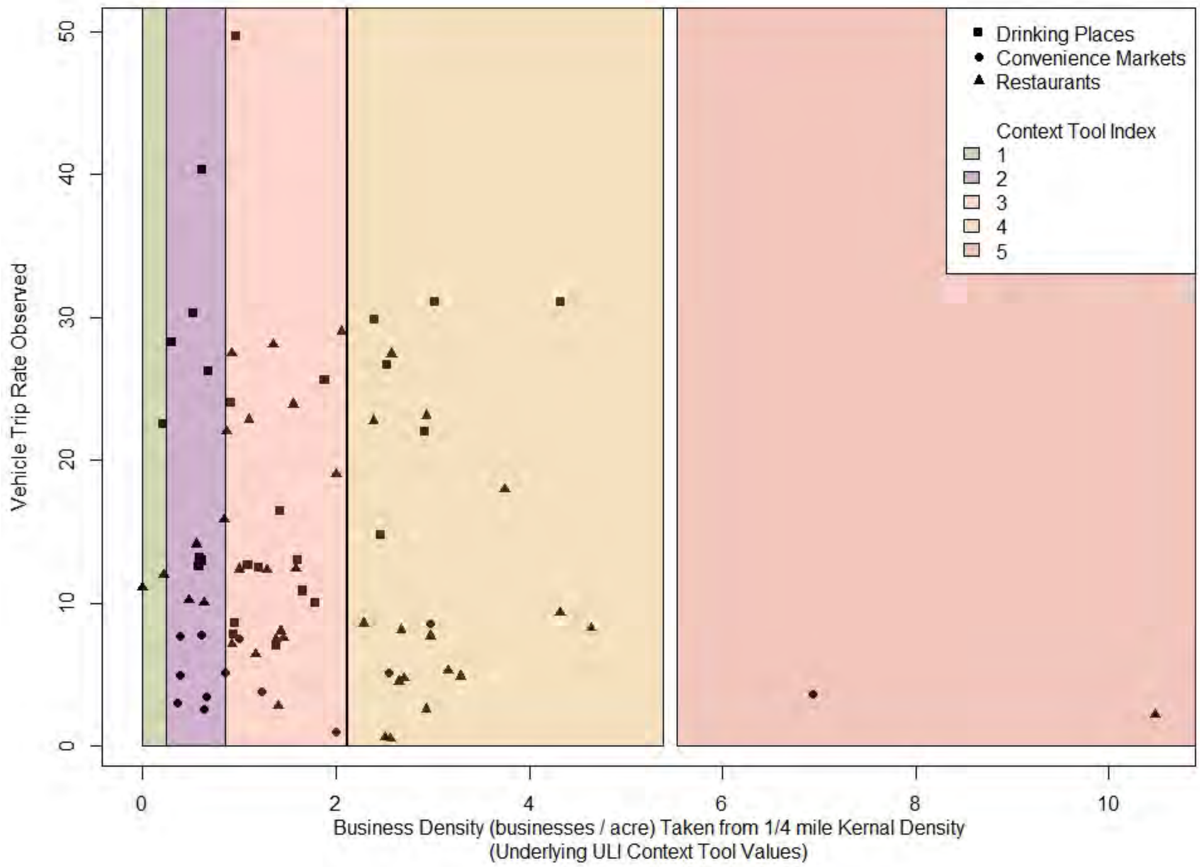

Figure 3-7. Context Tool Index Ranges and Observed Vehicle Trip Rates: ULI Business Density

We use ULI in our analysis by calculating the average ULI score within a half mile radius of the establishment. This average provides a representation of area surrounding the establishment. An example is illustrated in Figure 3-8. The ULI score found at this establishment point is 3, while the average ULI score within the establishment buffer is 2.19.

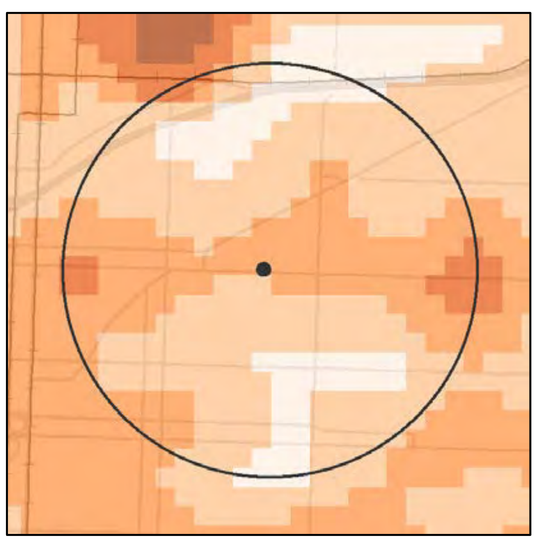

Figure 3-8. Example Establishment with ½-mile Buffer and ULI Context Tool

ULI is also highly correlated with other built environment attributes that are associated with higher rates of non-automobile travel, such as measures of density, street configuration, block size, bicycle and pedestrian networks and transit service. As such, ULI is an indicator of the character of a particular neighborhood: a place with a high ULI score is very likely to also have a more gridded street network with small blocks, higher densities of housing and employment, higher-quality transit access, and amenities that make walking and cycling more convenient. Figure 3-9 shows the observed mode shares within average ULI ranges of survey establishments. Clearly, ULI is strongly associated with non-automobile travel. Establishments with the highest ULI scores have the highest proportion of people who walked. Additionally, transit appears to have a greater mode share for those locations with a ULI of 3, areas often located along corridors and neighborhood centers.

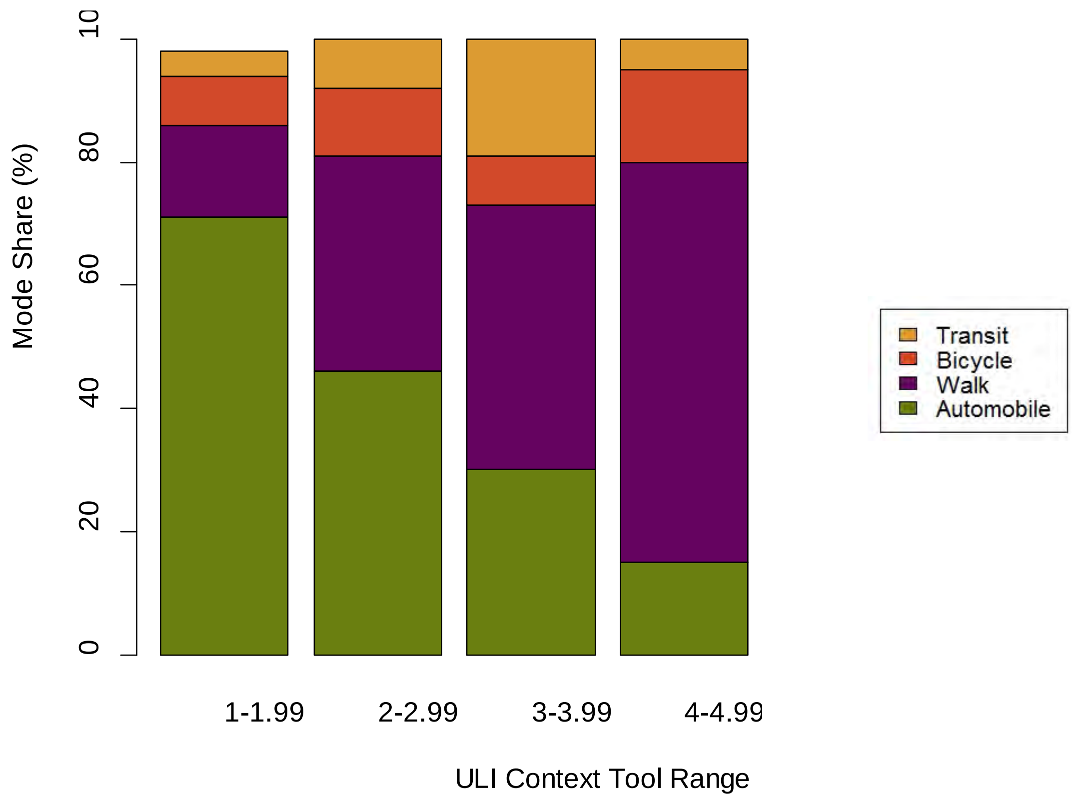

Figure 3-9. Average Mode Share by ULI Range (Metro Context Tool)

3.4.2 Other built environment data

In addition to the ULI measure discussed previously, several additional built environment features that are influential in travel choices were considered in our analysis. These built environment features were also measured at a ½ mile buffer around each establishment.[8] These measures are listed in Table 3-11 and are described below.

[8] Water features were excluded from all calculations when water fell within the ½ mile buffer

Table 3-11. Built Environment Measures List and Data Source

Measure	Units	Data Source*
Number of Transit Corridors	# Trimet lines within ½-mile	Light-rail and Bus Stop layer (RLIS, 2010)
People Density	Residents and employees per acre	ESRI Business Analyst (2010) and Multifamily/Household layers (RLIS, 2010)
Number of High-Frequency Transit Stops	# stops within ½-mile with headways under 15 Minutes	Bus Stop layer (RLIS, 2010) and TriMet schedules (2011)
Employment Density	Employees per acre	ESRI Business Analyst (2010)
Lot Coverage	Percent	Tax lot and Building Layers (RLIS, 2010)
Length of Bike Facilities	Miles	Bike Route layer (RLIS, 2010)
Access to Rail	Presence of rail station within ½-mile	Light-rail Stop layer (RLIS, 2010)
Intersection Density	Intersections per million square feet	Lines file (TIGER 2009)
Median Block Perimeter	Miles	Faces file (TIGER 2009)

* RLIS: Regional Land Information System, Portland Metro.

Number of Transit Corridors: A count of the transit routes accessible within the establishment buffer.

People Density: The total residential and employment population within the establishment buffer divided by its buffer area in acres.

Number of High-Frequency Transit Stops: The number of high-frequency bus stops within the establishment buffer. High-frequency stops have service headways of 15 minutes or less (including at least four stops) between 4:30 and 5:30PM. Data for 5:00-6:00PM are not available.

Employment Density: The number of employees within the establishment buffer divided by its area in acres.

Lot Coverage: The percent of tax lot parcel area covered by building footprints. This measure is a proxy for parcel setbacks and is calculated for all parcels within the establishment buffer.

Length of Bike Facilities: Miles of bicycle facility links within the establishment buffer.

Access to Rail: A binary variable indicating access to a light-rail station within the establishment buffer. A value of one indicates the presence of at least one rail station within the buffer, and a value of zero indicates no station.

Intersection Density: The number of intersections per 1,000,000 square feet within the establishment buffer.

Median Block Perimeter: The median perimeter distance (miles) of census blocks within the establishment buffer.[9]

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[9] The median is selected as a more robust measure than the mean of the typical block size; the median is less influenced by outliers and uneven distributions than the mean.

4.0 ANALYSIS

Based on the descriptive analysis discussed in the previous chapter, we detail here the methods and assumptions employed to compare study findings with ITE. We aim to develop a consistent method for adjusting ITE trip generation estimates to control for urban context. This is based upon relationships between built environment characteristics and mode shares found from analysis of data collected from specific establishments across the Portland region.[10]

This chapter is organized as follows:

1. Testing key assumptions in our analysis
2. Comparison of ITE trip rates to data collected in this study
3. ITE adjustment method
4. Implications for planning the built environment

4.1 ASSUMPTIONS TESTING

A critical assumption in this study is that person trip rates for a specific establishment type (land use category) and size (gross floor square footage or similar measure) do not vary across urban contexts. Rather, the distribution of those person trip rates across various modes of transportation varies by the urban built environment. If this hypothesis is true, it suggests that automobile and non-automobile trips may be substitutable across contexts (person trip rates are constant) rather than complements (non-automobile trips may be additional trips). If non-automobile trips are complementary (vary across contexts), the ability to compare ITE vehicle trip rates with collected data proves difficult. In that case, the error between observed and estimated vehicle trip rates cannot be distinguished from non-automobile trip rates. See Figure 4-1 for an illustration.

In order to test the hypothesis illustrated in Figure 4-1, person trip rates (entering and exiting the establishments) are compared across the various area types described in Section 3.1, controlling for differences in land use type and establishment size.

The average person trip rate (trips per square foot gross floor area) from the PM peak hour (5:00 – 6:00 PM) across land use types was tested for significant variance across contexts. Tests were performed for: (1) all land uses combined across contexts (pooled data) and (2) specific land use types across contexts (data segmented by establishment type). The null hypothesis (H_0) stated that average person trip rates are equal across contexts, and the alternate hypothesis (H_1) stated that average person trip rates are not equal across contexts. Hypothesis testing was performed via one-way analysis of variance statistical means testing at 95% confidence. The results of the hypothesis testing are shown in Table 4-1.

[10] Statistical analyses were performed with SPSS, Version 19.0 (IBM Company, 2010) and R, version 2.6 (The R Foundation for Statistical Computing, 2008). Spatial analysis was conducted in ArcGIS 10.0 (ESRI, 2011).

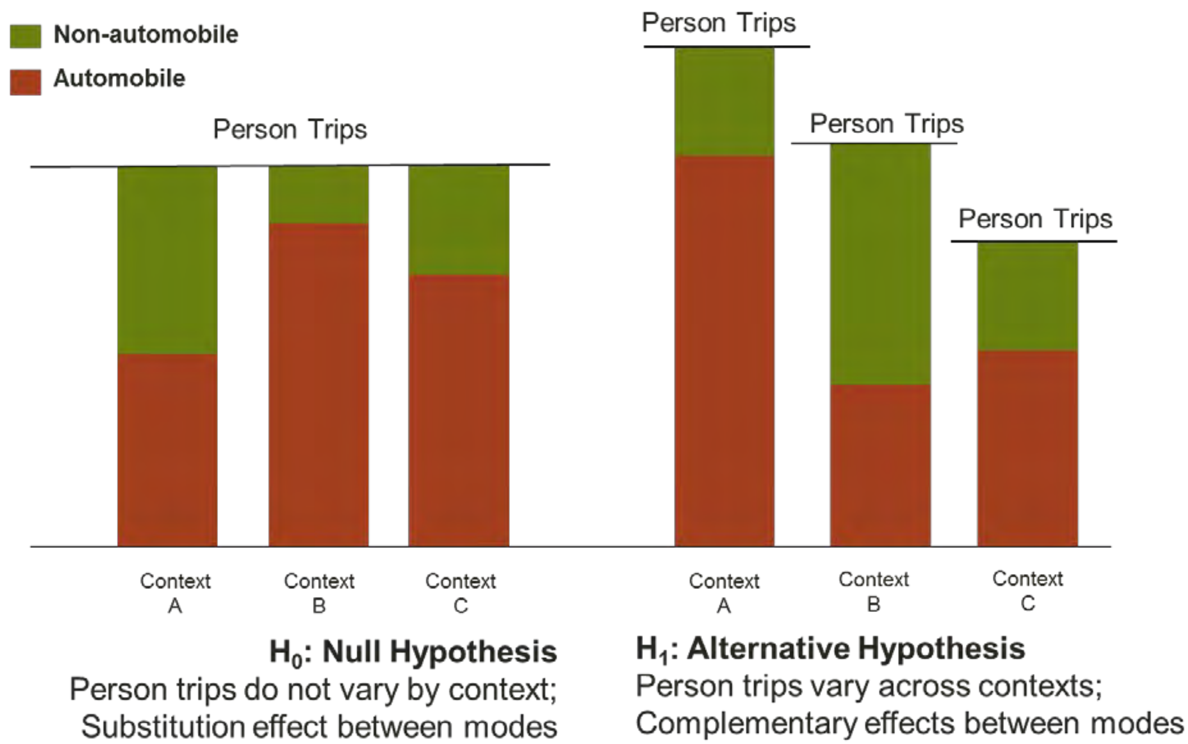

Figure 4-1. Do Person Trip Rates Vary Across Contexts?

Table 4-1. Hypothesis Testing ($\alpha = 0.05$)

Scenario (across contexts)	Result	p-value	Interpretation
All land uses combined	H_0	0.652	Person-trip rates similar across contexts
24-hour convenience stores	H_0	0.695	Person-trip rates similar across contexts
High-turnover restaurants	H_0	0.323	Person-trip rates similar across contexts
Drinking places	H_0	0.189	Person-trip rates similar across contexts
High-turnover restaurants + drinking places*	H_0	0.616	Person-trip rates similar across contexts

*Note: land uses combined due to similarities between brew-pubs and restaurants.

The results show that average person trip rates do not differ significantly across different context types, suggesting that non-automobile travel may be a substitute for automobile trips. Person trips do not vary significantly for establishments of a specific size and type, but rather the distribution of trip rates by different travel modes.

4.2 COMPARISON OF TGS WITH ITE

This section details a comparison between the Trip Generation Study (TGS) data and the ITE Trip Generation data. To compare TGS person trips to ITE vehicle trips for each establishment, we need estimates of the number of vehicles entering and exiting sites. In Equation 4-1, we estimate vehicle trip rates from survey data[11].

Equation 4-1. TGS Vehicle Trip Rate

Where: P_{IN} = Person count entering the establishment,
P_{OUT} = Person count exiting the establishment,
$\%AUTO_{TGS}$ = automobile mode share from the survey, and
$VEH\ OCC_{TGS}$ = Average vehicle occupancy for the survey

Comparison of TGS to ITE vehicle trip rates for the weekday peak hour of the facility (5– 6PM) can be seen in Figure 4-2, Figure 4-3, and Figure 4-4.[12,13] TGS vehicle trips are consistently below ITE rates and ITE data points for convenience stores and drinking establishments. Figure 4-4 shows that for high-turnover, (sit-down) restaurants, the TGS vehicle trips and ITE trip rate are in agreement. Table 4-2 shows a comparison of ITE and TGS vehicle trip rates for all three land uses. Convenience markets are the least correlated with ITE. Although high-turnover (sit-down) restaurants agree the most with ITE trip rates, a local refinement on application in various contexts may assist in explaining the variation observed at establishments with greater gross floor areas.

ITE lists the criteria recommended to adopt the ITE Trip Generation methodology for local use and TGS results (see Table 4-3). All criteria must be met to consider application of ITE Trip Generation data in local context. Otherwise, it is recommended that a local rate or equation be developed (Institute of Transportation Engineers 2004, 21). From Table 4-2 and Table 4-3, we recommend a local adjustment to ITE rates for convenience stores and drinking establishments. We do not have sufficient evidence to recommend adjusting ITE rates for high-turnover (sit-down) restaurants in the Portland region.

We hypothesize that the differences between ITE and TGS are largely due to differences in the travel modes customers use to access/egress these sites. As discussed in section 4.1, this is supported by the fact that person trip rates are similar across area types. This points to the need to adjust ITE rates for urban context, as differences in vehicle trips across context are largely due in part to the built environment attributes that support transit and non-motorized modes. The next section introduces the model used for adjusting ITE vehicle trip rates.

[11] For an explanation on the development of Equation 1, see Appendix F.
[12] No sites were evaluated during the peak hour of the generator, and limited data were available to determine the number of seats provided by restaurant-type establishments for comparison.
[13] No models are provided by ITE for any of these land uses due to weak correlation between establishment size and vehicle trips produced for adjacent street traffic during PM peak hours.

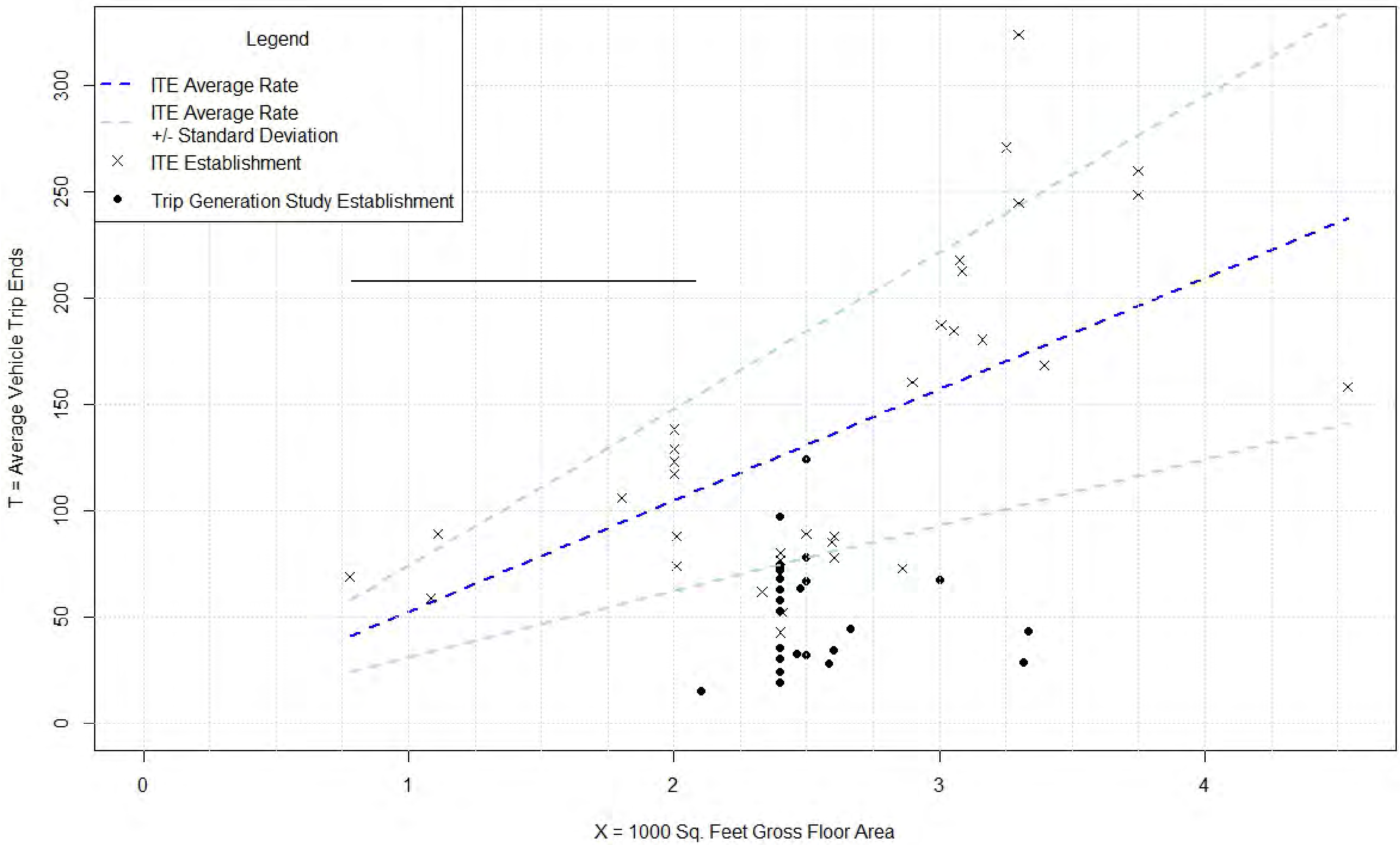

Figure 4-2. Convenience Market (Open 24-hours) (LU 851): Weekday, Peak Hour of Adjacent Street Traffic, 4-6PM - TGS Vehicle Trips and ITE Vehicle Trip Rates Data

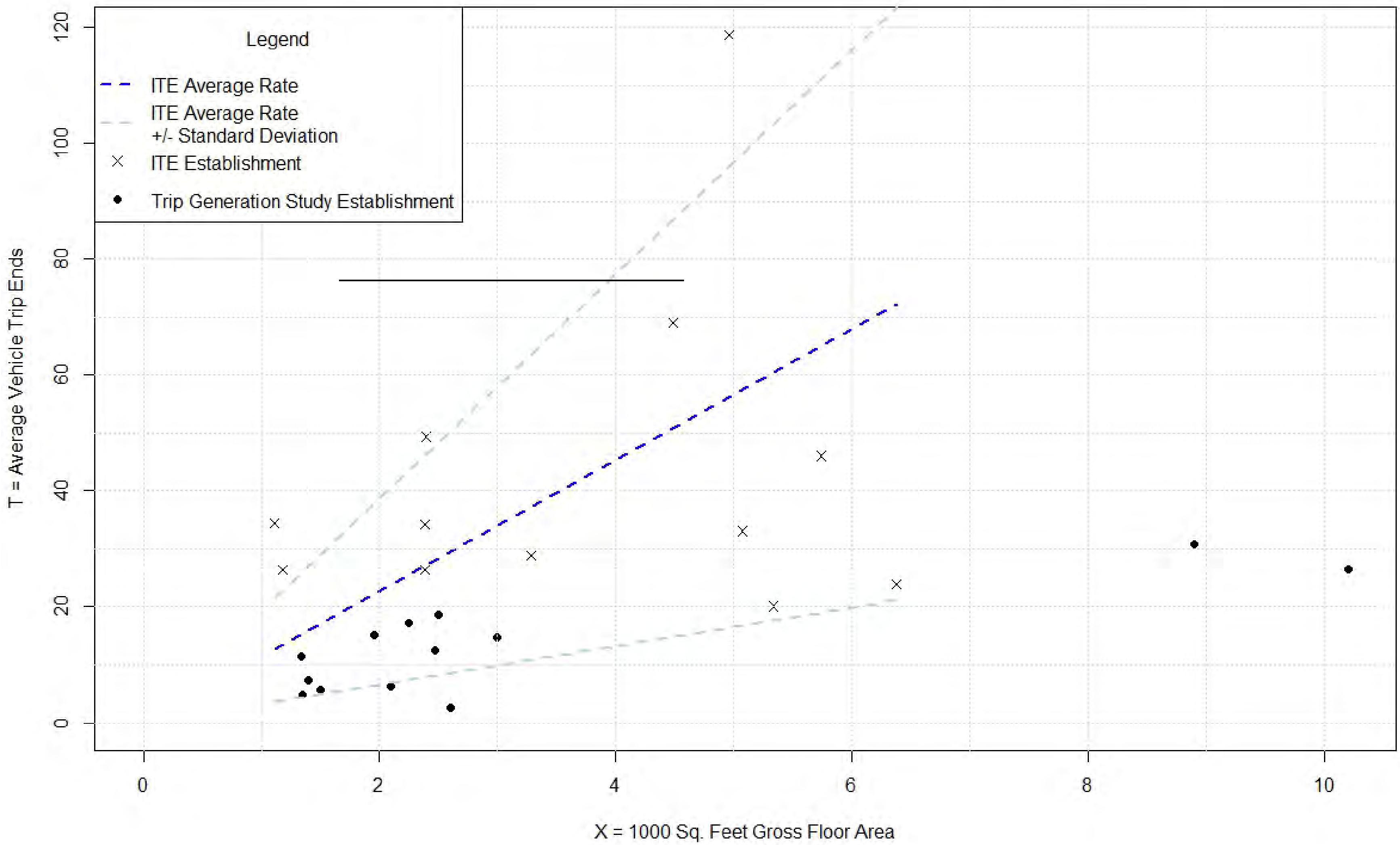

Figure 4-3. Drinking Places (LU 925): Weekday, Peak Hour of Adjacent Street Traffic, 4-6PM - TGS Vehicle Trips and ITE Vehicle Trip Rates Data

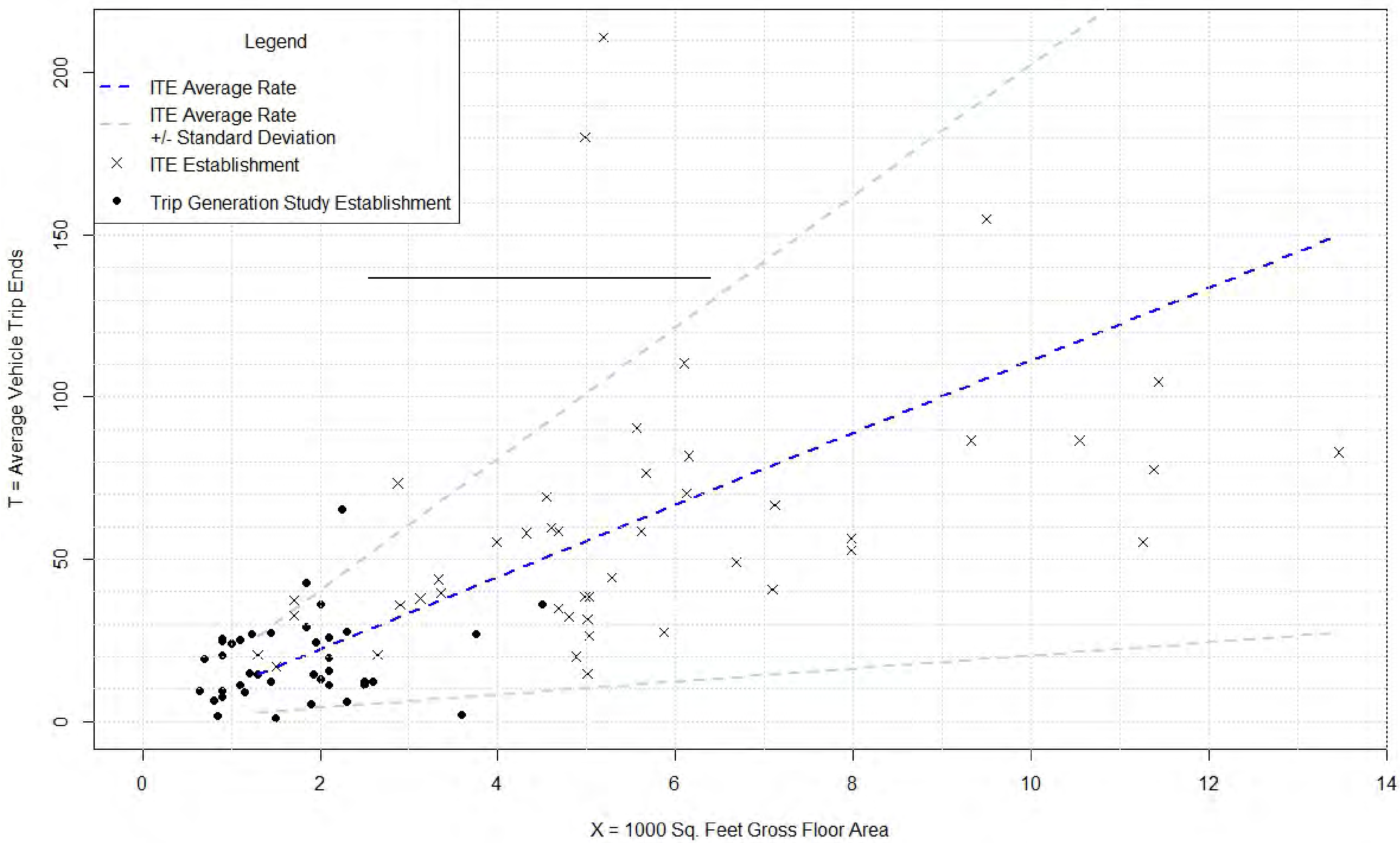

Figure 4-4. High-Turnover (Sit-Down) Restaurants (LU 932): Weekday, Peak Hour of Adjacent Street Traffic, 4-6PM - TGS Vehicle Trips and ITE Vehicle Trip Rates Data

Table 4-2. Comparison of Vehicle Trip Rates - ITE versus TGS rates

ITE Land Use	**Convenience Market (Open-24 Hours)**		**Drinking Place**		**High-Turnover (Sit-Down) Restaurant**	
ITE Land Use Code	851		925		932	
Sample Size (N)	26		13		39	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
TGS vehicle trip rate (vehicles per 1000 Sq. Ft. area)	20.8	*10.8*	4.9	*2.3*	12.3	*8.3*
ITE Vehicle trip rate (vehicles per 1000 Sq. Ft. area)	52.4	*21.4*	11.3	*9.1*	11.2	*8.0*
Vehicle trip rate difference (TGS - ITE)	-31.6	*10.8*	-6.4	*2.3*	1.2	*8.3*

Table 4-3. ITE Criteria for Local Rate Development

ITE Criteria	LU 851: Convenience Market (Open 24-Hours) (N=26)	LU 925: Drinking Place (N=13)	LU 932: High-Turnover (Sit-Down) Restaurant (N=39)
1.) A trip generation study (with at least three locations) provides a vehicle trip rate that falls within one standard deviation of the mean provided by ITE.	TGS_{RATE} (20.8) does not fall within one standard deviation ITE_{RATE} (31.0 - 73.8)	**TGS_{RATE} (4.9) falls within one standard deviation ITE_{RATE} (3.3 - 19.4)**	**TGS_{RATE} (12.3) falls within one standard deviation ITE_{RATE} (2.0 - 20.3)**
2.A.) At least one study site has a rate that falls above the ITE weighted average or equation, and one that falls below; OR	0 locations fall above, 26 location fall below	0 locations fall above, 13 locations fall below	**17 locations fall above, 22 locations fall below**
2.B.) All study locations fall within 15% of the ITE average rate or equation. ($(TGS_{RATE} - ITE_{RATE}) / ITE_{RATE}$) < ±15%	1 of 26 location falls within 15%	0 of 13 locations fall within 15%	7 of 39 locations fall within 15%
3.) Locally collected studies fall within the scatter of rates provided by ITE	Appear slightly below	Appear below	**Appear within scatter**
4.) "Common sense" indicates appropriate use of ITE rates for location application.	Vague	Vague	Vague
Conclusion	Local rate or adjustment is recommended.	Local rate or adjustment is recommended.	Use of ITE methods may be appropriate.

Note: bold indicates a met criterion

4.3 LOCAL ITE RATE ADJUSTMENT FOR URBAN CONTEXT

In this section, we introduce a method to estimate an adjustment to ITE vehicle rates for the land uses: high-turnover (sit-down) restaurants (LU 932), convenience markets (LU 851), and drinking places (LU 925) based upon urban context. Using ordinary least squares regression, we have estimated several models of the adjustments to ITE rates (for the weekday, PM peak hour of the facility) using a variety of model specifications with a number of built environment measures and controlling for land use type. The model with the best performance is shown in Equation 4-2 below and makes use of the Context Tool Urban Living Infrastructure (ULI) Indicator as a proxy for context (see Section 3.4 for a complete discussion of ULI).

ULI is a measure of local access to a number of retail and service establishments that accommodate a variety of non-work activities. This measure is highly correlated with other built environment attributes also known to be associated with higher rates of non-automobile travel, such as measures of density, street configuration, block size, bicycle and pedestrian networks and transit service. However, many of these measures are correlated with one another and cannot be used together in a single model. Thus, in this preferred model, ULI serves as a proxy for these other built environment characteristics, yet provides a simple and straightforward method for adjusting ITE trip rates for different urban contexts. See the following section (4.4) for a detailed discussion of these other built environment measures and their relative contributions to vehicle trip rates, as they are also important to consider for planning and policy.

The difference in the ITE vehicle trip rate for convenience markets is nearly five times larger than those for high-turnover restaurants and drinking places. Additionally, the average TGS vehicle trip rate for drinking places is significantly lower than the ITE vehicle trip rate and the average TGS trip rate for restaurants is higher than the provided ITE vehicle trip rate (see Table 4-2 for more details). However, the sample size for each land use is too small to develop a segmented model, and so we estimate a pooled model that uses binary variables to indicate the land use type.

The model below predicts the difference between ITE vehicle trip rates and TGS vehicle trip rates, or the local adjustment *to* ITE trip rates for the weekday PM peak hour of the facility.[14] The model fit as indicated by Adjusted R^2 is 0.763. Note that drinking places are the base case for the model; if calculating the adjustment to a drinking establishment, set values for restaurant and convenience variables to zero.

From the model coefficients, the land use indicators contribute more to the adjustment than the ULI variable representing context. However, once land use is controlled for, significant differences in trip generation can be attributed to context.

Using this model, we can see the range of possible adjustments for different contexts. For example, in locations with an average ULI of 1.0 (the lower bound of ULI), the ITE trip rate for restaurants should not be increased more than 4.7[15], resulting in a new vehicle trip rate of 15.2

[14] Drinking establishments are the base case for this model, so the "Restaurant" and "Convenience" terms equal zero if calculating an adjustment to a drinking place. Significance level for Restaurant is at 99%, Convenience at 99.9%, ULI at 98%.

[15] Computed from Equation 4-2, 0.643 – 3.29 * (1.0) + 7.41 * (1) – 26.04 * (0) = 4.7

vehicle trips (per PM peak hour, per 1,000 square feet of gross floor area). The adjustment to convenience markets in the same area (with average ULI of 1.0) would be a reduction of 28.7 to the ITE trip rate[16]; when applied to the ITE trip rate this results in 23.7 vehicle trips per hour per 1,000 sq. ft. (a 45% reduction from the ITE vehicle trip rate). The adjustment to drinking places in the same area (average ULI = 1.0) is a reduction of 2.6 to the ITE trip rate[17]; the resulting trip rate is 8.7 vehicle trips per hour per 1,000 sq. ft. (a 77% reduction from ITE).

Equation 4-2. ITE Vehicle Trip Rate Adjustment Model

Note: Drinking places are the base case for the model. To calculate adjustments to drinking places, set the values for ***Restaurant*** and ***Convenience*** to zero.

Table 4-4 and Figure 4-5 provide some additional guidance on the range of observed values for which this equation is valid. Table 4-4 shows the ranges observed in this study. Figure 4-5 illustrates the results of Equation 4-2 plotted for each of the three land uses (see Appendix F for more detail).

Table 4-4. Range of Observed Values in Data Used for Model Estimation

ITE Land Use and Code		Average ULI Score	Establishment Size (sq. ft.)	Estimated Vehicle Trip Rate (trips per 1000 sq. ft. per hour)
851	Convenience Market (Open 24-hours)	1.10 – 3.29	2,100 – 3,334	7.1 – 49.7
925	Drinking Place	1.25 – 3.27	1,340 – 10,200	1.0 – 8.5
932	High Turnover (Sit-Down) Restaurant	1.02 – 4.20	650 – 4,500	0.5 – 29.0

[16] Computed from Equation 4-2, 0.643 – 3.29 * (1.0) + 7.41 * (0) – 26.04 * (1) = -28.7
[17] Computed from Equation 4-2, 0.643 – 3.29 * (1.0) + 7.41 * (0) – 26.04 * (0) = -2.6

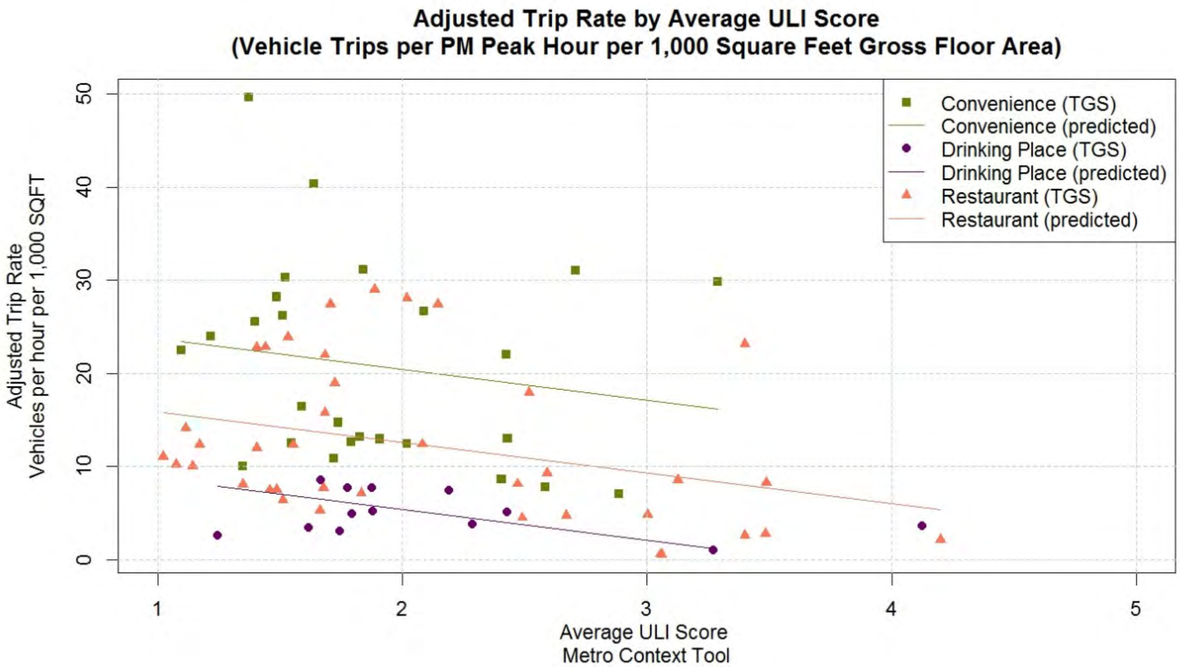

Figure 4-5. Adjusted Trip Rate by Average ULI Score[18]

4.4 IMPLICATIONS IN PLANNING & POLICY

The model shown in Equation 4-2 is based on the ULI variable from the Metro Context Tool. It is important to note that ULI is highly correlated with many other built environment measures and may not be directly sensitive to policy. In this section, we relate ULI to several additional built environment variables. Understanding these relationships is useful since ULI may not always be the most sensitive built environment measure for policy decisions. If planners seek to make long-term changes to neighborhoods, this section will help identify important characteristics associated with lower automobile mode shares, based upon our findings.

Table 4-5 shows a list of the built environment measures highly correlated with ULI and their respective model performance in an ordinary least squares regression model predicting an adjustment to the ITE vehicle trip rates. Each row in this table represented a separate regression considered; the first row is the identical model presented in Equation 4-2. Each model considered contains the same two land use measures to identify whether the establishment is a restaurant or convenience market and one built environment measure representing context. Drinking places are the base case for each model.

[18] Vehicle trip rate is measured in vehicle trip ends (entering and exiting) per PM peak hour per 1,000 square feet of gross floor area

Table 4-5. ITE Rate Adjustment Models Using Built Environment Measures

Built Environment Measure (units)	Correlation with ULI	Adjusted R^2	Model Variable Coefficient	Convenience Market Coefficient	Restaurant Coefficient	Intercept Coefficient
Average ULI (unitless)		0.763	-3.29**	-26.04***	7.41***	0.64
Number of Transit Corridors (count)	0.78	0.767	-0.09***	-25.48***	7.62***	-4.31*
People Density (residents and employees per acre)	0.89	0.766	-0.07***	-26.19***	7.24***	-3.41
Number of High-Frequency Bus Routes (count)	0.84	0.766	-0.05***	-26.07***	7.19***	-3.62
Employment Density (employees per acre)	0.84	0.764	-0.08**	-26.13***	7.16***	-4.24*
Lot Coverage (%)	0.92	0.760	-0.17**	-26.60***	6.97**	-0.86
Length of Bike Facilities (mi.)	0.86	0.760	-0.79**	-26.24***	7.55***	-0.75
Rail Access (binary)	0.47	0.756	-3.99**	-24.31***	8.09***	-5.19**
Intersection Density (number per 1,000,000 sq. ft.)	0.77	0.755	-0.57*	-26.77***	6.65**	-0.85
Median Block Perimeter (mi.)	-0.41	0.750	1.33	-26.21***	6.93**	-8.59***

***p-value ≤ 0.01
** p-value ≤ 0.05
*p-value ≤ 0.10

The land use measures are highly significant in all models, indicating that identifying land use type in this pooled model structure is very important when determining an adjustment to ITE vehicle trip rates. However, predicting an ITE vehicle trip rate adjustment based on land use type indicators alone is not very sensitive to planning or evaluations of policy. Therefore, the additional independent variables are investigated individually to identify potential influences of the built environment on travel behavior.

All of the models shown in the table have good statistical fit (adjusted $R^2 > 0.75$). Four models perform better than the ULI model (Number of transit corridors, people density, number of high-frequency bus routes, and employment density), but ULI was selected because it is a more robust measure of the overall built environment than any of the other independent contextual variables and has more explanatory power while remaining significant. For example, the Number of Transit Corridors model has an adjusted R^2 of 0.767, higher than that of the ULI model at 0.763. But in application, adding one transit corridor within the half-mile establishment buffer equates to a trip rate adjustment of -0.1 vehicle trips per 1000 sq. ft. per hour for a drinking place. An increase of average ULI from 1.0 to 2.0 provides an adjustment of -3.3 vehicle trips per 1,000 sq. ft. per hour for a drinking place. Therefore, we choose ULI as the more useful model. Increasing the number of transit corridors in an area has less of an effect on ITE rates (per unit increase) than increasing the average ULI does.

Examining the underlying data comprising the Metro Context Tool ULI Indicator shows that as the ULI scores increase, densities of retail and service establishments also increase (see Table 4-6). Additionally, Table 4-6 shows that the ranges of densities increase along with ULI. This means that the ability to increase a ULI score by *one unit* is easier to achieve in suburban areas with ULI scores of 1 or 2 than in more urban areas of ULI 4 or 5.

Table 4-6. Retail and Service Establishment Densities Associated with ULI Index

ULI Index	Density of Establishments associated with ULI			Range
1	0.0	-	0.2	0.2
2	0.2	-	0.9	0.7
3	0.9	-	2.1	1.2
4	2.1	-	5.4	3.3
5	5.5	-	12.6	7.1

Comparing the ULI index with other built environment measures is useful in order to relate these findings to planning and policy decisions. Table 4-7 summarizes measures of the built environment that are associated with ULI. All measures in the table are correlated with ULI (Pearson's correlation of greater than 0.4; bold measures have a correlation of greater than 0.6). For an average ULI index value calculated within an establishment buffer, this table shows the associated mean values of other built environment attributes found in the same buffer.

Table 4-7. Built Environment Measures Correlated with Observed Average ULI Score

Built Environment Measure	Average ULI Score									
	1 - 1.99 N = 47		**2 - 2.99 N = 19**		**3 - 3.99 N = 10**		**4 - 4.99 N = 2**		**ALL N = 78**	
	Mean	*S.D.*	Mean	*S.D.*	Mean	*S.D.*	Mean	*S.D.*	Mean	*S.D.*
Number of Transit Corridors (count)	9	*6*	26	*29*	72	*35*	98	*11*	24	*31*
People Density (residents and employees per acre)	16	*6*	38	*24*	90	*25*	158	*9*	34	*35*
Number of High-Frequency Transit Routes (count)	19	*15*	58	*39*	125	*51*	200	*63*	47	*52*
Employment Density (employees per acre)	6	*6*	24	*22*	66	*25*	37	*5*	21	*31*
Lot Coverage (%)	20%	*6%*	33%	*6%*	50%	*8%*	66%	*2%*	28%	*13%*
Length of Bike Facilities (mi.)	5.2	*1.5*	7.3	*2.3*	11.3	*0.8*	13.3	*0.6*	6.7	*2.8*
Access to Rail Station (binary)	30%	*46%*	53%	*51%*	90%	*32%*	100%	*0%*	45%	*50%*
Intersection Density (number per 1,000,000 sq. ft.)	6	*3*	10	*2*	12	*1*	14	*0.3*	8	*3*
Median Block Perimeter (mi.)	2.5	*1.2*	1.6	*0.4*	1.6	*0.4*	1.5	*0.0*	2.1	*1.1*

Note: **Bold** measures are highly correlated with ULI (Pearson’s correlation > 0.6).

5.0 DISCUSSION

The documentation of the findings and methodology provided here can aid local communities assess the transportation impacts of new development as well as planning for the desired transportation demand outcomes over the long term for commercial centers, corridors and transit oriented development. Results from this study reveal a trend: for all land uses tested here, vehicle trip rates decrease as neighborhood types become more urban. Specifically, findings strongly support the need for a local adjustment for both convenience markets and drinking places. High-turnover restaurants appear to be better aligned with the ITE rates, but a vehicle trip rate adjustment is recommended to better match locally observed travel patterns.

The method developed in this study to adjust ITE trip rates for convenience markets, restaurants and bars for weekday evening peak hour of the facility is simple and straightforward to apply in the Portland metropolitan area. It relies on one built environment measure – the Urban Living Infrastructure (ULI) – representing the density and diversity of retail and service establishments that support daily activities. This measure is available for current conditions for all communities in the region. The estimated model performs well with a good statistical fit. This finding is consistent with a study that showed increasing shares of non-motorized travel as the density of discretionary businesses increases (Guo, Bhat and Copperman 2007).

ULI can also be related to a variety of policy-relevant built environment characteristics, such as density and intensity of development, transportation system attributes, and urban design features. Thus, the study findings can be used not only for transportation impact assessments for new development but also to guide planning decisions to better achieve the desired travel patterns in an area over the long term.

Despite these conclusions, the study has some limitations that impact its applicability. More research is needed in order to broaden the types of land uses considered and to strengthen the conclusions. The remainder of this section discusses the aspects of the study that limit our findings and set the agenda for future work.

5.1 LIMITATIONS

The greatest limitation of this study is the number of establishments and the few types of land uses studied. ITE requires only three or four points to develop a rate for a land use (Institute of Transportation Engineers 2004, 20-21), and in that respect, this study exceeds the standards of sample size set forth by ITE. In this analysis, however, the aim was to provide a robust method for contextual adjustments and establishment sample size for each type of land use did not allow for separate models to be developed. With a greater number of establishments, segmented models could be estimated for each land use type. In addition, larger numbers would allow for statistical testing of the impacts of more built environment variables on trip generation, including those site-level attributes such as parking, building orientation, bicycle parking and pedestrian circulation, and the location of transit stops.

Three land use types were included in the research design. ITE Trip Generation includes 162 land use classifications. Including more land uses is imperative to understanding how urban context influences vehicle generation as different land uses within the same urban context are likely to have varying mode shares. A large scale study of a magnitude rivaling ITE Trip Generation would be cost prohibitive. But including more land uses in future studies, particularly those commonly found in mixed use, infill, transit oriented developments, historic downtowns and other smart growth projects, would greatly address the practical needs of planning for appropriate travel demand.

While the ULI measure used here can be replicated, it is not a measure that is readily available outside of the Metro region. Although we have related the ULI to other built environment attributes that can be easily constructed for other communities, the model cannot be directly applied without the ULI measure. Thus, for the time being, our approach is limited in its applicability to the Portland metropolitan area.

There were a few issues that impacted our data collection. First, the urban nature of many sites restricted the ability to count vehicles entering and exiting the sites. On-site parking lots are less common in urban areas and it is difficult to determine the extent of on-street parking that serves a particular establishment. In shared parking lots, it is difficult to count vehicles and attribute them to specific establishments.

The characteristics of survey respondents were similar to the demographics of the region as a whole; however, there may be response bias in the survey based upon mode of travel. It is possible that people who drive or take transit were less willing to complete the survey. Similarly, customers who have a larger group size (greater vehicle occupancy) may also be less likely to respond.

We controlled for the weather in this study by only collecting data on fair days without precipitation. The data collection period ranged from June to October, when conditions were most favorable for the use of alternative modes. Thus, the study observed non-automobile mode shares at their peak. These shares likely decline in other times of year when temperatures are low and rain is common. However, we have no basis for estimating the degree to which modes shift by season.

5.2 FUTURE WORK

There are several issues that merit consideration in the near term. This section discusses plans for addressing additions to the project that would benefit our understanding of the contextual influences of trip generation.

5.2.1 Validation

The method developed in this study will be validated using vehicle count data collected from additional sites in the Portland metropolitan region. Establishments of the same land use types from varying contexts have been selected. This process is underway. Sample sizes for validation are supplied in Table 5-1 below. Validation will be included in a supplementary chapter.

Table 5-1. Validation Sample Size by Land Use Type

ITE Land Use and Code	Sample Size
851 – Convenience Market (Open 24-hours)	18
925 – Drinking Place	6
932 – High-Turnover (Sit-Down) Restaurant	13

5.2.2 Additional Land Uses

We recognize the limitations of just three land use types studied in this project. Incorporating additional land uses in developing is critical to implementing accurate vehicle trip rate adjustments to the region. The following list documents potential ITE land uses (LU) for future data collection and analysis:

- Supermarket (ITE LU 850)
- Coffee/Donut Shops with or without Drive-Through Windows (ITE LU 936 – 938)
- Bread/Donut/Bagel Shops with or without Drive Through Windows (ITE LU 939 – 940)
- Banks, Walk-in and Drive-in (ITE LU 911 – 912)
- Pharmacy/Drugstore with or without Drive-Through Window (ITE LU 880 – 881)
- Apartments and Townhouses (ITE LU 220 – 224)

Data from a large supermarket chain in the Portland area are currently being gathered. The adjustment method will be tested and validated on this land use. This analysis will also be incorporated into a supplementary chapter to this report.

5.2.3 Micro-scale Analysis

The study relies heavily upon the Metro Context Tool ULI Indicator (retail density and diversity), but many other built environment factors interact to make places with high levels of non-automobile travel. Understanding the relationships between micro-scale or site-level characteristics and travel behavior is important. Site-level attributes include things such as vehicle and bicycle parking supply, sidewalk width, circulation patterns and building orientation. These micro-scale built environment characteristics were observed at the study locations of this project. Next steps are to qualitatively understand how they impact mode shares. Here matched pairs of establishments of similar land use, size and context but with different levels of vehicular trips will be compared to understand more about how these fine-grain site details contribute to our findings. This site-level analysis may provide a better understanding of travel characteristics and could potentially enhance vehicle trip rate adjustments and policy and investment choices to reduce trips and vehicle miles traveled.

Another built environment measure that is critical to understanding vehicle trip generation is parking supply. To address the question, at least in part, will require analysis of the parking data collected in this study. Here, we need to allocate parking supply in mixed use developments to the individual establishments therein. Parking will then be tested in both the statistical models and the qualitative site analysis to understand its role. The micro-scale analysis will also be incorporated into a supplementary chapter to this report.

5.2.4 Transferability

A universally applicable method to adjust ITE rates would facilitate effective planning for current and future smart growth. We hope to evaluate the transferability of our findings to communities in locations beyond the Portland, Oregon region. The issues identified with ITE trip generation rates persist across the United States; however, it is not clear that our findings are valid for locations beyond our study area. Therefore, to broaden the range of influence of our approach, another proposed project includes a cross-validation exercise with an ongoing study in California, sponsored by CalTrans and conducted by the University of California at Davis. Here we aim to test our methodology on data collected in sites in California and vice versa. The opportunity also exists to pool our data to increase our sample size and develop an alternative approach.

APPENDIX A. LONG SURVEY

Question	Text To Read to Respondent	Answers
Q55. Age	*What best describes your AGE?*	[ ] under 18, [ ] 18-24, [ ] 25-34, [ ] 35-44, [ ] 45-54, [ ] 55-64, [ ] 65-74, [ ] 75 and over
Q52. HH	*Please provide the following information for your household:* *Number of Adults*	[ ] 0, [ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5 or more
	Number of Children	[ ] 0, [ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5 or more
	Number of Automobiles	[ ] 0, [ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5 or more
	Number of people with BICYCLES	[ ] 0, [ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5 or more
	Number of Transit Passes	[ ] 0, [ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5 or more
Q57. Decision	*When did you decide that you would visit [LOCATION]?*	[ ] passing by, [ ] after leaving home, [ ] today before leaving home, [ ] yesterday, [ ] before yesterday, [ ] do not know
Q2. Origin	*We would like to ask you some questions about your travel here today, Can you tell me the nearest intersection or address from where you came from?*	____ ____ ____
Q30. Beginning of Day	*Is this the place where you began your day?*	[ ] yes, [ ] no
Q3. Origin Type	*The best description of this location is one of the following:*	[ ] Home, [ ] Work, [ ] School, [ ]Restaurant, [ ] Coffee shop, [ ] Service errand, [ ] Other: ___________________
Q8. Origin Mode	*How did you travel to [establishment]?* **Explain that we want travel modes in the order used. Remind respondent for walk trips if >1 block.**	
	Segment 1: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
	Segment 2: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
	Segment 3: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
	Segment 4: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
	Segment 5: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
	Segment 6: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
Q9-Q14. Veh Occ	**IF VEHICLE CHOSEN:** *For trip segment [#], how many people were in the vehicle?*	[ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5 or more
Q58. Parking cost	**IF VEHICLE CHOSEN:** *How much did you pay for PARKING in traveling to [LOCATION]? (Enter zero if you have a parking pass)*	$_________

Question	Text To Read to Respondent	Answers
Q60. Transit Cost	**IF TRANSIT CHOSEN:** *How did you pay for your public transportation in travelling to [LOCATION] today?*	[ ] cash only, [ ] ticket at kiosk, [ ] transit pass, [ ] free zone
Q63. Mode Attitudes	*Now, we will ask you about your attitudes towards different transportation options in traveling to [LOCATION]. Please evaluate the following on a scale from 1 (strongly disagree) to 5 (strongly agree), even if you do not use these modes:*	
	Car parking here is easy and convenient	[ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5
	Bike parking here is easy and convenient	[ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5
	Biking here is safe and comfortable	[ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5
	Walking here is safe and comfortable	[ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5
	Taking transit here is convenient	[ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5
Q38. Shopping frequency	*In order to understand more about why you came here, we will ask a few questions about your consumer habits. Can you tell me how frequently you come here?*	[ ] rarely, [ ] once a month, [ ] a few times per month, [ ] once a week, [ ] a few times a week, [ ] daily
Q62. Time spent	*Could you tell me the approximate amount of TIME you spent here at [LOCATION]*	________ Minutes
Q39. Money spent	*Could you tell me the approximate amount of money you spent here at [LOCATION]?*	$_________
Q53. Group size	*How many people in your group did this purchase pay for?*	[ ] 1, [ ] 2, [ ] 3, [ ] 4, [ ] 5 or more
Q31. Destination location	*We are going to ask you a series of questions about where you will be going after [Location]. Can you tell me the nearest intersection or address you will be going NEXT?*	________________________ ________________________ __ ________________________ ________________________ __ ________________________ ________________________ __
Q32. Destination type	*The best description of this location is one of the following:*	[ ] Home, [ ] Work, [ ] School, [ ]Restaurant, [ ] Coffee shop, [ ] Service errand, [ ] Other: ___________________
Q8*. Destination mode	*How will you travel to the next location from here?* **Explain that we want travel modes in the order used. Remind respondent for walk trips if >1 block.**	
	Segment 1: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
	Segment 2: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
	Segment 3: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	

Question	Text To Read to Respondent	Answers
	Segment 4: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
	Segment 5: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
	Segment 6: [ ] Walk, [ ] Bicycle, [ ] MAX/WES, [ ] Bus, [ ] Streetcar, [ ] Vehicle-driver, [ ]Vehicle-passenger, [ ] Other:_______________	
Q36. Home location	**IF HOME NOT ALREADY GIVEN IN ORIGIN/DESTINATION QUESTIONS:** *Can you tell me the nearest intersection or address for your HOME?*	________________________ ________________________ ________________________
Q37. Work location	**IF WORK NOT ALREADY GIVEN IN ORIGIN/DESTINATION QUESTIONS** *Can you tell me the nearest intersection or address for your WORK?*	________________________ ________________________ ________________________
Q54. Limitations	*Do you have any medical limitations that prevent you from walking, bicycling or driving?*	[ ] yes, [ ] no
Q56. HH Income	*What best describes your total annual HOUSEHOLD INCOME?*	[ ] less than $25,000, [ ]$25K - $49,999, [ ] $50K - $99,999, [ ] $100K - $149,999, [ ] $150K - $199,999, [ ] $200K or more
Q40. Gender	*What gender do you most identify with?*	[ ] male, [ ] female
Q71. Follow up	*Finally, would you like to participate in follow-up research about travel & consumer choices?*	Name:__________________ Phone/email: ________________________
END	*We appreciate your time in completing this survey. Thank you, and have a great day!*	

APPENDIX B. SHORT SURVEY

Contextual Influences on Trip Generation Survey II
Location: ____________________
Date: ________________

Thank you for taking this 30 second survey about your travel choices and consumer behavior. The information you provide will inform Portland State University research about transportation, environment and behavior. Your participation in this study is voluntary, your information will be kept confidential and you can opt out at any time. (Circle M for male respondents and F for Female respondents.)

Questions:

1. How did you get here? (multiple modes allowed)

    (Walk; Bicycle; MAX/WES; Bus; Streetcar; Vehicle driver; Vehicle passenger; Other--write in)

2. Can you tell me the nearest intersection or address to/of your home?

3. Can you tell me how frequently you come to this plaid pantry?

    (Rarely; Once / month; A few times / month; Once / week; A few times / week; Daily)

4. Could you tell me the approximate amount of money you spent here during this visit?

APPENDIX C. DATA COLLECTION FORMS

Person Count Tally Sheet				
Date:				
Location:				
Name of Counter:				
	Male		**Female**	
	Entering	**Exiting**	**Entering**	**Exiting**
0:00 – 0:14				
0:15 – 0:29				
0:30 – 0:44				
0:45 – 0:59				
1:00 – 1:14				
1:15 – 1:29				
1:30 – 1:44				
1:45 – 1:59				
Data entered Date: **Data entry name:**				

Automobile/Bicycle Exit Tally Sheet		
Date:		
Location:		
Name of Counter:		
(For customers observed exiting establishment.)	**Automobiles Exiting**	**Bikes Exiting**
Feasible to count at this location ? Please mark NO if no counts are taken.	**YES or NO**	**YES or NO**
If no, please explain:		
# of Parking Spaces		
0:00 – 0:14		
0:15 – 0:29		
0:30 – 0:44		
0:45 – 0:59		
1:00 – 1:14		
1:15 – 1:29		
1:30 – 1:44		
1:45 – 1:59		
Data entered Date: **Data entry name:**		

<table>
<tr><th colspan="3">Site Data Collection Sheet</th></tr>
<tr><td>Date*:</td><td colspan="2"></td></tr>
<tr><td>Location*:</td><td colspan="2"></td></tr>
<tr><td>Team*:</td><td colspan="2"></td></tr>
<tr><td>Weather:</td><td colspan="2"></td></tr>
<tr><td>Entrance Description</td><td colspan="2">❒ Single Entrance
❒ Multiple Entrances (num____)
❒ Shared entrance
❒ Awning present</td></tr>
<tr><td>Description of parking</td><td>Automobiles
❒ On Street unrestricted
❒ On street, restricted
❒ Lot
❒ Garage</td><td>Bikes
❒ Bike Corrals________
❒ Bike Racks_________</td></tr>
<tr><td>Site Amenities</td><td>❒ Drive Through
❒ Awning
❒ Tree Canopy
❒ Benches
❒ Sidewalks
Width ________</td><td>❒ Bio-swales
❒ Pedestrian Refuge
❒ Sidewalk Bump-out
❒ Bus line
❒ Bus Stop</td></tr>
<tr><td>Is there construction present?*</td><td colspan="2"></td></tr>
<tr><td>Other observations about site & customer behavior*</td><td colspan="2"></td></tr>
<tr><td>Pictures Taken</td><td colspan="2">❒ Entrance
❒ Example Auto Parking & Parking Lot
❒ Example Bike Parking
❒ Streetscape
❒ Surveyors in action (Smile!)</td></tr>
<tr><td colspan="3">Data entered Date:
Data entry name:</td></tr>
</table>

APPENDIX D. MODE SHARES

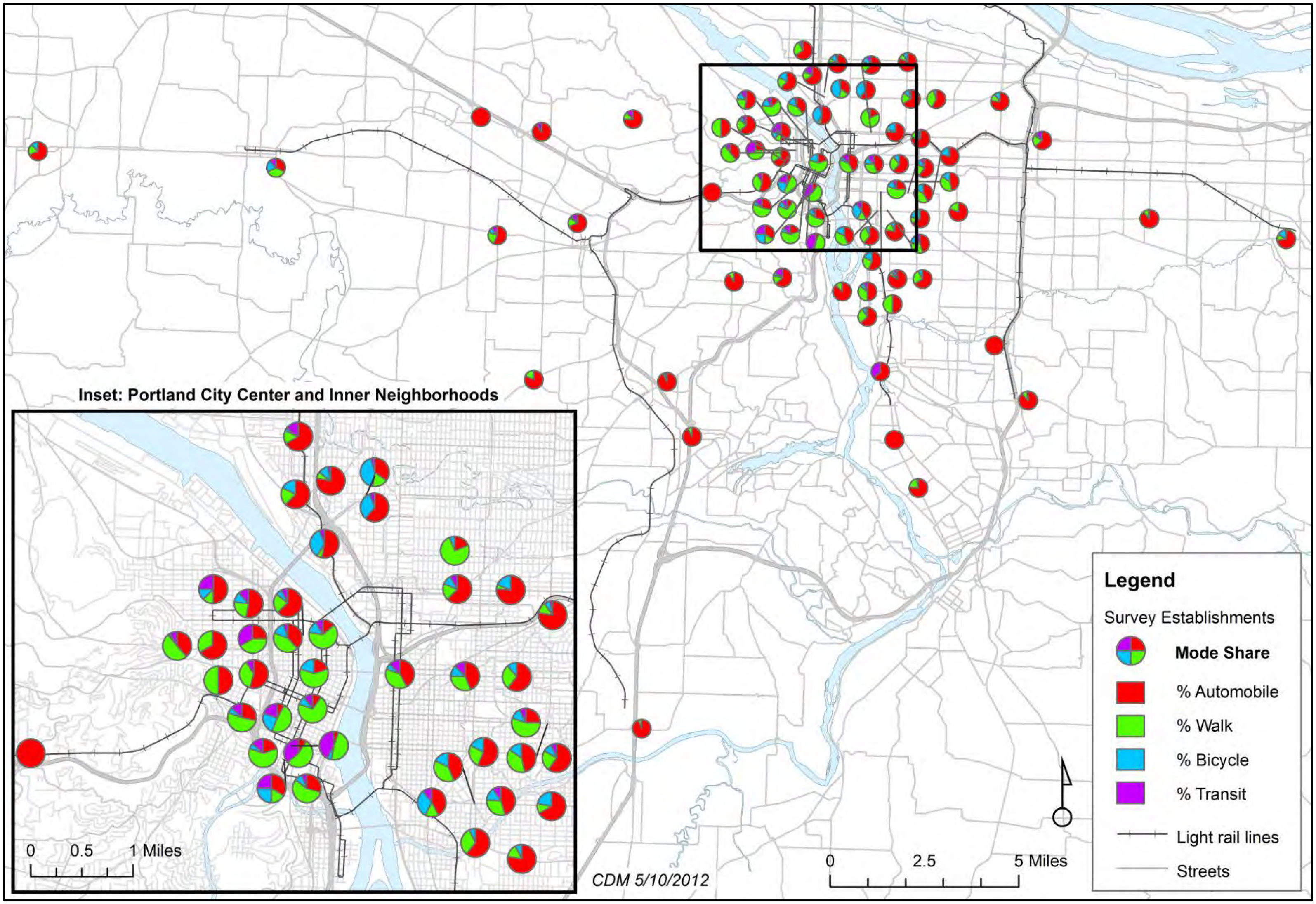

Figure 5-1. Survey Establishment Mode Shares

APPENDIX E. CONVERTING PERSON TRIPS TO VEHICLE TRIPS

Vehicle trip estimation method

To develop a method to adjust ITE vehicle trip rates, we used vehicle trips from our data collection effort. But vehicle trips exiting sites were obtained for just 44 of the 78 establishments studied. Many study sites, especially those in urbanized neighborhoods, contained on-street and complex parking situations and did not allow vehicle counts to be obtained during data collection. We describe the method used to develop vehicle-equivalent trips from person counts and vehicle occupancy.

At all study establishments, person counts entering and exiting the establishment were collected. Both the short-form and long-form survey collected mode choice, and the long-form survey gathered vehicle occupancy data from those who traveled by automobile. Vehicle occupancy was not collected in the short survey. Because vehicle occupancy data were only collected within the long-form survey, it has a smaller sample size. Therefore, for establishments with less than ten observations for vehicle occupancy, average vehicle occupancy observed for that particular land use was used in the vehicle-equivalent trip estimate type (see Table 3-8 and Table 3-9**).**

Vehicle trip estimation method to exiting trips

In Equation 5-1 we estimate vehicle trips exiting establishments.

Equation 5-1. Conversion to vehicle trip equivalents method for exiting trips.

Where: P_{OUT} = Person count existing the establishment,
$\%AUTO$ = Automobile mode share from the long- and short-form surveys,
V_{OCC} = Average vehicle occupancy from the long-form survey,
$VT_{CNTS,OUT}$ = Vehicle trips counted from patrons exiting establishment, and
$VT_{EST,OUT}$ = Vehicle trips estimated from patrons exiting establishment.

Verification of estimation method

Since only exiting vehicle counts were counted at establishments, we test our method by comparing estimated exiting vehicle trips with observed exiting vehicle trips. A plot of estimated exiting vehicle trips is plotted against observed exiting vehicle trips is shown in Figure 5-2. Estimated vehicle trips are close to observed vehicle trips. Ideally, the points would follow the 1:1 unit line plot. The graph shows that results are not very far from the unit line.

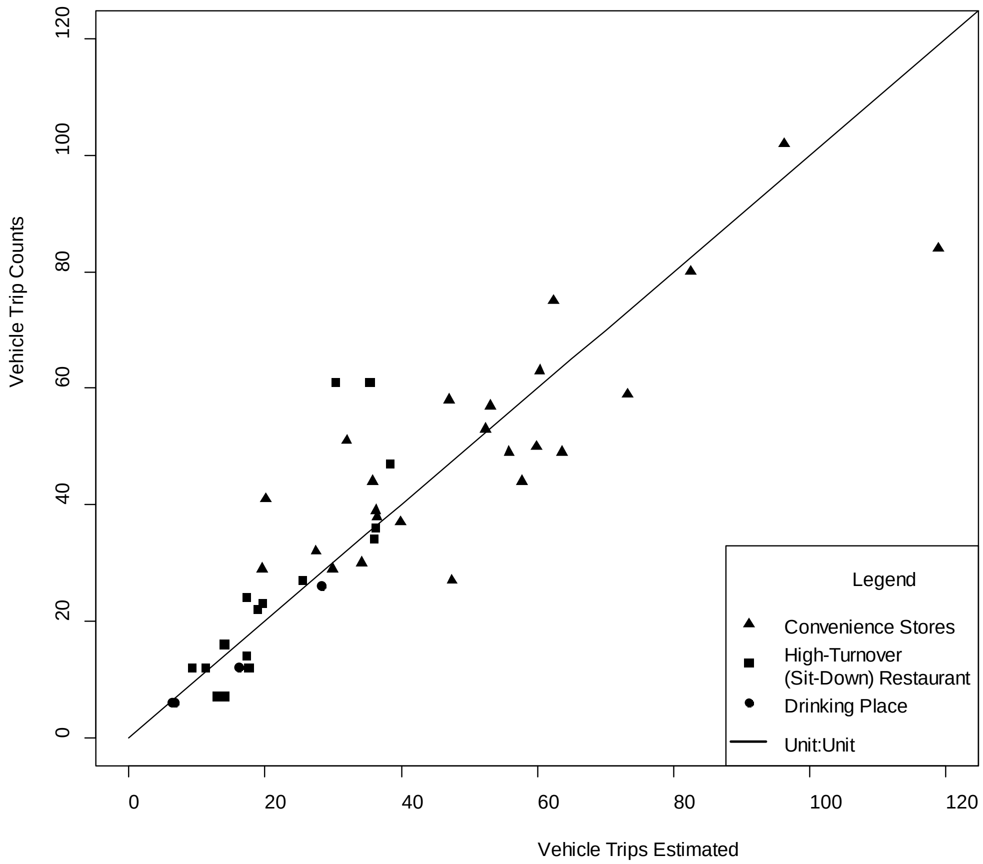

Figure 5-2. Comparison of vehicle trip counts to calculated

Table 5-2. Estimated vehicle trips compared to observed

Type	Mean Square Error	Weighted Average*	Sample Size
All Land Uses	128.3	1.02	44
Convenience Markets	155.9	0.98	24
High-Turnover (Sit-Down) Restaurants	117.4	1.17	16
Drinking Place	6.1	0.87	4

*Weighted averages less than one mean vehicle trips are overestimated (estimated vehicle trips > actual vehicle trips); values greater than one mean vehicle trips are underestimated.

Table 5-2 shows the comparison between estimated exiting vehicle trips and observed exiting vehicle trips. Weighted averages indicate the accuracy of the estimation method (Equation 5-1). Restaurants tend to have underestimated vehicle trips when compared with observed counts (weighted average > 1.0). Drinking places tend to have overestimated vehicle trips, but that may be due to smaller sample size. Overall, the weighted average between observed and estimated vehicle trips for all land uses is very close to 1.0, suggesting that converting person trips to vehicle trips using observed mode share and vehicle occupancy is a valid approach. This method could be applied elsewhere, since estimating vehicle trips in highly urbanized areas is difficult.

APPENDIX F. ADJUSTED VEHICLE TRIP RATE GRAPHICS

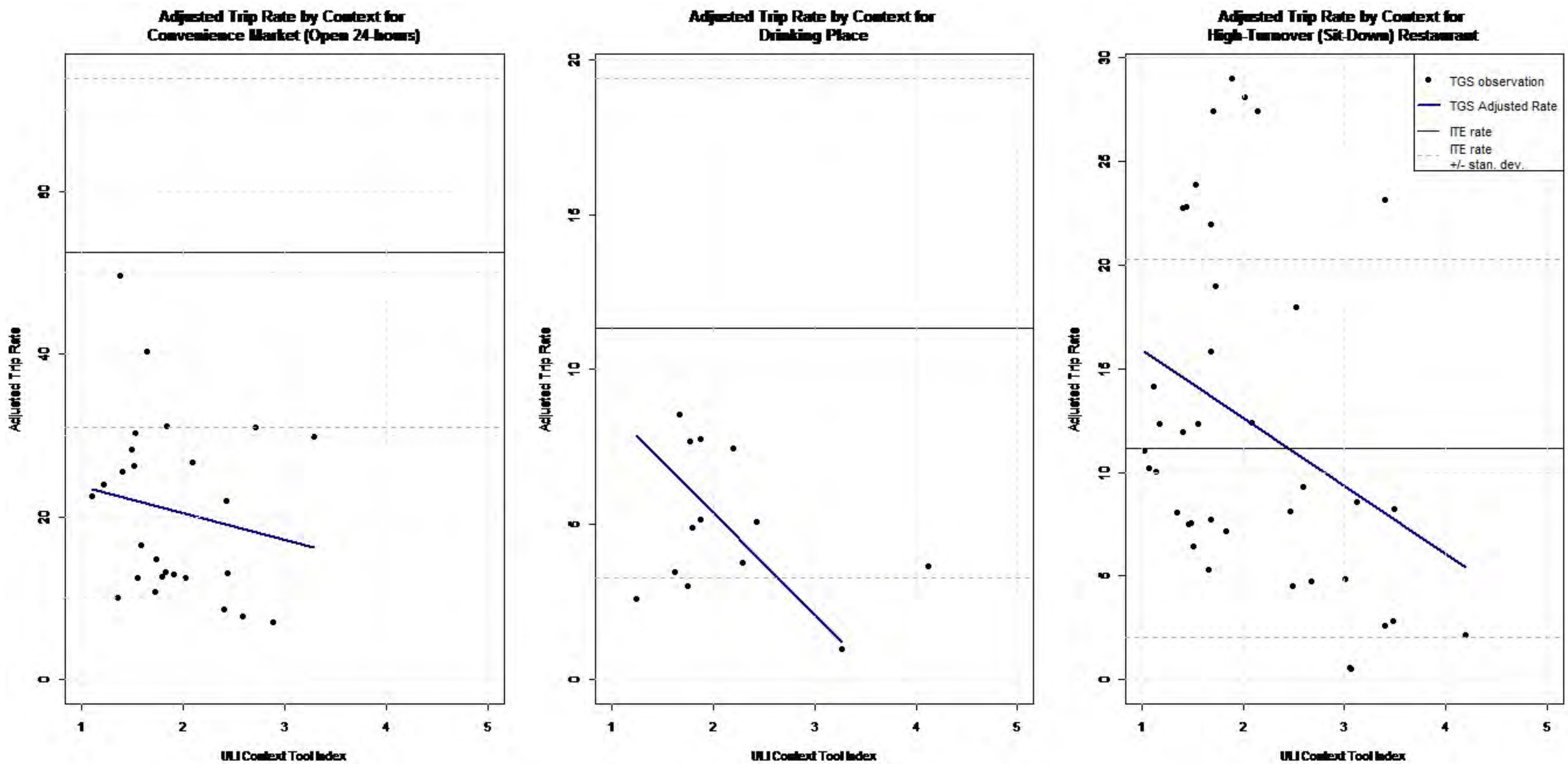

Figure 5-3. Adjusted Vehicle Trip Rate by Average ULI Score and Land Use

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Materials following this page were distributed at the meeting.

Contextual Influences on Trip Generation

MTAC Meeting

06/06/2012

Portland State University

OTREC
OREGON TRANSPORTATION RESEARCH AND EDUCATION CONSORTIUM

Metro

Outline

- Introductions
- Review
  - Goals
  - Methodology
  - Site Selection
  - Data Collection
- Comparison to ITE
- Analysis
- Portland Metro Adjustment
- Implications for Planning and Policy

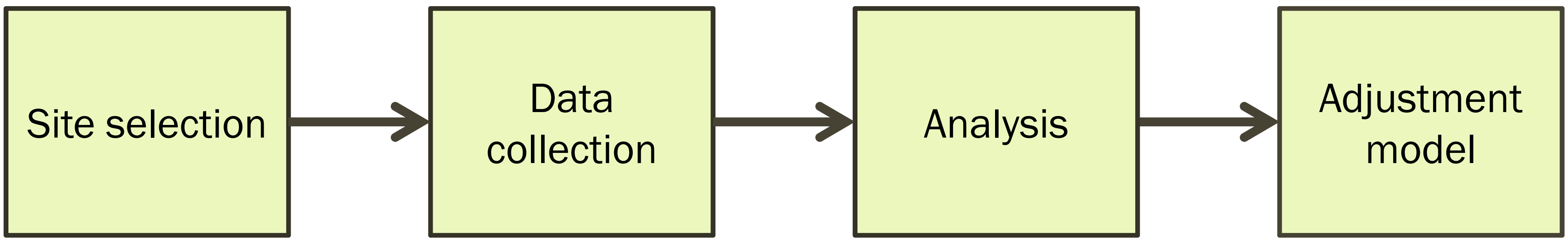
Meet the PSU Team

- Kelly Clifton, PhD
- Kristi Currans
- Chris Muhs
- Sara Morrissey
- Chloe Ritter
- April Cutter
- Myeonwoo Lim
- 12 undergraduate students

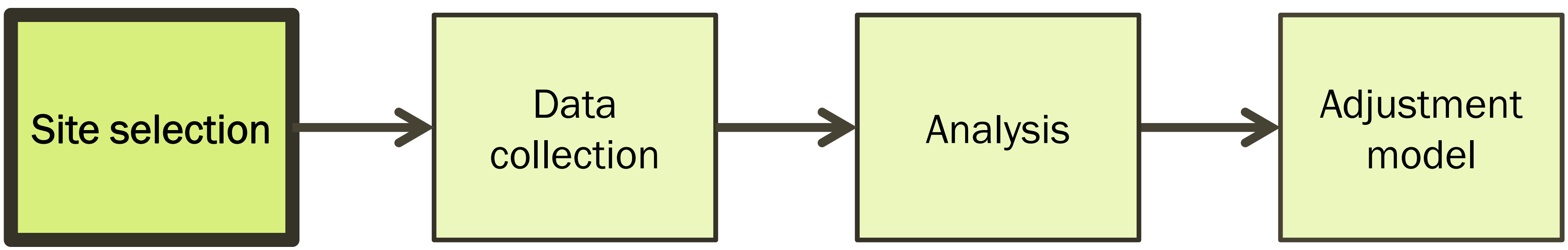
Review: Project Goals

- To understand the influence that context has on trip generation, with emphasis on desired futures;
- Develop a consistent approach to adjusting trip generation rates (ITE) in the Portland metropolitan area; and
- Determine adjustment rates for three specific land uses.

TGS Method Overview

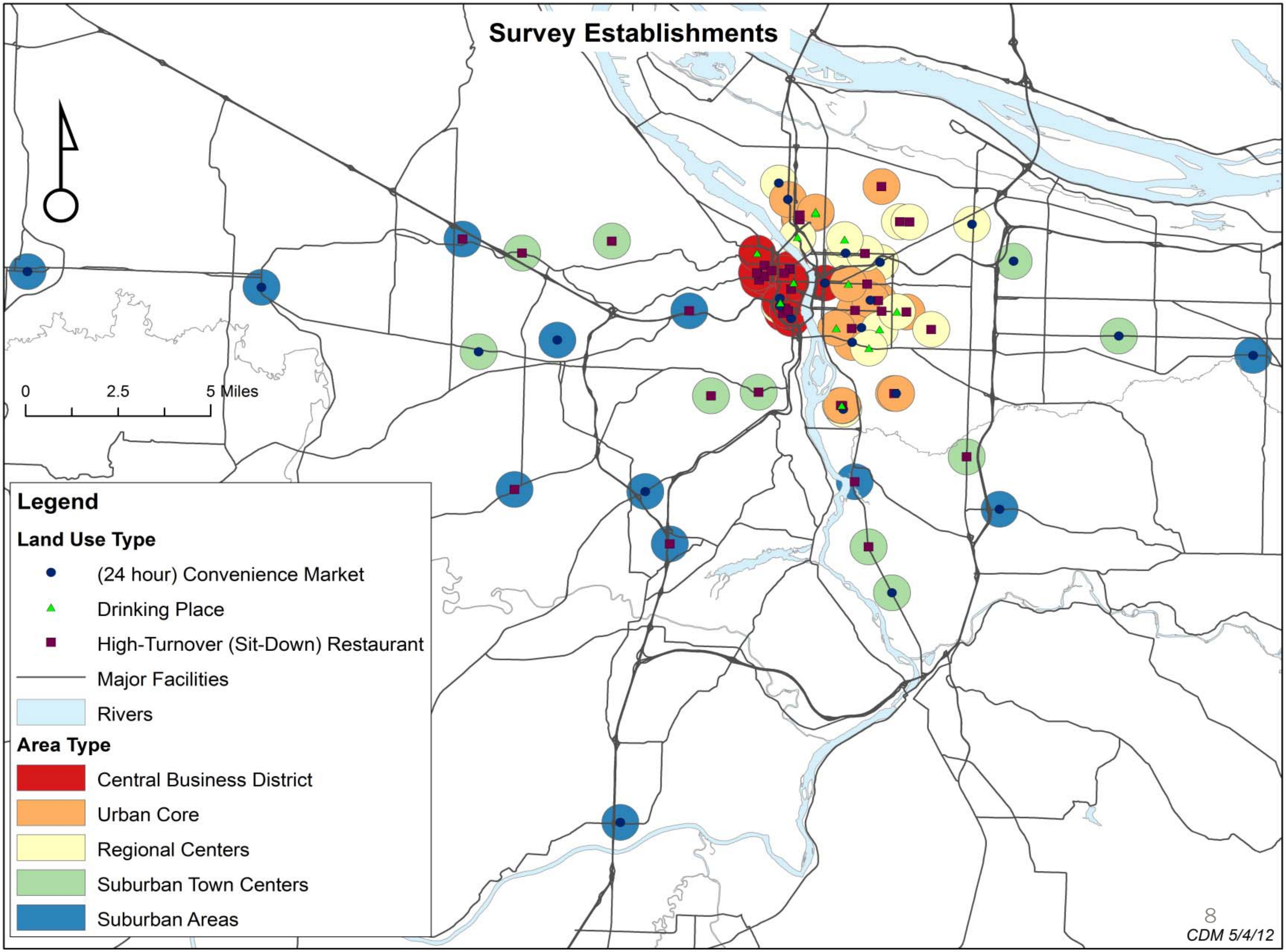


Site Selection



Site Selection

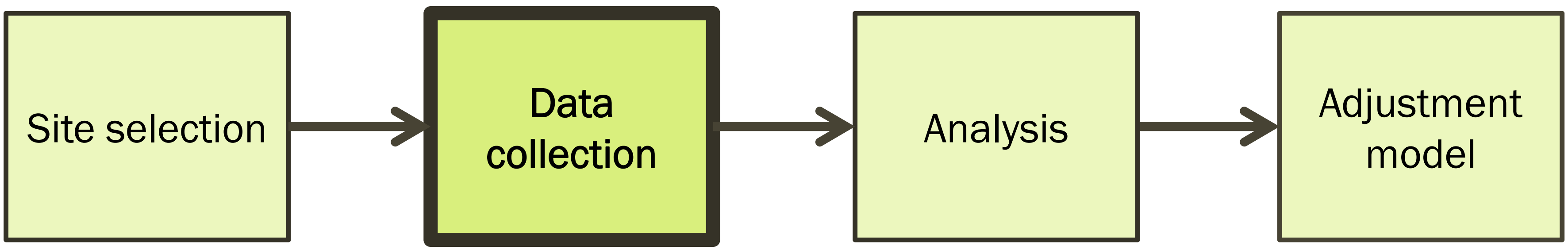
- Common land use types
  - Convenience Market (24-hours) – LU 851
  - High-Turnover (Sit-Down) Restaurant – LU 932
  - Drinking Place – LU 925
- Use built environment to help define area type
- Evening peak hour time period
  - Weekday, PM Peak Hour (5-7PM)
  - Attempt to include some of peak hour of generator (5-7PM) and facility (4–6PM)


Survey Establishments
0
2.5
5 Miles
Legend
Land Use Type
(24 hour) Convenience Market
Drinking Place
High-Turnover (Sit-Down) Restaurant
Major Facilities
Rivers
Area Type
Central Business District
Urban Core
Regional Centers
Suburban Town Centers
Suburban Areas
8
CDM 5/4/12

Location Summary

Area Type	# Restaurant Locations	# Convenience Locations	# Bar Locations	Total
Central Business District	12	4	3	19
Urban Core Neighborhoods	10	5	6	21
Neighborhood and Regional Centers	6	6	4	16
Suburban Town Centers	5	7	0	12
Suburban Areas	6	4	0	10
Total	39	26	13	78

Data Collection



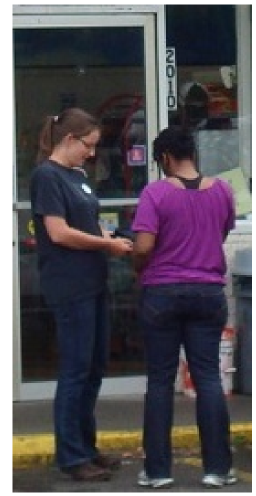
Data Collection

Long-Form Survey (Tablet)
Short-Form Survey

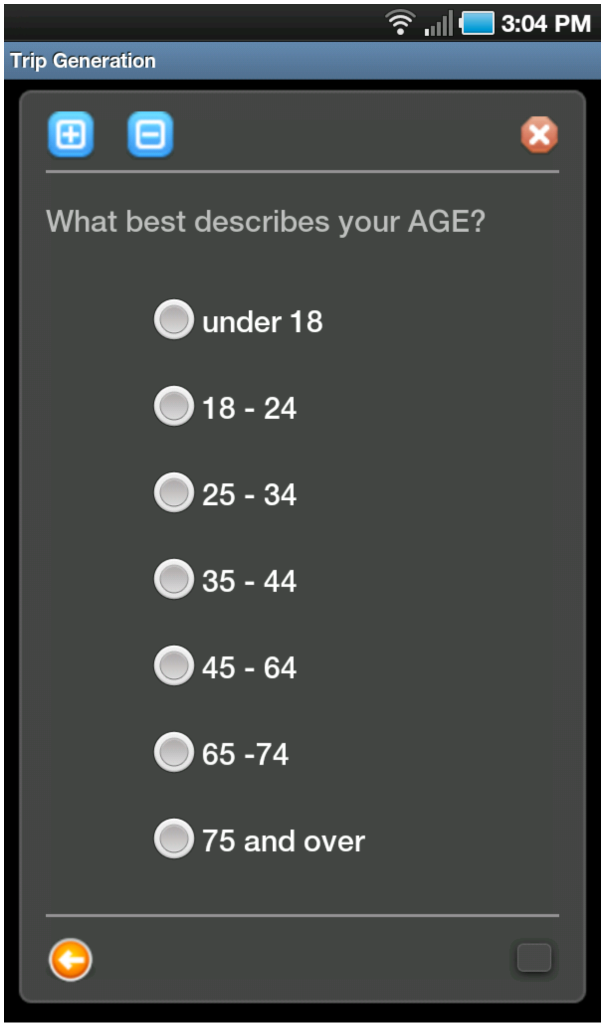
Monday – Thursday
5 – 7PM

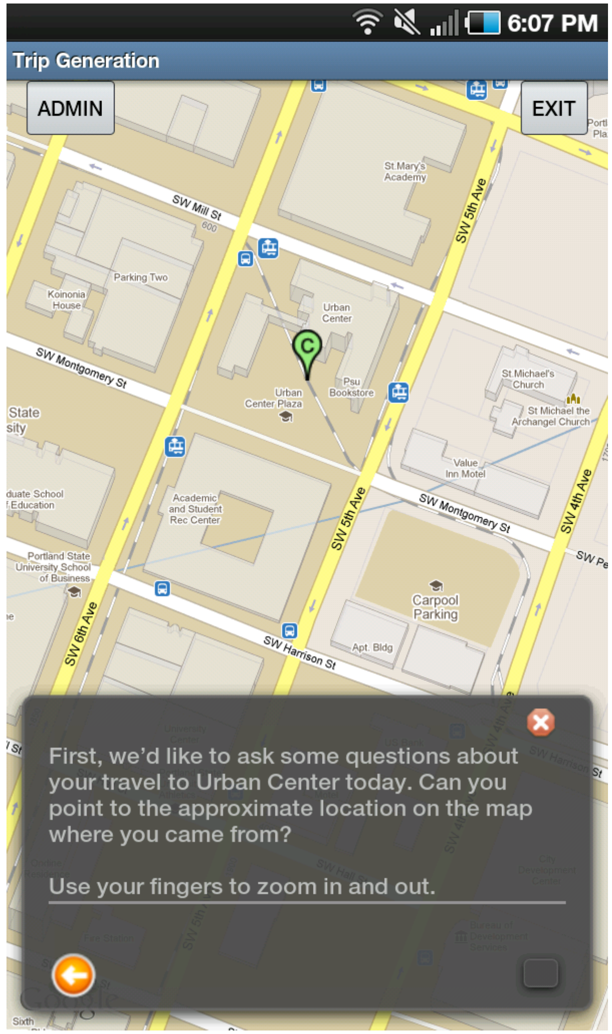
May through October

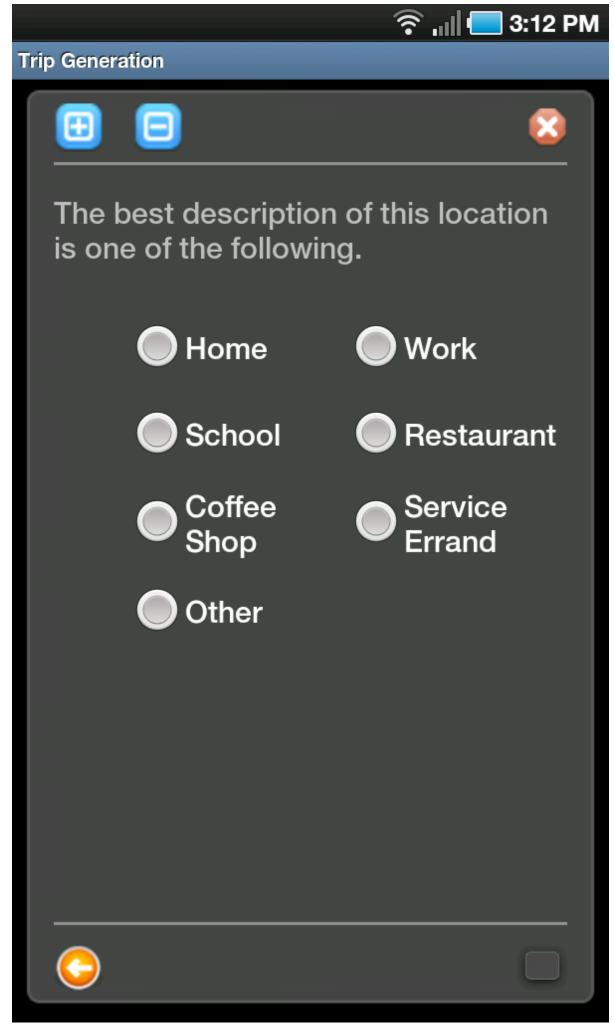
No data collection during rainy weather.



Data Collection







Samsung Galaxy Tablet, Android

Data Collection Summary: Response Rate

Land Use	Establishments (N)	Long Surveys (N)	Short Surveys (N)	Response Rates		Total
				Long Survey*	Short and Long Survey**	
Drinking places	13	107	108	30%	50%	215
Convenience	26	281	710	14%	61%	991
Restaurants	39	309	369	24%	52%	678
Total	78	697	1187	19%	52%	1884

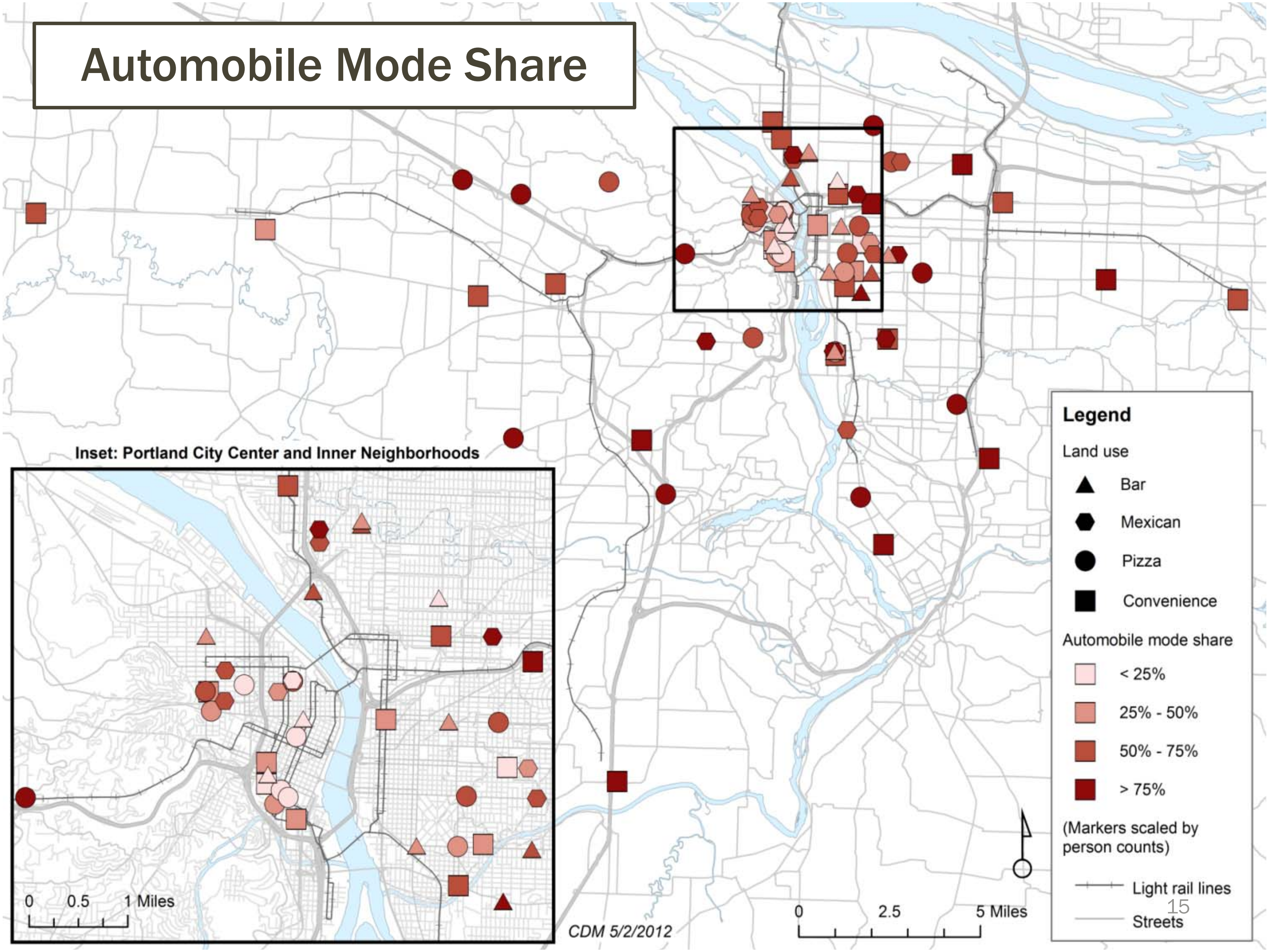
*Long survey response rate = $N_{long\ survey}$ / ($N_{long\ survey}$ + $N_{short\ survey}$ + refusals)
**Short and long survey response rate = ($N_{long\ survey}$ + $N_{short\ survey}$) / ($N_{long\ survey}$ + $N_{short\ survey}$ + refusals)

Data Collection Summary: Automobile Mode Share

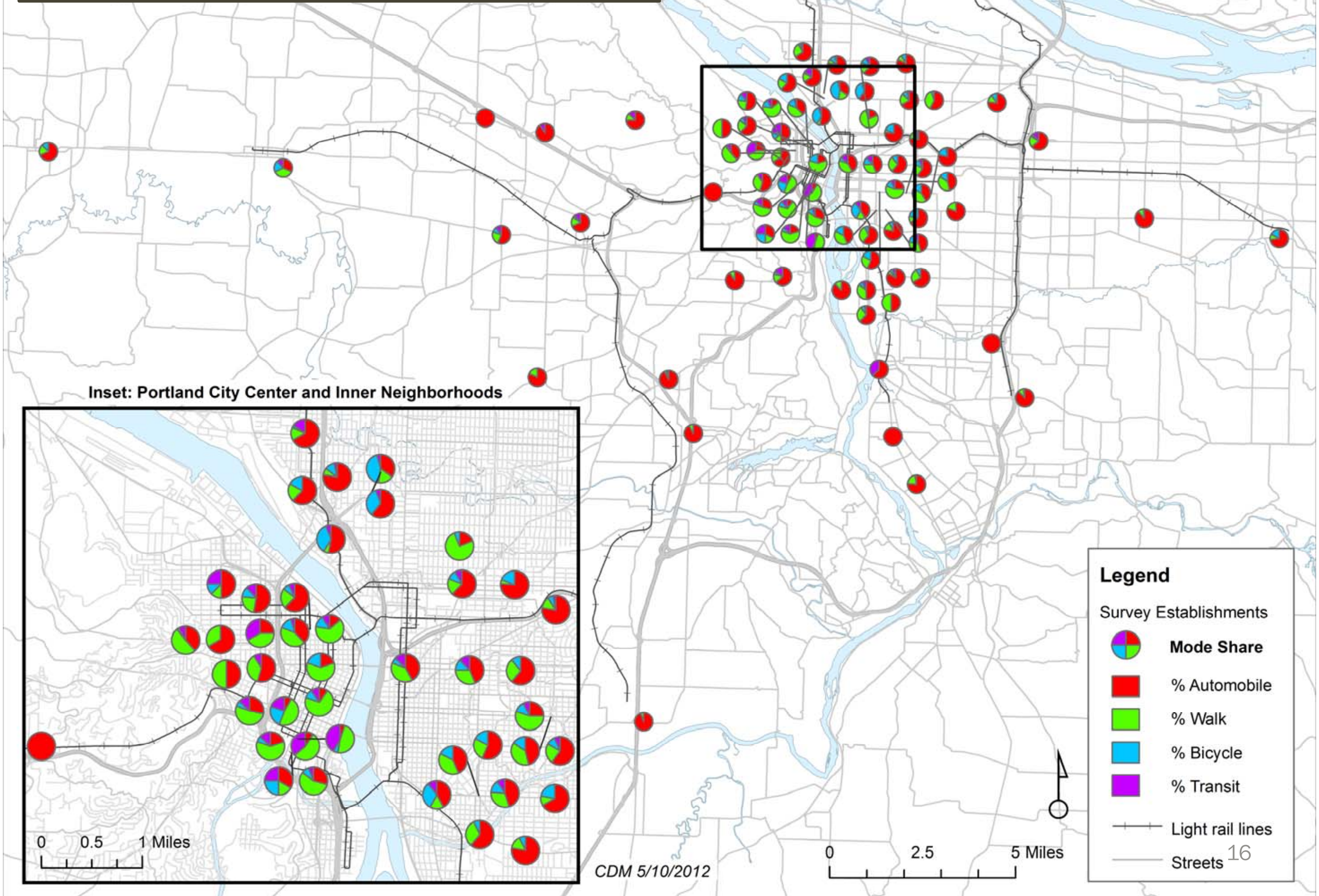
Area Type	Drinking Place	24-hour Convenience Store	High Turnover (Sit-Down) Restaurant
Central Business District (N = 19)	26%	34%	35%
Urban Core (N = 20)	46%	51%	64%
Regional Centers (N = 17)	52%	60%	70%
Suburban Town Centers (N = 12)	N/A	70%	85%
Suburban Areas (N = 10)	N/A	72%	86%

From long- and short-survey responses (N = 1187).

Automobile Mode Share



Overall Mode Share



TGS versus OHAS Automobile Mode Share

Land Use	TGS Survey[1]	Oregon Household Activity Survey Data[2] (OHAS, 2011)
Convenience Market (Open 24-Hours)	58.5%	84.8%*
High-Turnover (Sit-down) Restaurant	62.9%	79.0%**
Drinking Place	43.3%	79.0%**

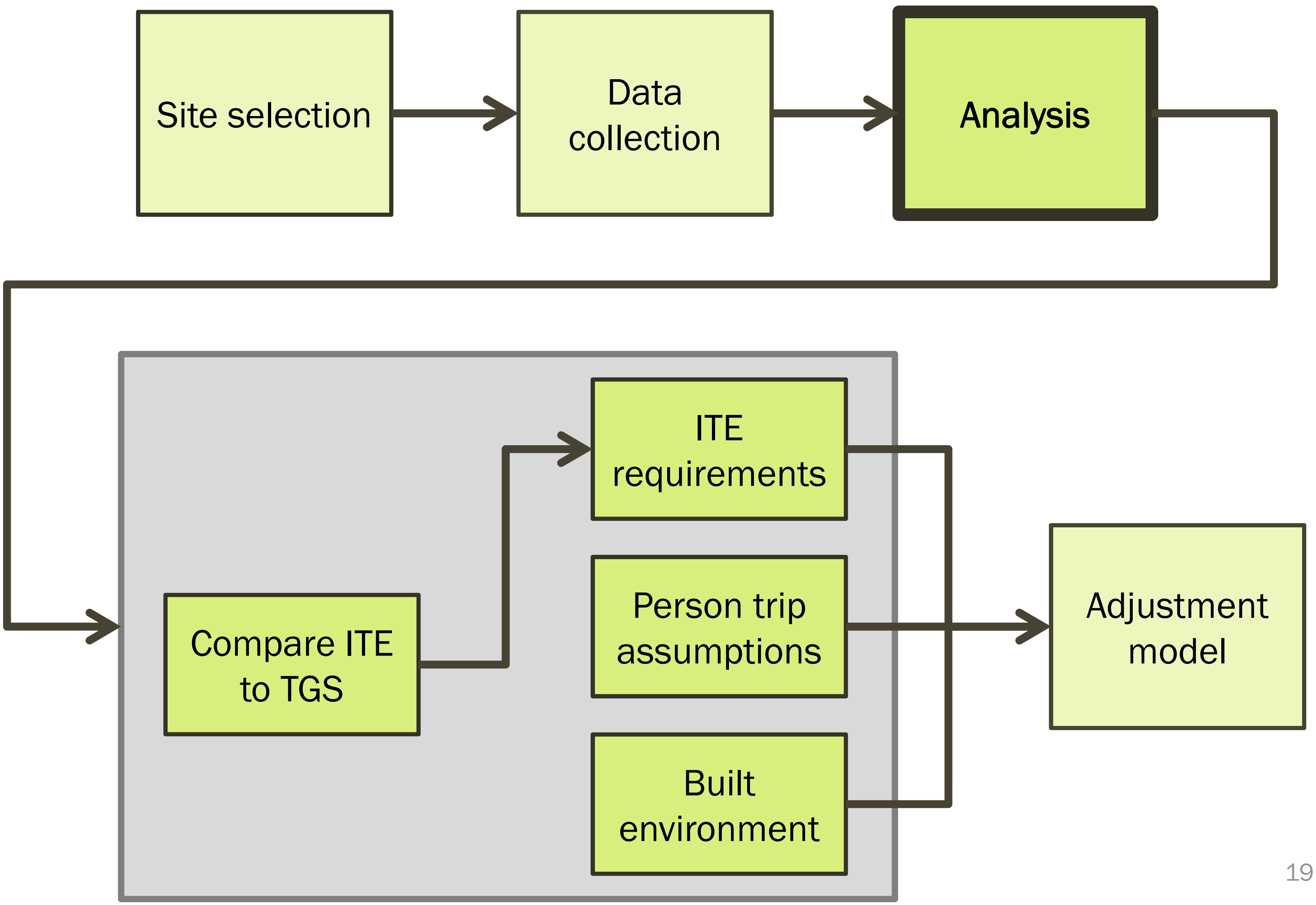
[1] Long- and short-survey sample (N = 1187).
[2] OHAS data are from ODOT Region 1.
*Trip purposes "Routine Shopping (e.g. Groceries, Clothing, Convenience Store, Household Maintenance)".
**Trip purpose "Eat Meal Outside of Home".

TGS versus OHAS Vehicle Occupancy

Land Use	TGS Survey[1]	Oregon Household Activity Survey Data[2] (OHAS, 2011)
Convenience Market (Open 24-Hours)	1.2	1.6*
High-Turnover (Sit-down) Restaurant	1.8	2.0**
Drinking Place	1.6	2.0**

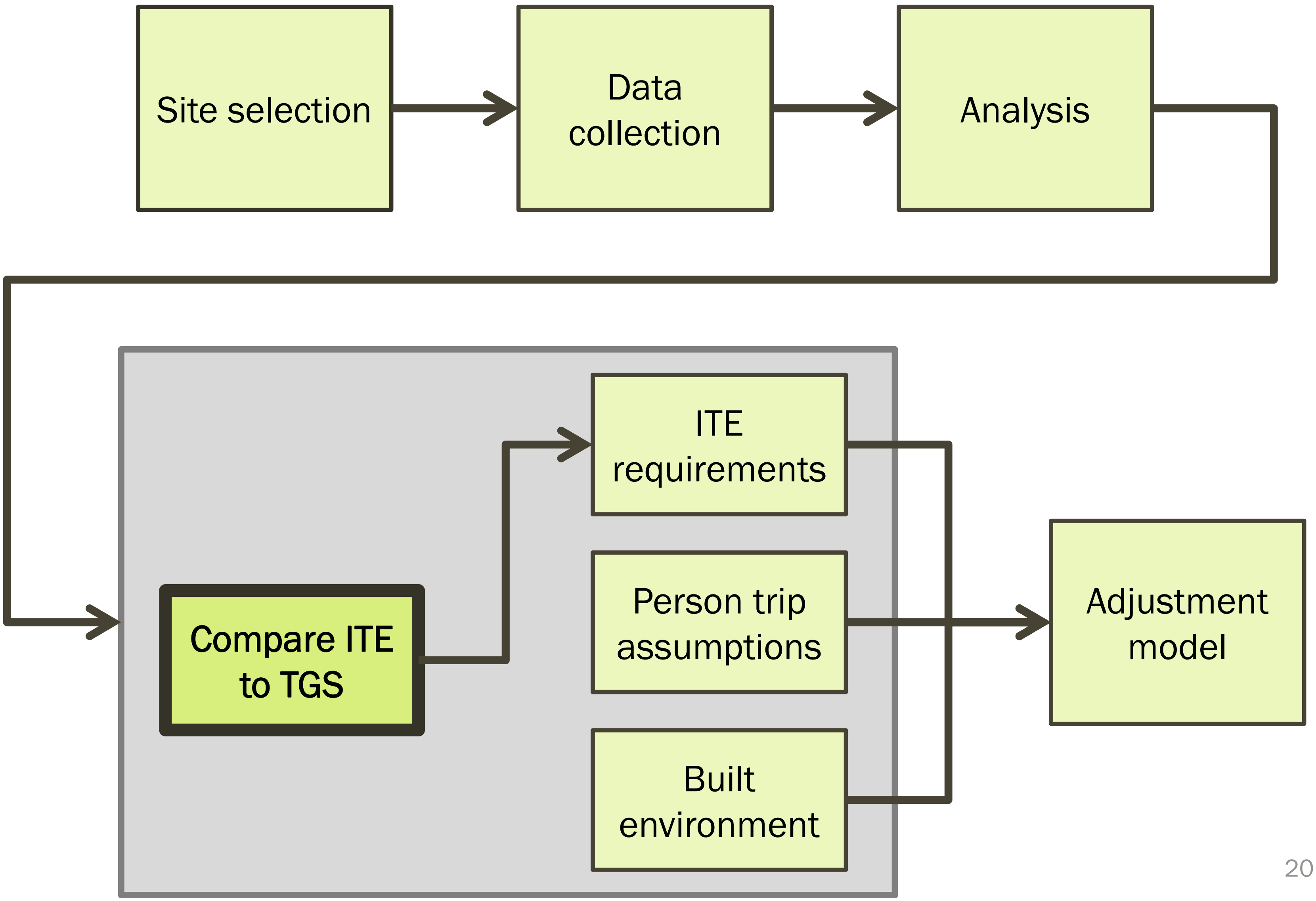
[1] Long-survey sample (N = 697).
[2] OHAS data are from ODOT Region 1.
*Trip purposes "Routine Shopping (e.g. Groceries, Clothing, Convenience Store, Household Maintenance)".
**Trip purpose "Eat Meal Outside of Home".

Analysis



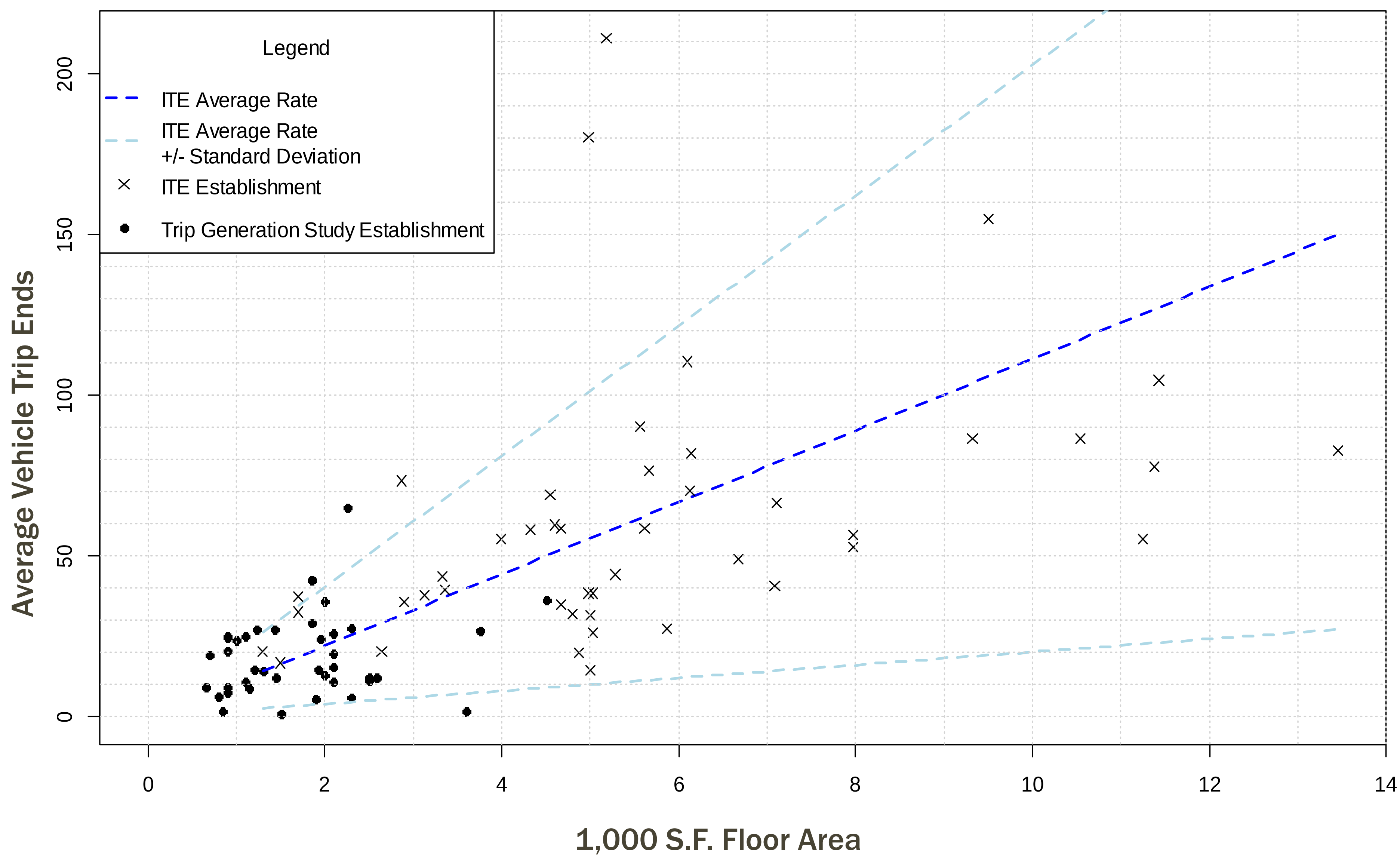
Site selection
Data collection
Analysis
ITE requirements
Person trip assumptions
Built environment
Compare ITE to TGS
Adjustment model

Analysis



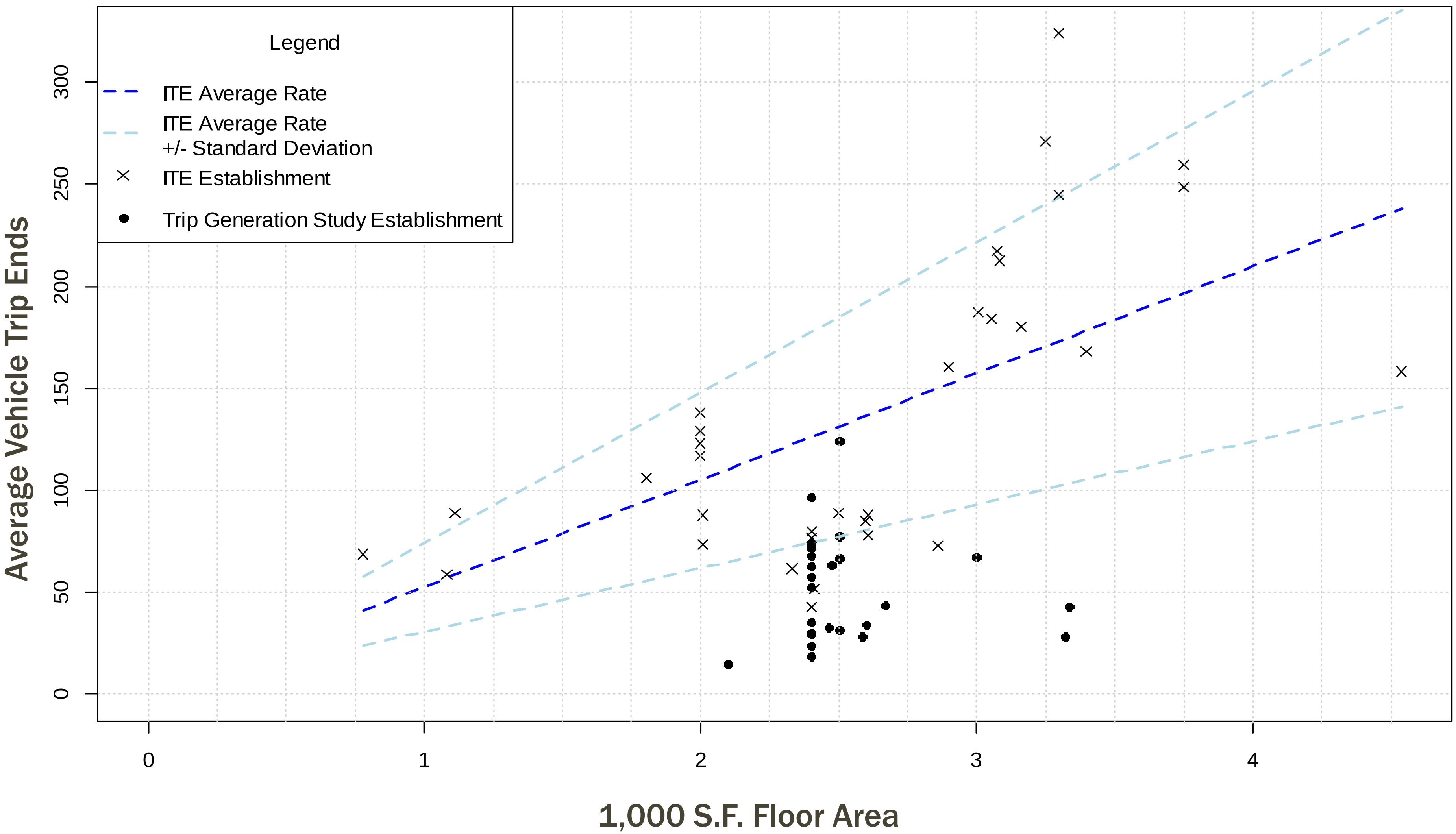
Site selection
Data collection
Analysis
Compare ITE to TGS
ITE requirements
Person trip assumptions
Built environment
Adjustment model

High-Turnover (Sit-Down) Restaurant (932)
Average Vehicle Trip Ends – ITE and TGS
Weekday, Peak Hour of Adjacent Street Traffic, 4 - 6 PM



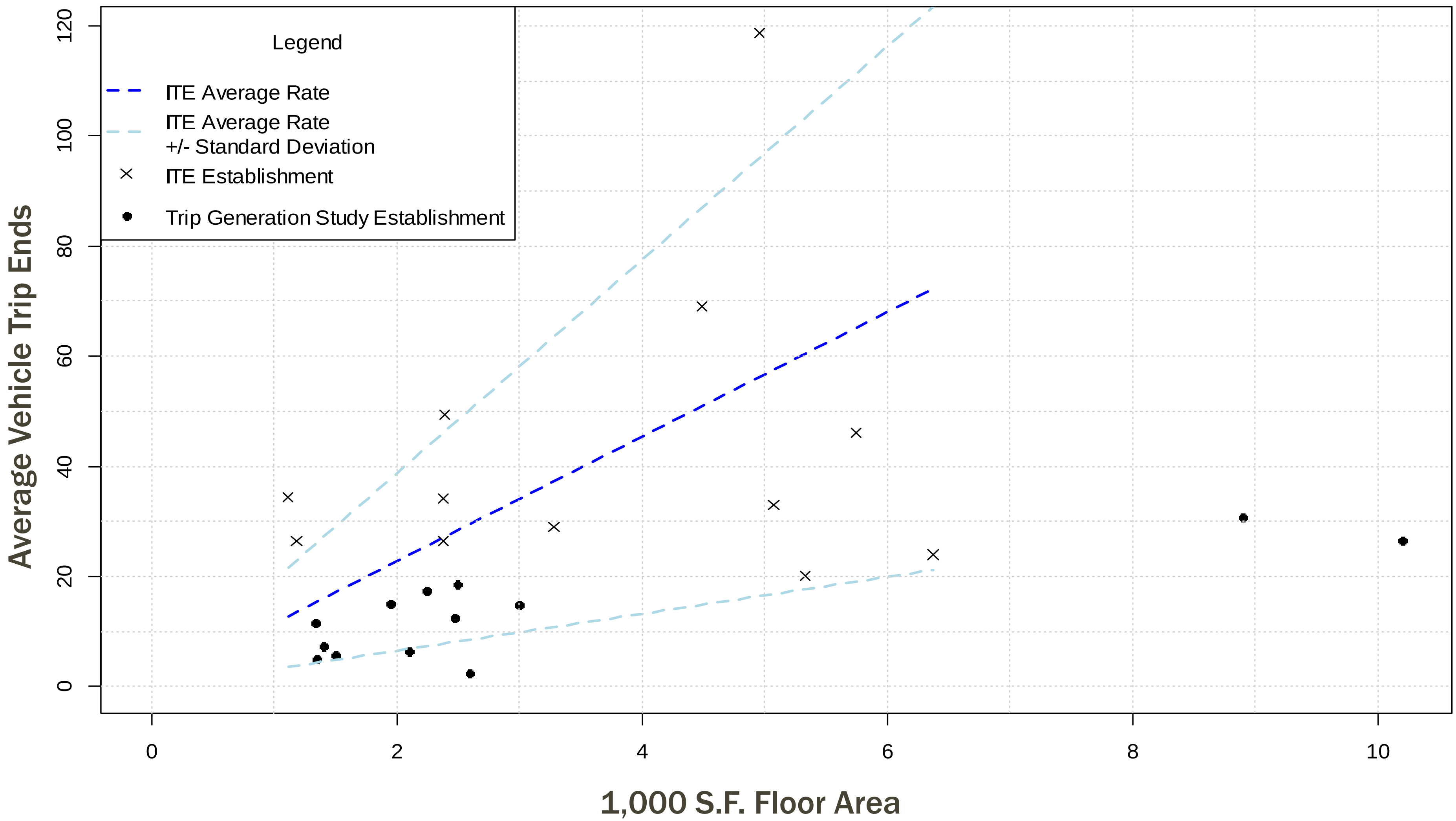
Note: TGS data includes weekday, 5-6PM.

Convenience Market (Open 24-hours) (851)
Average Vehicle Trip Ends – ITE and TGS
Weekday, Peak Hour of Adjacent Street Traffic, 4 - 6 PM



Note: TGS data includes weekday, 5-6PM.

Drinking Place (925)
Average Vehicle Trip Ends – ITE and TGS
Weekday, Peak Hour of Adjacent Street Traffic, 4 - 6 PM

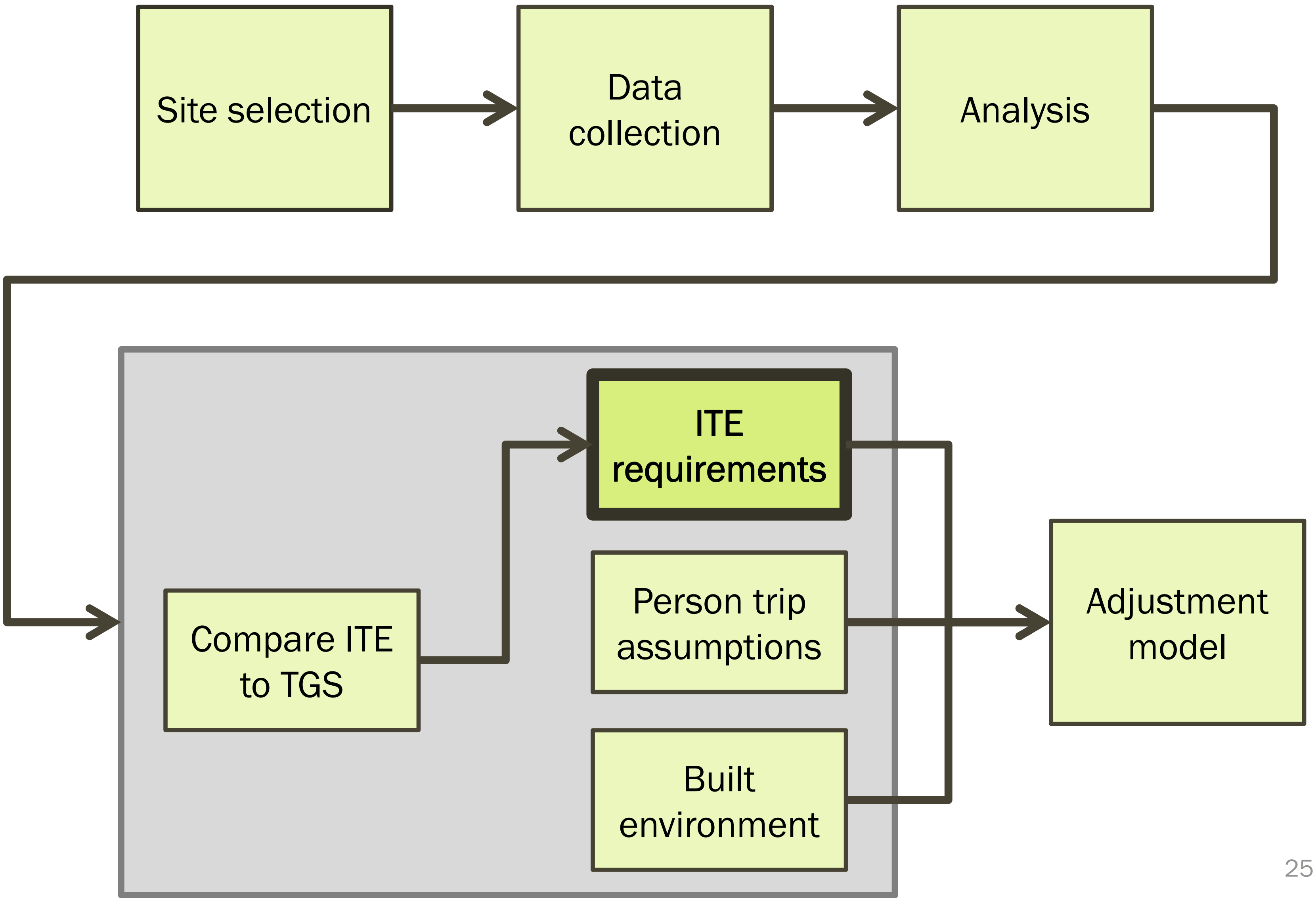


Note: TGS data includes weekday, 5-6PM.

Comparison of TGS to ITE

ITE Land Use	Convenience Market (Open-24 Hours)		Drinking Place		High-Turnover (Sit-Down) Restaurant	
ITE Land Use Code	851		925		932	
Sample Size (N)	26		13		39	
	Avg.	*Std. Dev.*	Avg.	*Std. Dev.*	Avg.	*Std. Dev.*
TGS vehicle trip rate (vehicles per 1000 Sq. Ft. area)	20.8	*10.8*	4.9	*2.3*	12.3	*8.3*
ITE Vehicle trip rate (vehicles per 1000 Sq. Ft. area)	52.4	*21.4*	11.3	*9.1*	11.2	*8.0*
Vehicle trip rate difference (TGS - ITE)	-31.6	*10.8*	-6.4	*2.3*	1.2	*8.3*

Analysis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Establishing a Need for Local Rates

ITE Criteria	LU 851: Convenience Market (Open 24-Hours) (N=26)	LU 925: Drinking Place (N=13)	LU 932: High-Turnover (Sit-Down) Restaurant (N=39)
A trip generation study (with at least three locations) provides a vehicle trip rate that falls within 1 standard deviation of the mean provided by ITE.	TGS_{RATE} = 20.8 $ITE_{RATE \pm SD.}$ = 31.0 - 73.8	TGS_{RATE} = 4.9 $ITE_{RATE \pm SD.}$ = 3.3 - 19.4	TGS_{RATE} = 12.3 $ITE_{RATE \pm SD.}$ = 2.0 - 20.3

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At least 1 study site that falls above the ITE weighted average or equation, and 1 that falls below; OR All study locations fall within 15% of the ITE average rate or equation.	0 locations fall above, 26 location fall below OR 1 of 26 location falls within 15%	0 locations fall above, 13 locations fall below OR 0 of 13 locations fall within 15%	**17 locations fall above, 22 locations fall below** OR 7 of 39 locations fall within 15%

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Locally collected studies fall within the scatter of rates provided by ITE	Appear slightly below	Appear below	Appear within scatter

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"Common sense" indicates appropriate use of ITE rates for location application.	Vague	Vague	Vague

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"Common sense" indicates appropriate use of ITE rates for location application.	Vague	Vague	Vague
Conclusion	Local rate/adjustment is recommended.	Local rate/adjustment is recommended.	**Use of ITE methods may be appropriate.**

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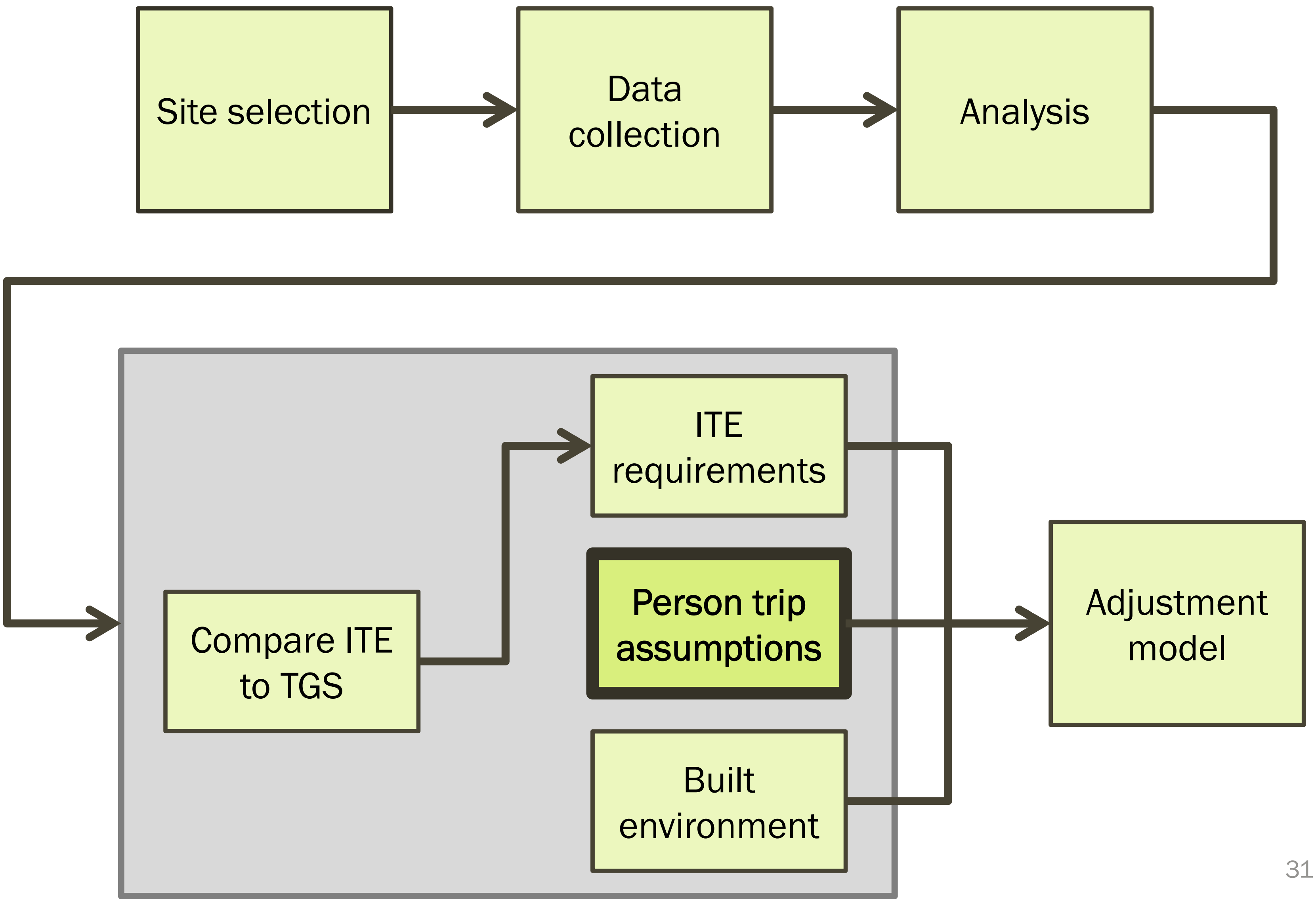
Analysis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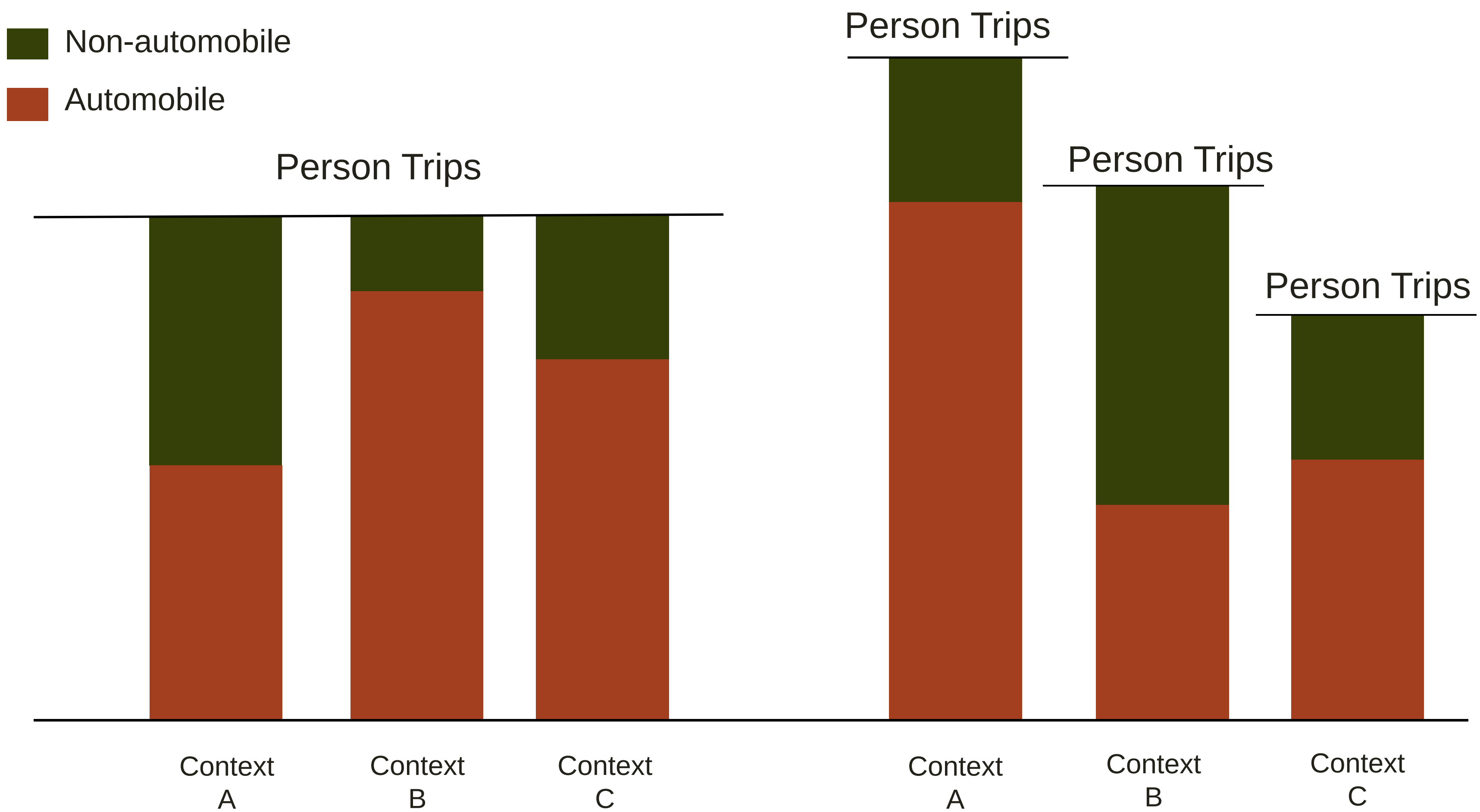
Testing Assumptions



H_0: Null Hypothesis
Person trips do not vary by context;
Substitution effect between modes

H_1: Alternative Hypothesis
Person trips vary across contexts;
Complementary effects between modes

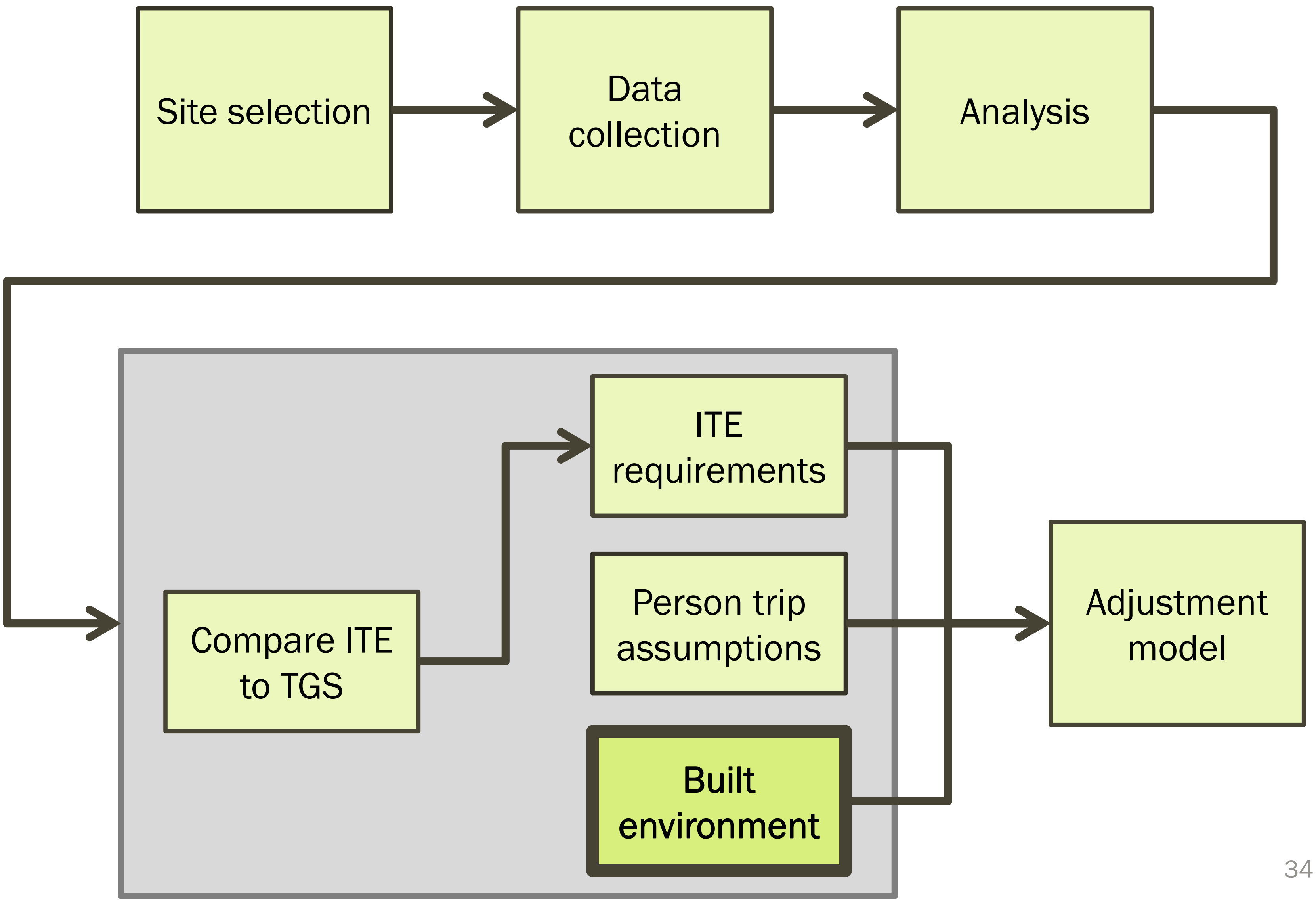
Testing Assumptions

Scenario (across contexts)	Result	p-value[1]	Interpretation
All land uses combined	H_0	0.652	Person-trip rates similar across contexts
24-hour convenience stores	H_0	0.695	Person-trip rates similar across contexts
High-turnover restaurants	H_0	0.323	Person-trip rates similar across contexts
Drinking places	H_0	0.189	Person-trip rates similar across contexts
High-turnover restaurants + drinking places*	H_0	0.616	Person-trip rates similar across contexts

[1]Hypothesis testing (95% confidence level)

*Note: land uses combined due to similarities between brew-pubs and restaurants.

Analysis



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Built Environment

- Built environment information was gathered from archived data sources at ½-mile buffer around establishments
- Measures associated with trip generation and mode choice (from literature review)
- Macro environment
- Variety of statistical tests to determine best measure(s) to use in adjustment model

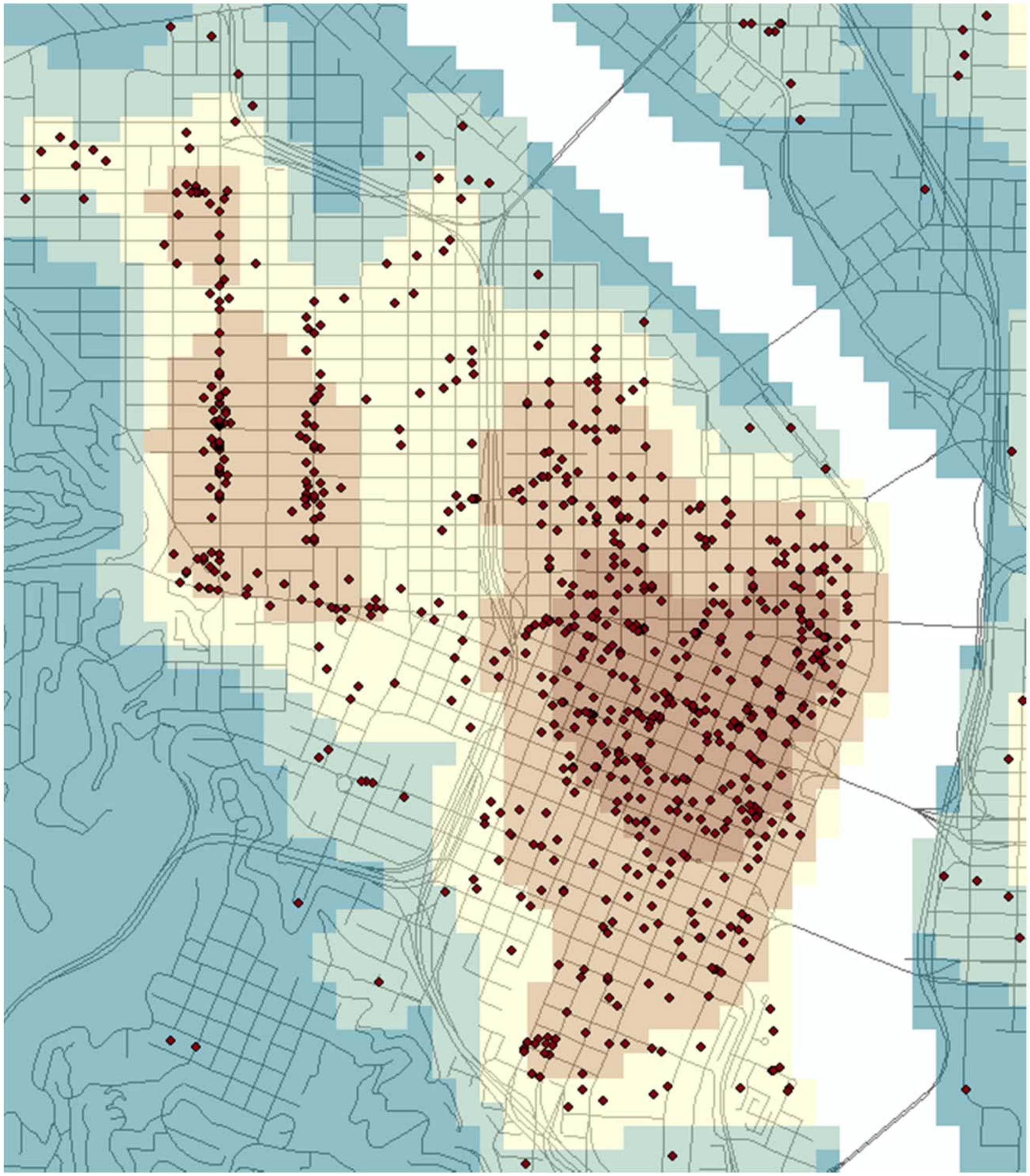
Measure	Units	Data Source*
Number of Transit Corridors	# Trimet lines within ½-mile	Light-rail and Bus Stop layer (RLIS, 2010)
People Density	Residents and employees per acre	ESRI Business Analyst (2010) and Multifamily/Household layers (RLIS, 2010)
Number of High-Frequency Transit Stops	# stops within ½-mile with headways under 15 Minutes	Bus Stop layer (RLIS, 2010) and TriMet schedules (2011)
Employment Density	Employees per acre	ESRI Business Analyst (2010)
Lot Coverage	Percent	Tax lot and Building Layers (RLIS, 2010)
Length of Bike Facilities	Miles	Bike Route layer (RLIS, 2010)
Access to Rail	Presence of rail station within ½-mile	Light-rail Stop layer (RLIS, 2010)
Intersection Density	Intersections per million square feet	Lines file (TIGER 2009)
Median Block Perimeter	Miles	Faces file (TIGER 2009)
Urban Living Infrastructure	1 to 5 index	Metro Context Tool

Urban Living Infrastructure (ULI)

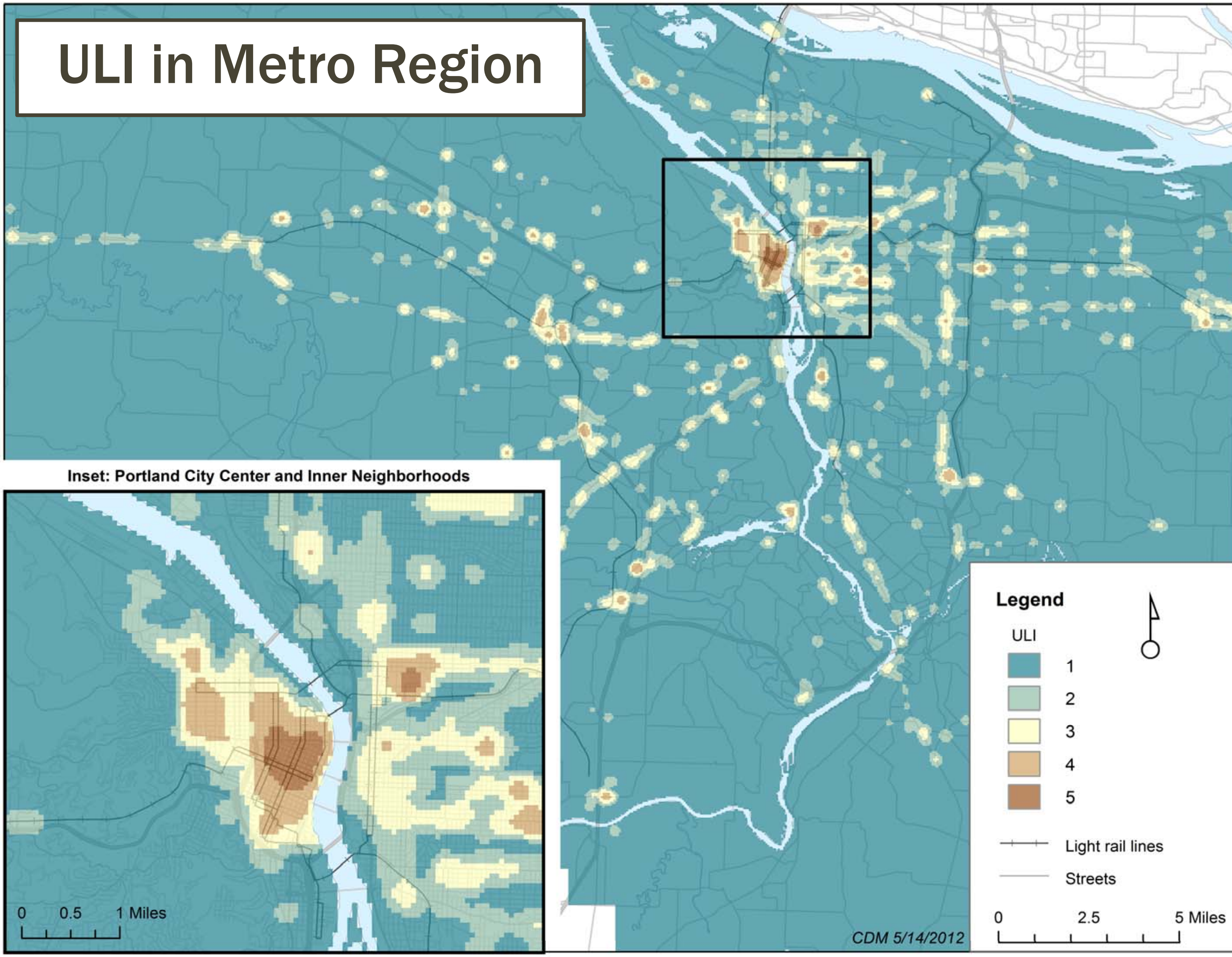
- Good model fit
- Correlated with other built environment measures
- Associated with non-automobile mode shares
- Available for the entire Metro region
- Can be used for transportation impact evaluation or long-range planning

What is ULI?

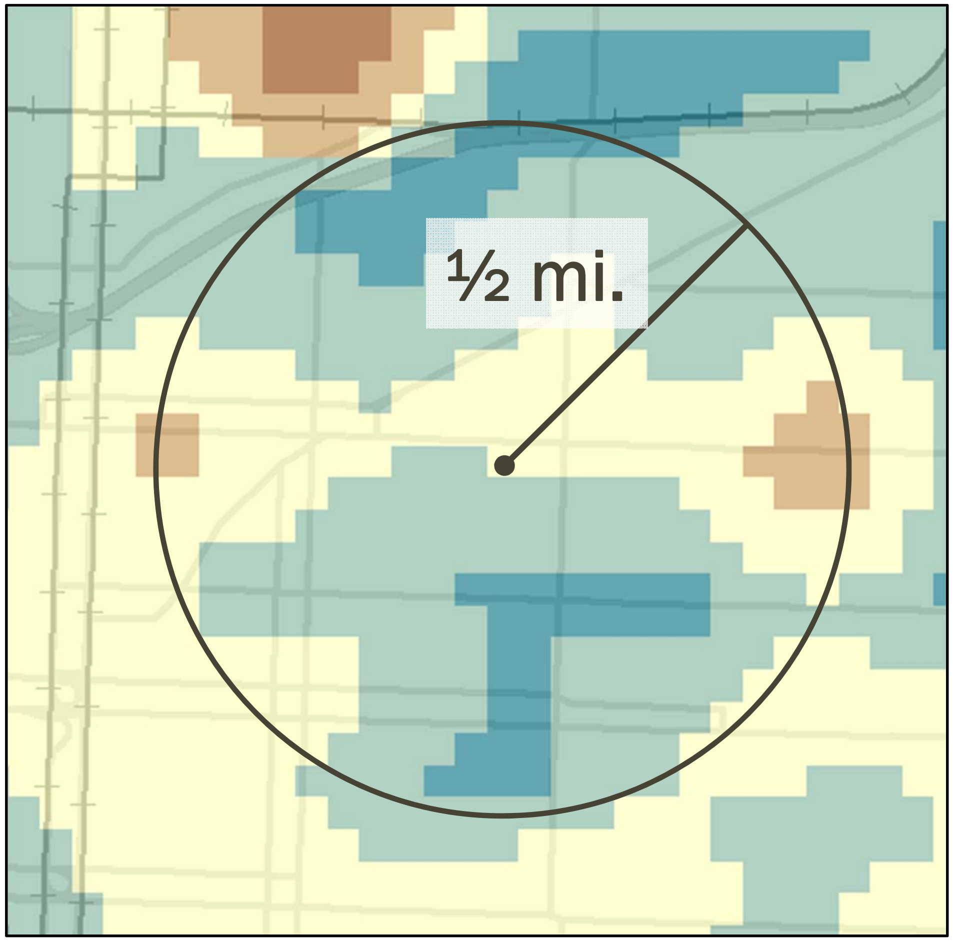
- Weighted index of density & diversity for retail/service businesses
- Areas with higher densities of desirable business types have higher ULI indices



ULI in Metro Region



ULI measured within ½-mile buffer



Point ULI: 3
Average ULI in buffer: 2.19

ULI Category 1
Raleigh Hills

ULI Category 2
Hillsdale

ULI Category 3
Westmoreland/Clinton

ULI Category 4
Nobb Hill/NW 23rd

ULI Category 5
Downtown and/or Pearl

ULI & Other Built Environment Measures[1]

	Avg. Built Environment Measure				
Range of ULI Score:	1 - 1.99	2 - 2.99	3 - 3.99	4 - 4.99	ALL
Employment Density (employees per acre)	6	24	66	37	21
People Density (residents + employees per acre)	16	38	90	158	34
Lot Coverage (%)	20%	33%	50%	66%	28%
Intersection Density (per 1,000,000 sq. ft.)	6	10	12	14	8
Median Block Perimeter (mi.)	2.5	1.6	1.6	1.5	2.1

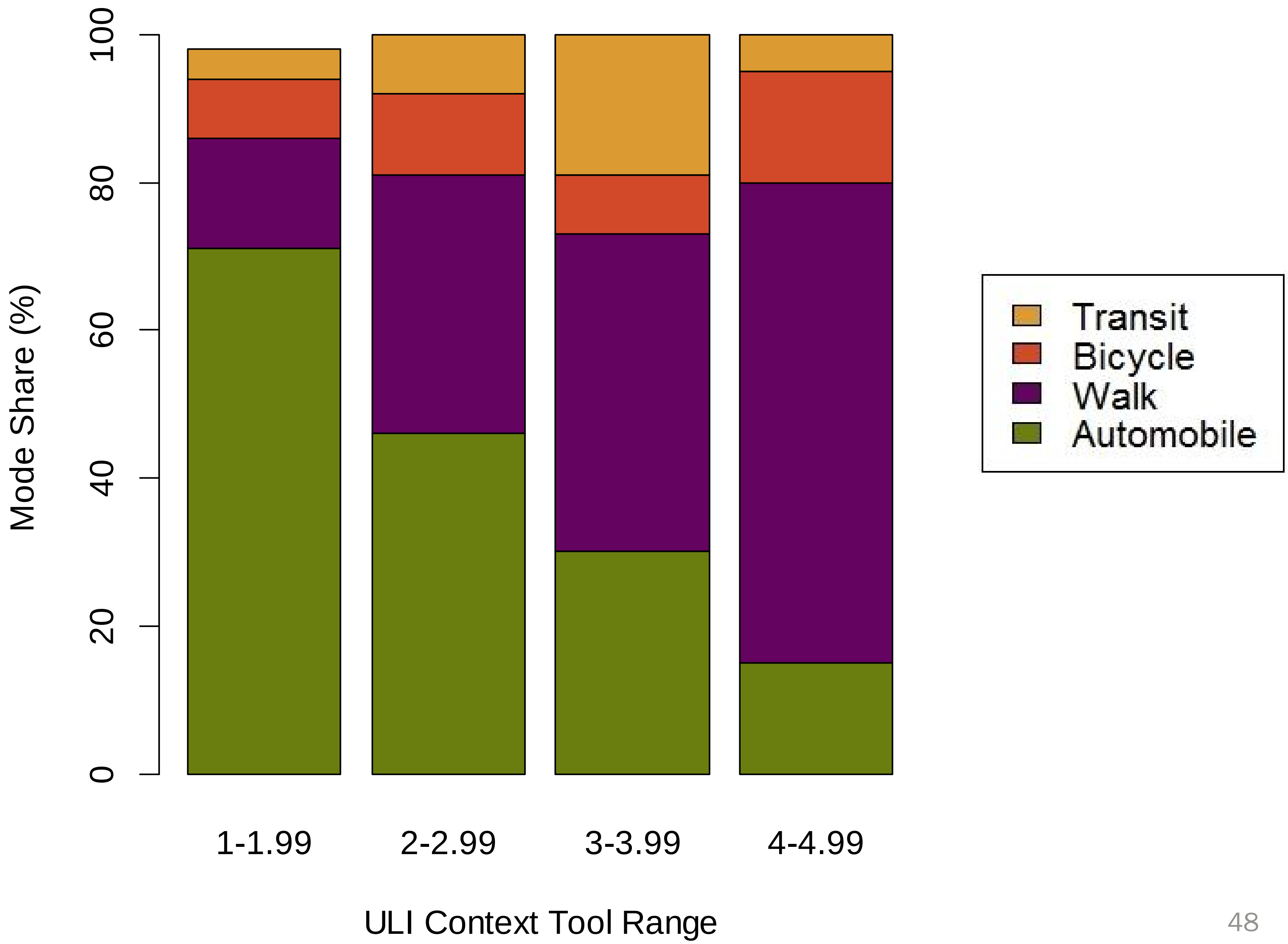
[1]Built environment variables correlated with ULI and also significant in predicting adjustment to ITE.

ULI & Other Built Environment Measures[1]

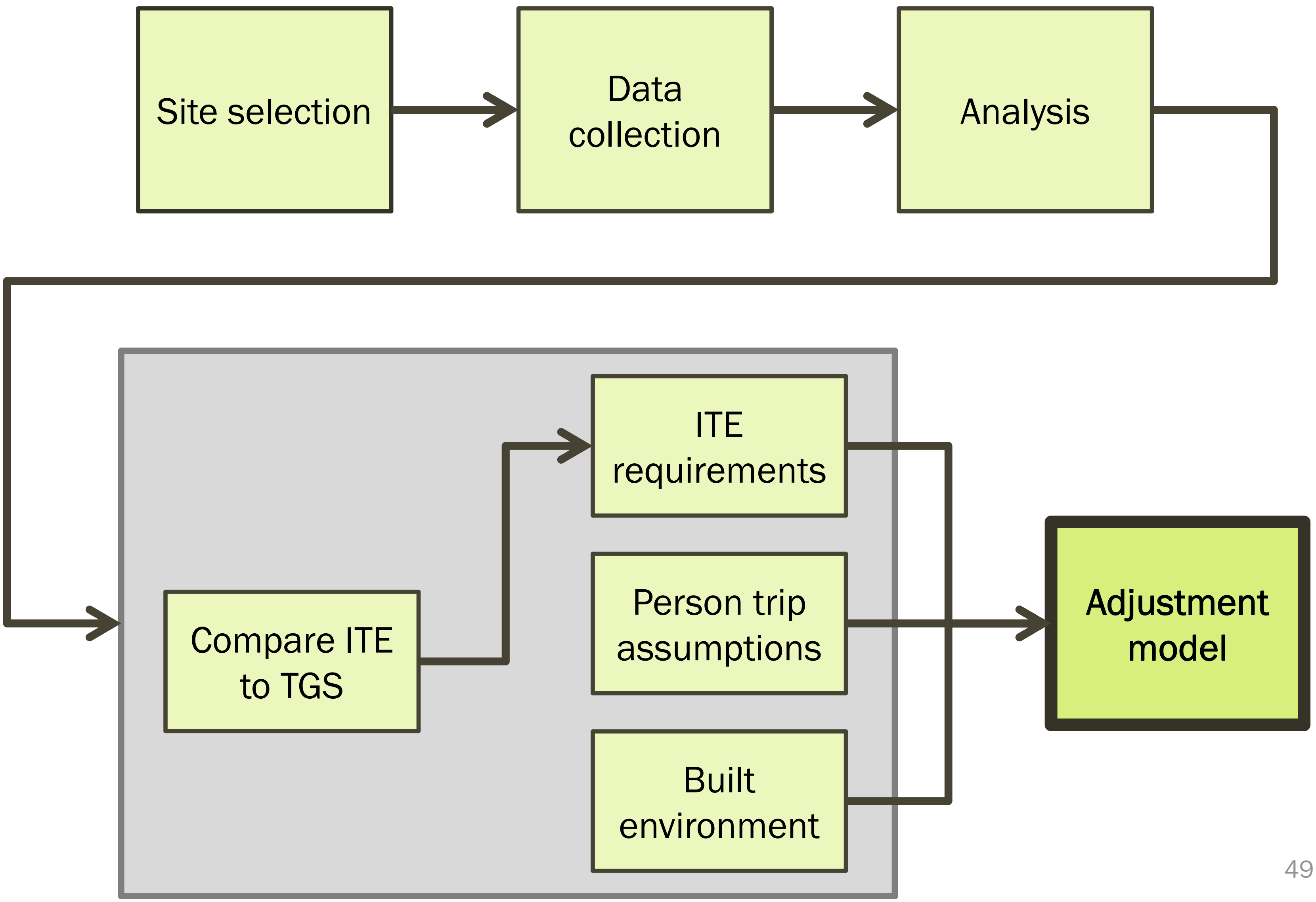
	Avg. Built Environment Measure (units)				
Range of ULI Score:	1 - 1.99	2 - 2.99	3 - 3.99	4 - 4.99	ALL
Length of Bike Facilities (mi.)	5.2	7.3	11.3	13.3	6.7
Rail Access (within buffer)	30%	53%	90%	100%	45%
Number of Transit Corridors (count)	9	26	72	98	24
Number of High-Frequency Bus Routes (count)	19	58	125	200	47

[1]Built environment variables correlated with ULI and also significant in predicting adjustment to ITE.

ULI Ranges and Mode Splits



Adjustment Model



Local Adjustment to ITE

$$ADJ = 0.643 - 3.286 * ULI + 7.412 * REST - 26.043 * CONV$$

$ADJ = VEH\ TRIPS_{TGS,LU} - VEH\ TRIPS_{ITE,LU} \equiv$ Difference in vehicle trip rates

$ULI \equiv$ Average of ULI values from Metro Context Tool within 1/2 mile buffer

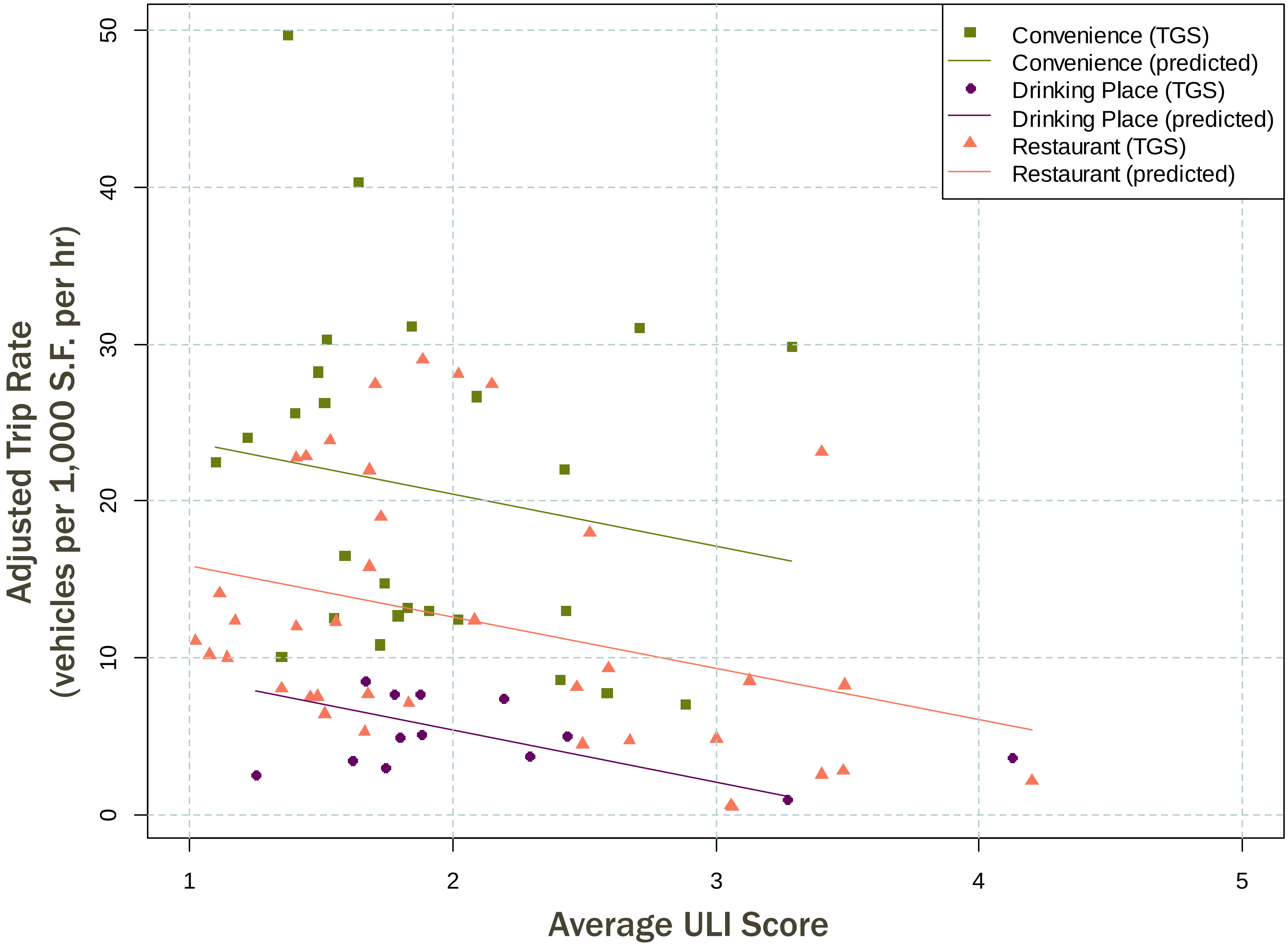
$$REST = \begin{Bmatrix} 1, \text{if ITE Land Use} = 932\text{: High}-\text{Turnover Restaurant} \\ 0, \text{if ITE Land Use} \neq 932\text{: High}-\text{Turnover Restaurant} \end{Bmatrix}$$

$$CONV = \begin{Bmatrix} 1, \text{if ITE Land Use} = 851\text{:Convenience Market} \\ 0, \text{if ITE Land Use} \neq 851\text{:Convenience Market} \end{Bmatrix}$$

$$Adjusted\ R^2 = 0.763$$

Note: Drinking places are the base case for the model

Average ULI Score vs. Adjusted Trip Rate



Example Application – Transportation Impacts

- New convenience store
- Location has ULI = 2.9, ½ mile buffer around proposed site
- Compute adjustment *to* ITE rate:

$$ADJ = 0.643 - 3.286 * ULI + 7.412 * REST - 26.043 * CONV$$

$$ADJ = 0.643 - 3.286 * \mathbf{2.9} + 7.412 * 0 - 26.043 * \mathbf{1} = -34.9$$

- Adjust ITE for context:

$$\text{New Adjusted rate} = \text{ITE rate} + \text{ADJ}$$

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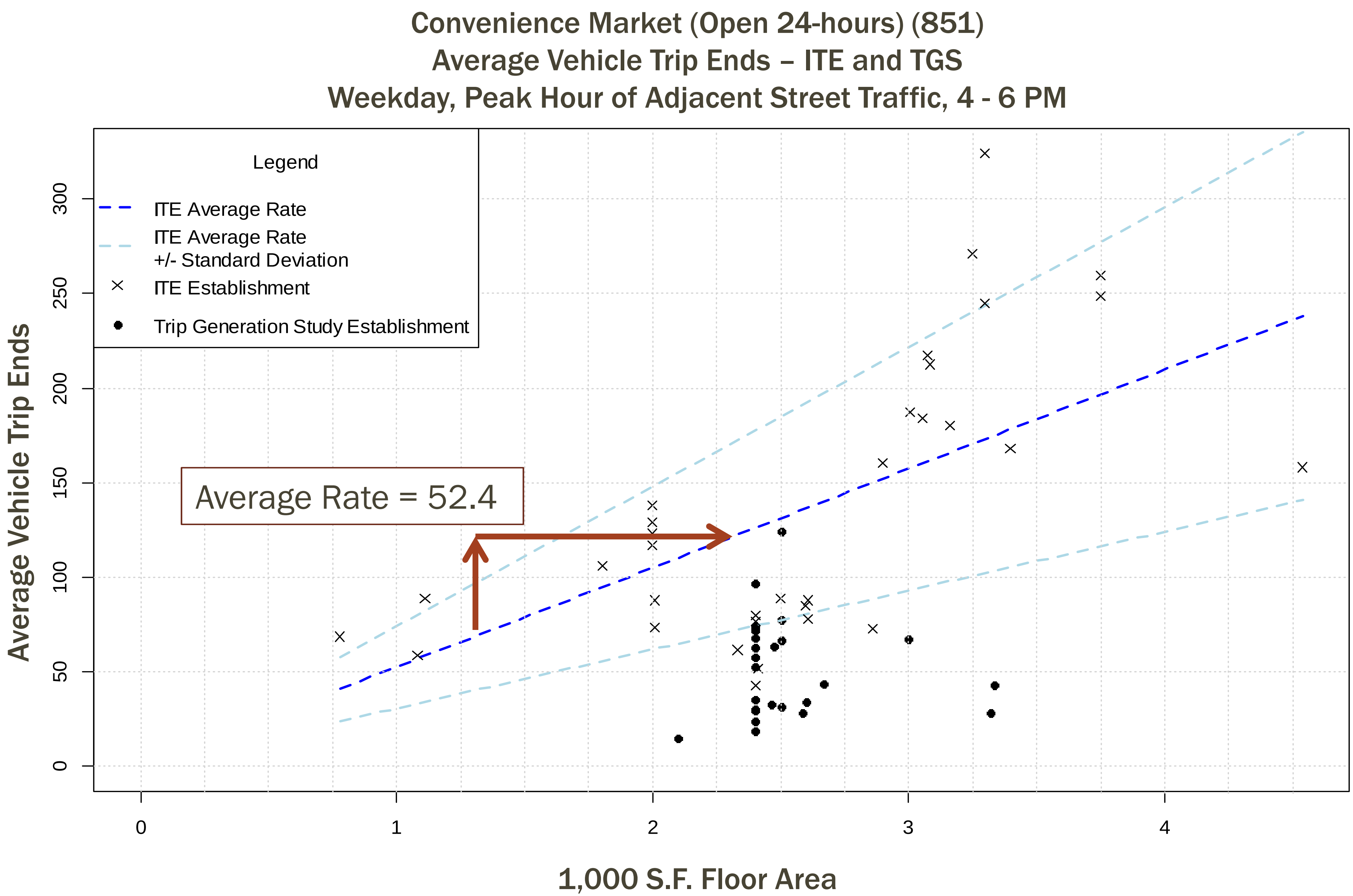
New Adjusted rate = ITE rate + ADJ

New Adjusted rate = ? + (– 34.9)



Note: TGS data includes weekday, 5-6PM.

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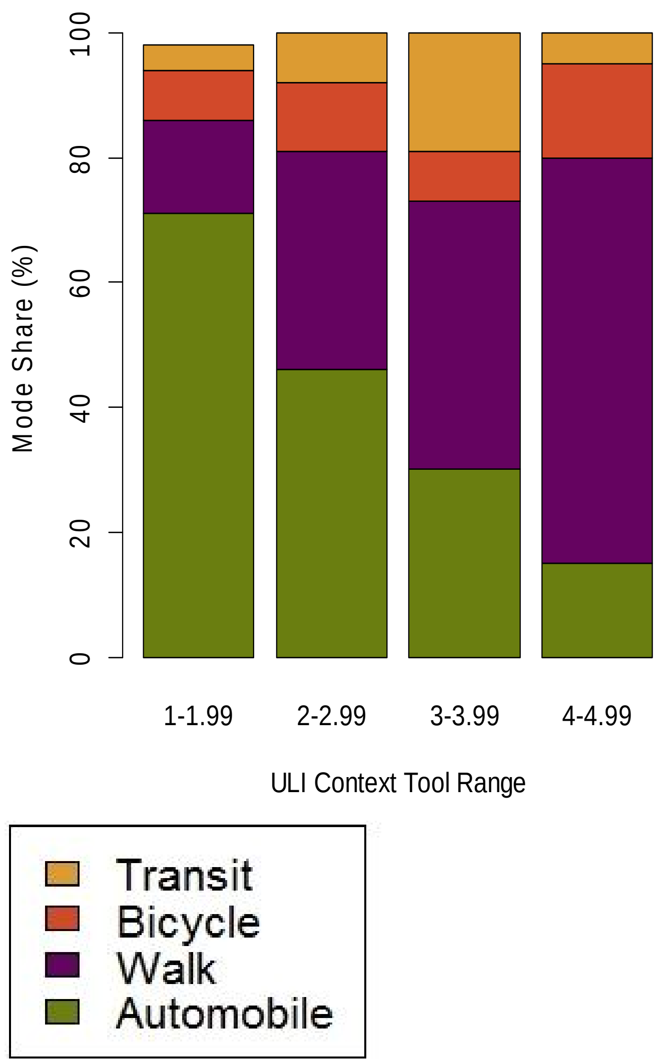
$$\text{New Adjusted rate} = \text{ITE rate} + \text{ADJ}$$

$$\text{New Adjusted rate} = 52.4 + (-34.9)$$

$$= 17.5 \text{ trip ends per 1000 SQFT per hour}$$

[-66% of ITE's rate]

Example Application – Future Planning



Desired mode share in area
~ 2/3 of trips non-automobile

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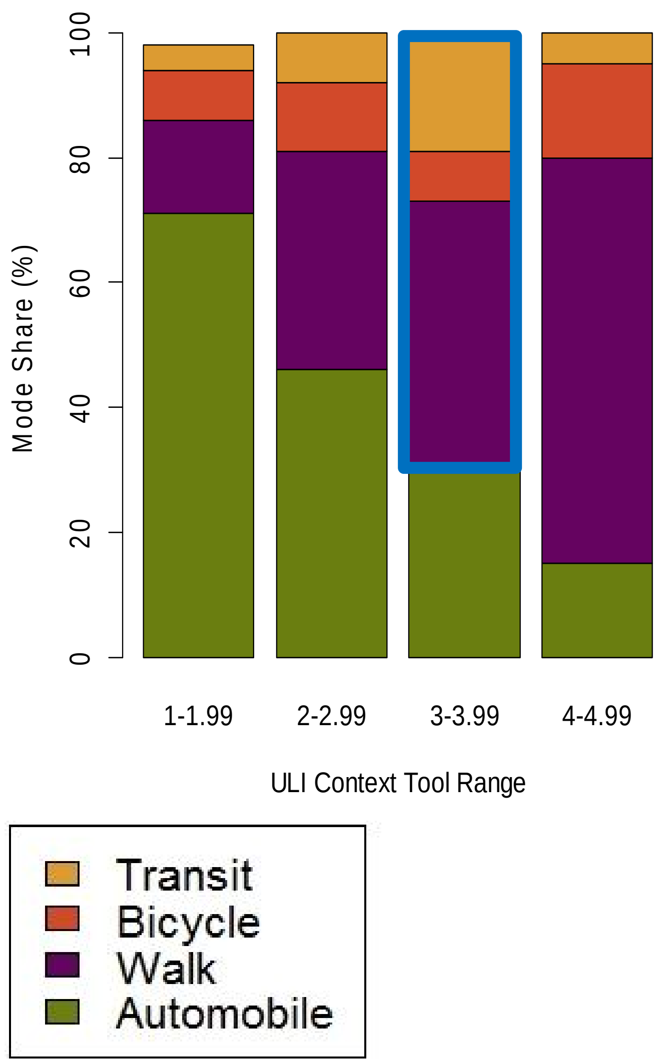

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ULI Range 3-4

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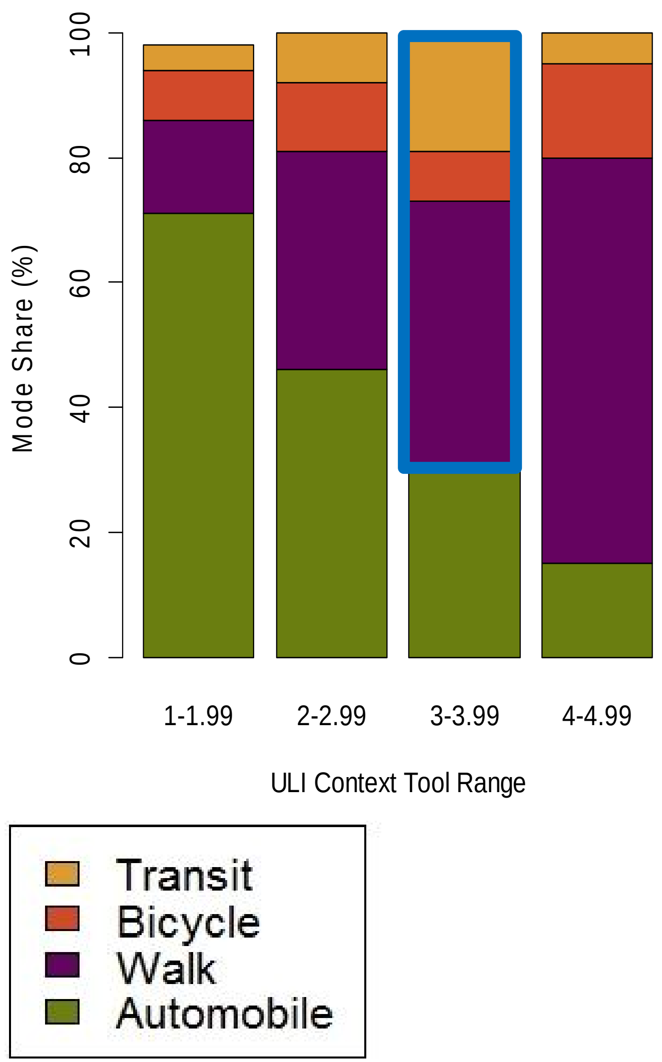

Desired mode share in area
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ULI Range 3-4
Range of built environment measures from table

ULI & Other Built Environment Measures[1]

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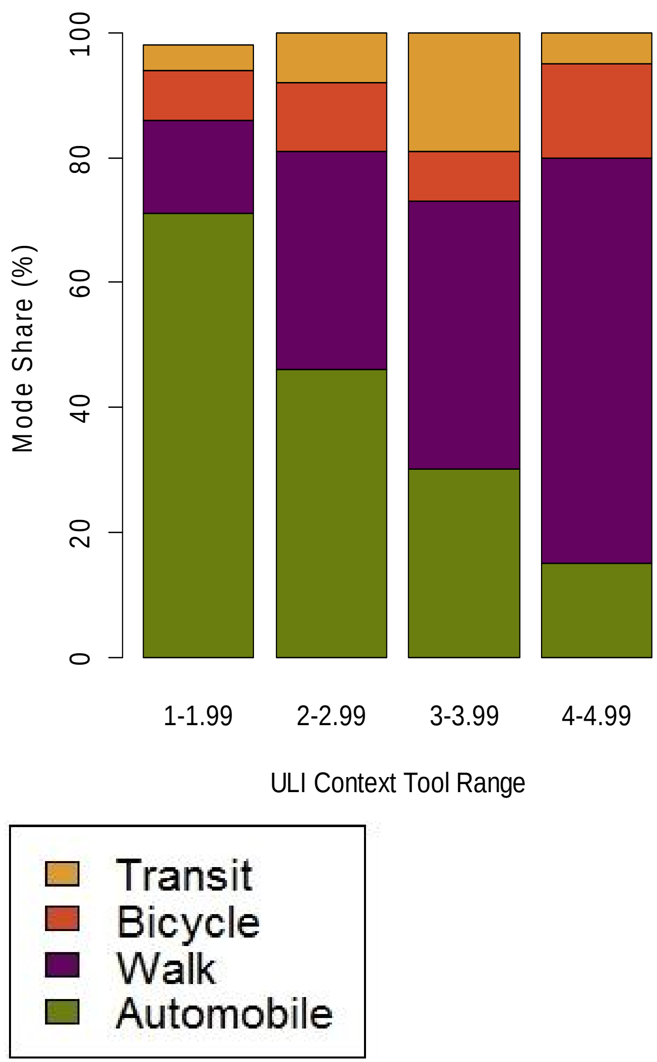

Desired mode share in area
~ 2/3 of trips non-automobile
ULI Range 3-4
Built environment measures w/in ½ mile buffer:

- Employment density ~66/acre
- People density ~90/acre
- Lot Coverage ~ 50%
- ~12 miles of bike facilities
- Rail access

Conclusions

- Person counts combined with survey provide valid estimates of vehicles
- Tablet technology facilitated data collection
- Simple method for adjustment
- Good model fit
- Can relate to a range of built environment attributes for planning and policy

Limitations

- Limited land uses
- Sample size small
  - No segmented adjustment models by land use
  - Too much variation in micro-scale environment for inclusion in statistical analysis
- Built environment measures highly correlated
- ULI is Metro specific; cannot generalize

Recommendations

- Establish local rates or method for Metro region
- Build evidentiary database of local traffic impact analysis studies
- Make local data available online (PSU)
- Collect data on all modes

Next Steps

- Validation
  – Currently collecting validation data for ~ 75 establishments
  – Variety of land uses and contexts
- Additional land use (grocery stores)
- Site-level analysis
  – Parking supply
  – Urban design features
- Proposed pooled study with UC Davis – CalTrans

Acknowledgements

- This project was sponsored by a grant from the Oregon Transportation Research and Education Consortium (OTREC) with assistance from:
  - Metro
  - Talia Jacobson, ODOT
  - Don Odermott, City of Hillsboro
  - Denny Egner, City of Lake Oswego
  - Jason Rice, City of Milwaukie
  - Judith Gray, City of Tigard

Questions?

Kelly Clifton

kclifton@pdx.edu