# CONTEXTUAL INFLUENCES ON TRIP GENERATION

## Final Report

## OTREC 2011-407

by

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OREGON TRANSPORTATION RESEARCH
AND EDUCATION CONSORTIUM

**August 2012**

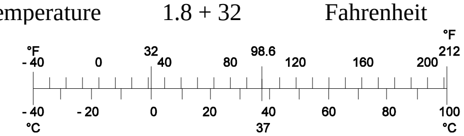
# SI* (MODERN METRIC) CONVERSION FACTORS

## 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$^3$. | | | | |
| | | **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
- Don Odermott, City of Hillsboro
- Denny Egner, City of Lake Oswego
- Jason Rice, City of Milwaukie
- Judith Gray, City of Tigard

# CONTEXTUAL INFLUENCES ON TRIP GENERATION

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# 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, *ITE Trip Generation Handbook* rates were developed beginning in the 1960s and focused on single-use, vehicle-oriented in suburban sites in the United States. *ITE Trip Generation Handbook* 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 Trip Generation 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 Trip Generation Handbook* and apply generic rates to inappropriate contexts, like high density areas with more multimodal trips (Nelson\Nygaard Consulting Associates 2005, Lerner-Lam, et al. 1992, Badoe 2000, Fleet and Sosslau 1976).

Interestingly, the *ITE Trip Generation Handbook* Data Form has a box for "Location within Area" where one can check a box for the urban 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 Handbook* methodology.

ITE acknowledges the limitations of the *Trip Generation Handbook* 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 Trip Generation 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 Trip Generation Handbook* also recognizes the impact of pedestrian and bicycle infrastructure on reducing estimated vehicle trips, but 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 extensive data will not likely be available soon. In the meantime, local governments burdened with short and 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 Handbook* 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. The creation of environments where there is more vehicle use, greater road capacity, abundant parking supply, and fewer automobile alternatives can be related to the overestimation of vehicle trip rates in sites and corridors and the subsequent accommodation of those estimates. Further, new development can be deterred by the impact fees associated with overestimating vehicle trips.

Compounding these challenges, cities in Oregon, like other communities with state-wide concurrency laws, are required to demonstrate that planning and zoning changes will not degrade the performance of state-owned transportation facilities based upon 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 concurrency requirements can conflict with the Portland region's 2040 Growth Concept, which calls for development of mixed-use centers and corridors, TODs and robust neighborhood and main street commercial districts. 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 by examining the relationship between trip generation and urban context. Here, we develop a method to adjust *ITE Trip Generation Handbook* 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) from a variety of land use and transportation contexts. These observed local trip rates were compared to *ITE Trip Generation Handbook* rates for the same land use category and establishment size and a methodology for adjusting the ITE rates was developed.

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 *Trip Generation Handbook* rates 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 relates the literature on the relationship between travel behavior and the built environment to this study: we aim to better inform which aspects of the built environment should represent context.

## 2.1 EVALUATION OF ITE TRIP GENERATION RATES

There have been many studies which evaluate the error in estimation of ITE Trip Generation rates compared to observed study values. These ranges of error, shown in Table 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**

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

As shown in Table 2-1, the greatest range of error in ITE estimation of vehicle trips occurs in Central Business District/Urban Core/Downtown areas. One retail shop studied in Oakland, California had an observed AM peak trip count of 133 vehicle trips and an ITE estimated trip count of 11 vehicle trips. When this establishment is treated as an outlier, Mixed-Use Developments then show the greatest range of variation in error in estimation. Retail and residential developments tend to be both over and under estimated when using ITE Trip Generation rates. Standard deviations provided by ITE Trip Generation rates were not used in this assessment.

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

**Table 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 provided in Table 2-1 for studies that counted person trips and calculated persons taking a vehicle. The Central Business District/Urban Core/Downtown area shows the largest range of automobile mode share. But, sites in Suburban Activity Centers and Corridors contain a substantial range: automobile mode shares were observed to be as small as 54%.

## 2.2 ADJUSTMENTS & ALTERNATIVES TO ITE METHODOLOGY

The ITE Trip Generation Report and Handbook are the most commonly referenced and utilized practical guidelines for predicting vehicle trip rates during the development process. However, sites studied by ITE are often limited to vehicle-oriented, suburban locations with little to no

[1] Sources include (Samdahl 2010, Hooper 1989, Fehr & Peers 2008, Schneider 2011, Lee, et al. 2011, Kimley-Horn and Associates, Inc. 2009 June 15, Cervero and Arrington 2008a, Cervero, Ridership Impacts of Transit-Focused Development in California (UCTC No. 76) 1993, Dill 2008, Lapham 2001, Colorado/Wyoming ITE Section Technical Committee - Trip Generation 1987, Jeihani and Camilo 2009, Sperry 2010).

public transportation or bicycle and pedestrian facilities. Jurisdictions that require traffic impact studies often provide guidelines on how to approach local vehicle trip rate adjustments for sites with mixed-uses, presence of transit, bicycle/pedestrian amenities, or transportation demand management practices in place. This section reviews a selection of jurisdictional guidelines in North America and then reviews existing models that predict vehicle trip generation rates based on factors that encompass context and mixed land uses.

### 2.2.1 Jurisdictional Guidelines on Adjustment to ITE Trip Generation

This section details a review of 23 jurisdictional guidelines for local adjustment from around the United States and Canada. These guidelines originate from mega cities like New York City, New York to smaller, lower-density places like Bend, Oregon. These compiled guidelines identify trends in estimation of trip generation rates and traffic impact studies currently in practice. Table 2-2 shows how the guidelines approach ITE vehicle trip rates and adjust vehicle trip rates based on public transit, bicycle and pedestrian facilities, and mixed-use sites. More generally, the guidelines are summarized as follows:

- 22 jurisdictions reference ITE Trip Generation rates and methods as being appropriate in their local contexts, barring the presence of local rates or studies are not available.[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 (Montgomery Planning 2010, Southern New Hampshire Planning Commission 2010, San Francisco Planning Department 2002, San Diego Municipal Code 2003 May, City of Mississauga 2008, New York City 2010).

- 11 jurisdictions provide conditions or thresholds that require a traffic impact study at a particular development site. Conditions are based on vehicle traffic thresholds, land use plan requirements, or stipulations associated with development near roadway facilities with congestion and/or access problems. Of these jurisdictions, ten jurisdictions use vehicle trip thresholds. Table 2-3 shows the wide range of vehicle trip thresholds for a traffic impact study used by these ten jurisdictions. Decisions on the depth required of the impact analysis typically occur on a case-by-case basis.

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

**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.

**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 February, Charlotte Department of Transportation 2006, City of Pasadena 2005 August 24, Georgia Regional Tranpsortation Authority 2002 January 14, Southern New Hampshire Planning Commission 2010, San Francisco Planning Department 2002, City of Bend 2009, San Diego Municipal Code 2003 May, City of San Diego 1998, Virginia Department of Transportaiton 2010 April, 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.

### 2.2.2 Alternative Models and Approaches

ITE also recommends using an approach developed by JHK & Associates, et al. (1996) published in the ITE Handbook (Institute of Transportation Engineers 2004) with considers reductions in vehicle trip generation for locations in closer proximity to transit with supportive land uses (e.g. greater density, higher floor-to-area ratios, available pedestrian and bike facilities). This report was published as a draft, and is only presented in the handbook as a guild in procedure, does not necessarily pressent reductions based on context. ITE has also supported other methodologies for determining reductions including Gard's approach for transit-oriented developments (2007) using multimodal information to provide development wide reductions (assuming vehicle-occupant trip to non-vehicle trip substitution).

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

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

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

Another post-processor is the INDEX tool used to assess the environmental impact at site-level developments baesd on changes to the built environment. This GIS-based post-procesor utilizes regional 4-step model output to determine changes in the built environment which may effect certain aspects of travel. While this tool to not explicitly estimate changes to estimates of vehicle trips generated, it remains a potential source for evaluating changes in site-level development (Hagler Bailly Services, Inc. and Criterion Planners/Engineers 1999).
Although out of the scope for this study, a few models and projects have been focusing on multi-use developments which tend to have increased levels of internal-capture due to the close proximity and design of such developments.

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

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

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

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

There are alternative methodologies to adjust *ITE Trip Generation Handbook* rates, but as of yet, none have shown to deliver consistent results (Lee, et al. 2011). Additionally, no research has been done in the Portland area alone to address the local adjustment of vehicle trip generation rates.

## 2.3 TRAVEL BEHAVIOR IN URBAN CONTEXTS

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

### 2.3.1 Built Environment

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

***Density***

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

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

### *Diversity (Land Use Mix)*

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

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

### *Design*

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

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

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

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

### *Distance to Transit*

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

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

### 2.3.2 Area Types

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

***Central Business District, Urban Core and Downtown Areas***

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

CBD, UC, and downtown areas are highly associated with lower vehicle mode shares. A study in San Francisco found vehicle mode shares to 3 pharmacies in UC areas between 8% and 13%, while 17 similar establishments in San Francisco suburbs had vehicle mode shares between 54% and 98%. UC locations had significantly higher land use mixes, on-street/paid parking, smaller site development setbacks, and pedestrian access (Schneider 2011). A separate study on commuting modes in the San Francisco Bay Area found that downtown stations in Oakland, Berkeley and San Jose had the highest use of commuter rail (Dill 2003).

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

***Transit-Oriented Development***

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

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

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

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

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

***Mixed-Use Developments***

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

Research has attempted to address this issue, but at this point in time is not comprehensive. Internal capture rates at mixed-use developments along the MAX corridor in Portland, Oregon were found to be between 2% and 20% of all trips to or from retail establishments during the PM peak hour and between 4% and 28% of all daily trips to or from retail (Lapham 2001). Another project—NCHRP 8-51, "Enhancing Internal Trip Capture Estimation for Mixed-Use Developments"—provides a method to estimate internal capture rates based on site characteristics and urban context. This research found that the highest levels of internal capture were at sites with diverse and balanced land use mixing, compact (or dense) development, and high connectivity between establishments, providing further agreement with the built environment measures identified in section 2.3.1.

***Suburban City Centers and Corridors***

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

## 2.4 SUMMARY

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

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

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

In this study, we present a method to adjust *ITE Trip Generation Handbook* rates based on urban context. The model presented is based on an extensive data collection effort at 78 establishments in the Portland, Oregon region. An adjustment model to *ITE Trip Generation Handbook* rates based on context is useful in many ways. A model of this type provides an off-the-shelf alternative to *ITE Trip Generation Handbook* rates that accompanies and improves upon other alternatives introduced earlier in this literature review. It also contributes an evaluation of *ITE Trip Generation Handbook* rates to existing establishments in the Portland region. By focusing on context, built environment measures, both individual measures and combinations of them, can be assessed for impacts on travel behavior to provide a contribution to that body of knowledge. The model effectively develops a local rate to the Portland region for the land uses studied. This method also provides a basis for other regions to develop adjustments to ITE based on local urban contexts. The study design underlying the method is presented in the next chapter, followed by a comparison to ITE rates and an analysis that introduces the model.

# 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. 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 visitor traffic during the 4:00PM to 5:00PM hour.

Information collected at each location included: (1) visitor 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.

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

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 included in the sampling analysis[4] to ensure that selected sites represented the entire spectrum of the urban landscape found in the Portland metropolitan region. Five unique classifications of area type resulted:

- 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)

[4] K-means clustering analysis was performed with the statistical package of R on built environment measures to classify area type. Variables in the cluster analysis include intersection density, block size, percent of dwellings that are single-family detached, percent of employment that is retail and percent of parcel lot coverage by buildings.

- Suburban Areas (the least densely developed areas)

Individual establishments from each of the five different area types were recruited to participate in the study. Oversampling of establishments was done 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 (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 are 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 different market segment than those patrons of national chains. 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 |

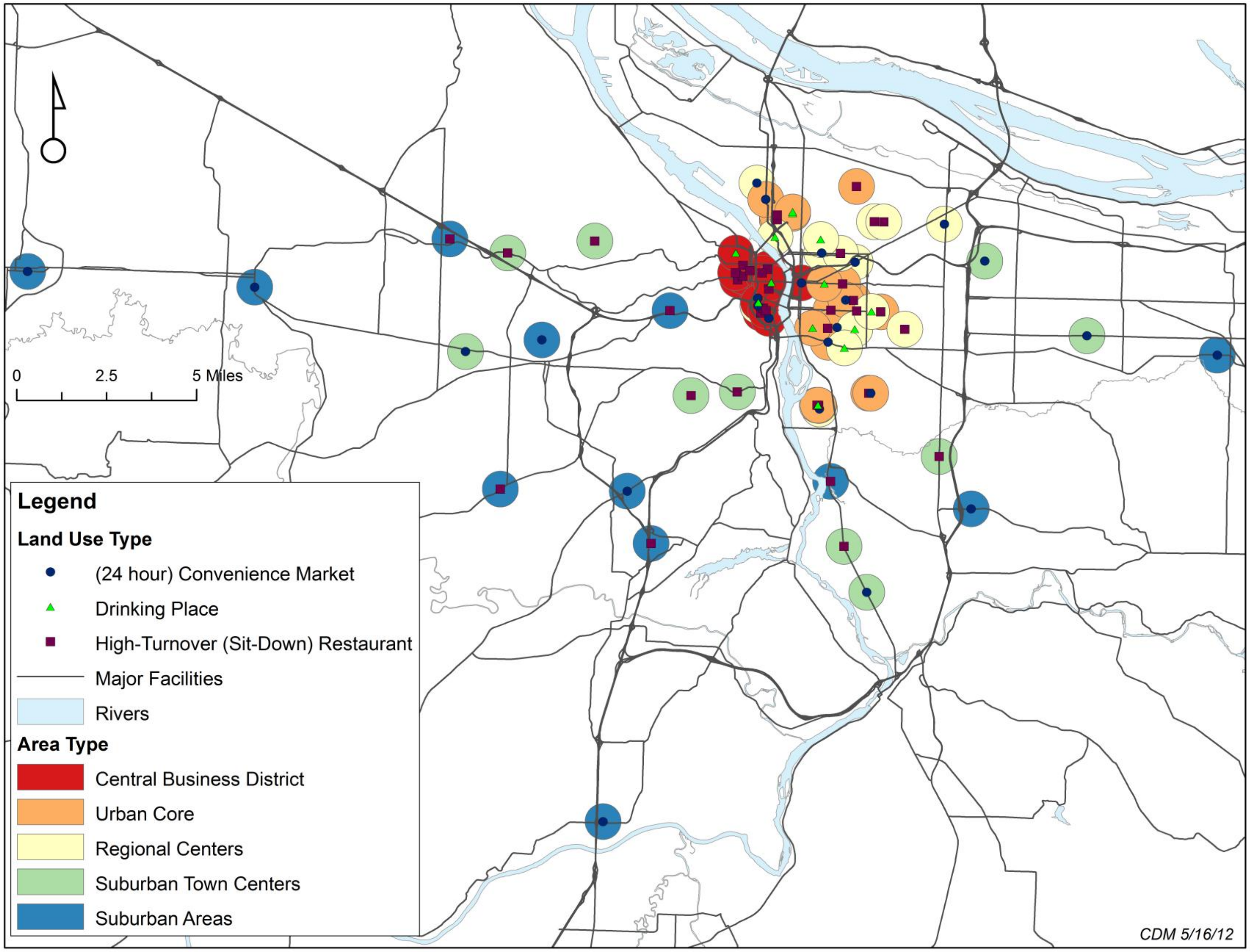


**Figure 3-1. Locations of Survey Establishments**

## 3.2 SURVEY DATA

This section details the methods used for survey data collection and provides a description of the survey sample. The surveys were administered by intercepting visitors as they leave the establishment. Two survey options were offered to visitors: (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 visitors 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 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**

| | | | | Response Rates | | |
|---|---|---|---|---|---|---|
| **Land Use** | **Establishments (N)** | **Long Surveys (N)** | **Short Surveys (N)** | **Long Survey** | **Short and Long Survey** | **Total** |
| 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 Census and 2010 3–year American Community Survey (ACS) data for the Portland metropolitan statistical 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/ACS Portland (MSA) |
|---|---|---|
| Median household income per year | $50,000 - $99,000 | $55,618 |
| Average household income per year | $50,000 - $99,000 | $72,200 |
| Median Age | 25-34 | 36 |
| Male respondents | 57% | 49% |
| Average # vehicles per household | 1.6 | 1.7 |
| Average # bicycles per household | 1.7 | NA |
| Average # transit passes per household | 0.5 | NA |
| Average # adults per household | 2.2 | NA |
| Percentage of households with children | 29% | 33% |
| Average household Size | 2.5 | 2.5 |

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

### *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.

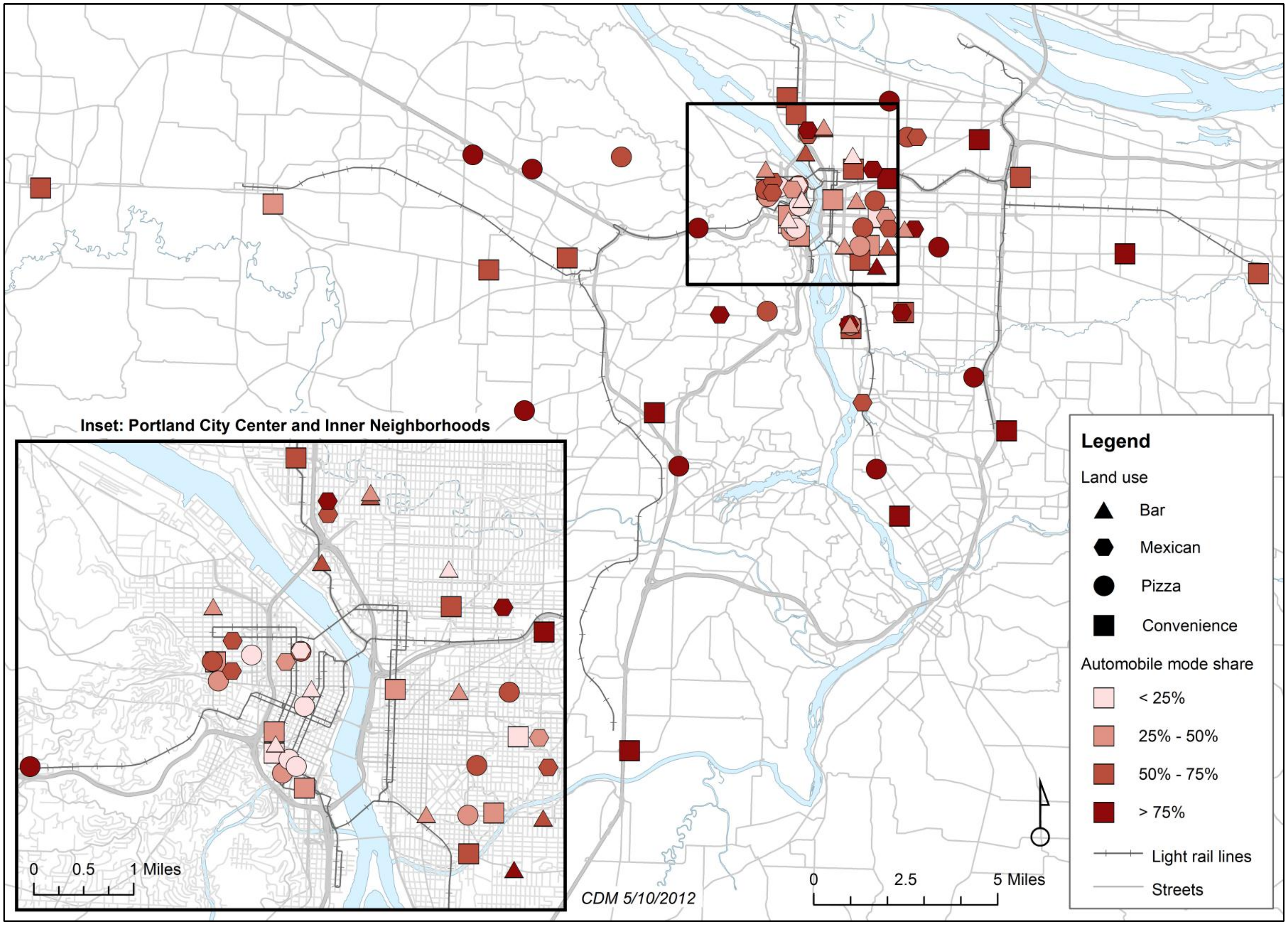


**Figure 3-2. Automobile Mode Share of Survey Establishments**

### *Vehicle occupancy*

Table 3-6 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 3-6. 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 |

### *Sample Comparison to Regional Data*

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 3-7 and Table 3-8 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 3-7. OHAS Comparison: Automobile Mode Share**

| Land Use | TGS Data | 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 3-8. OHAS Comparison: Vehicle Occupancy**

| Land Use | TGS Data | 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

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

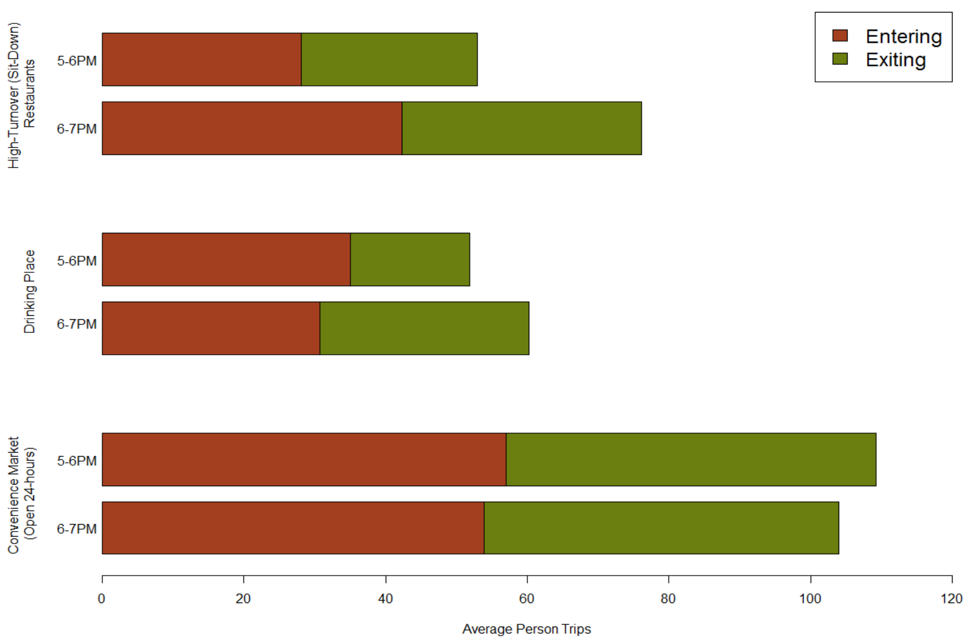


**Figure 3-3. Observed Person Trips by Establishment Type**

Figure 3-4 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.

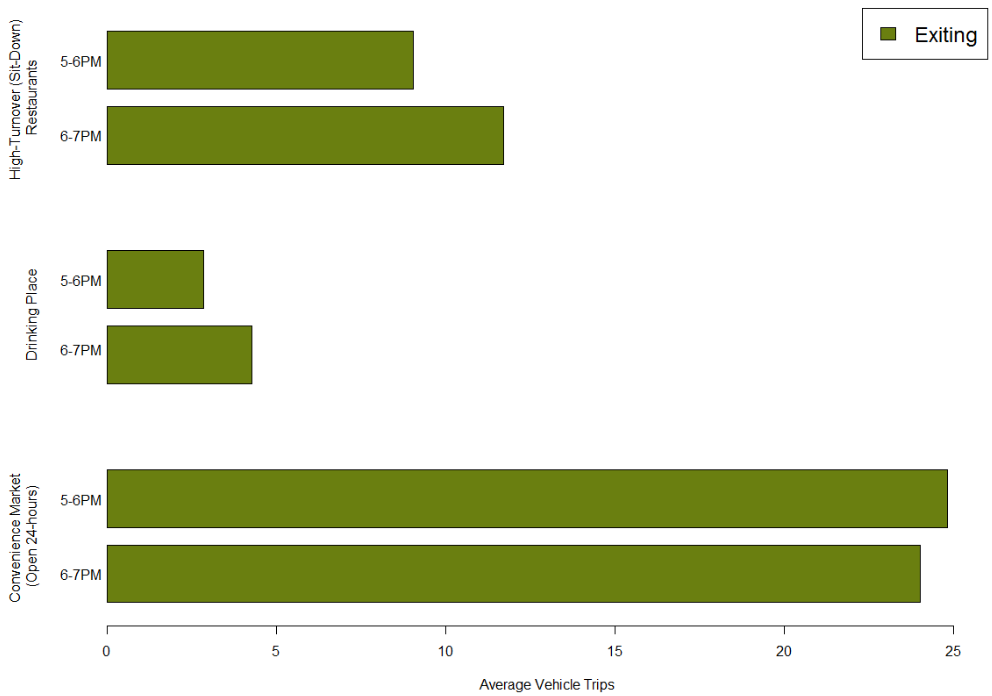


**Figure 3-4. Observed Vehicle Counts by Establishment Type**

Table 3-9 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 visitor traffic during the 5:00 – 7:00 PM hour.

**Table 3-9. 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 directly from the establishment sites and from archived data sources in order to support our analysis of context. The archived 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 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.

### 3.4.2 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 3-5 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.

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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 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 3-5 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.

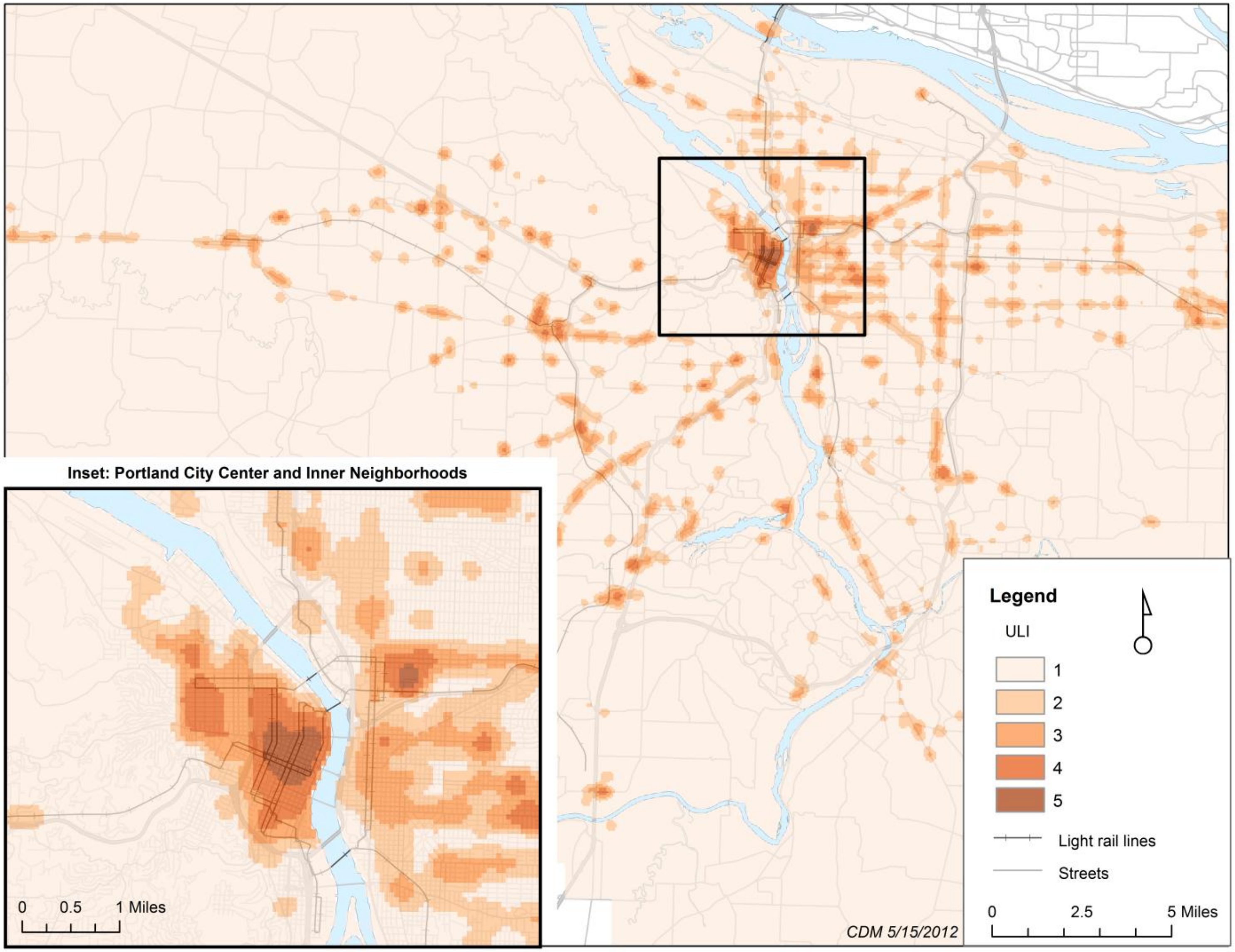


**Figure 3-5. Urban Living Infrastructure Context Tool**

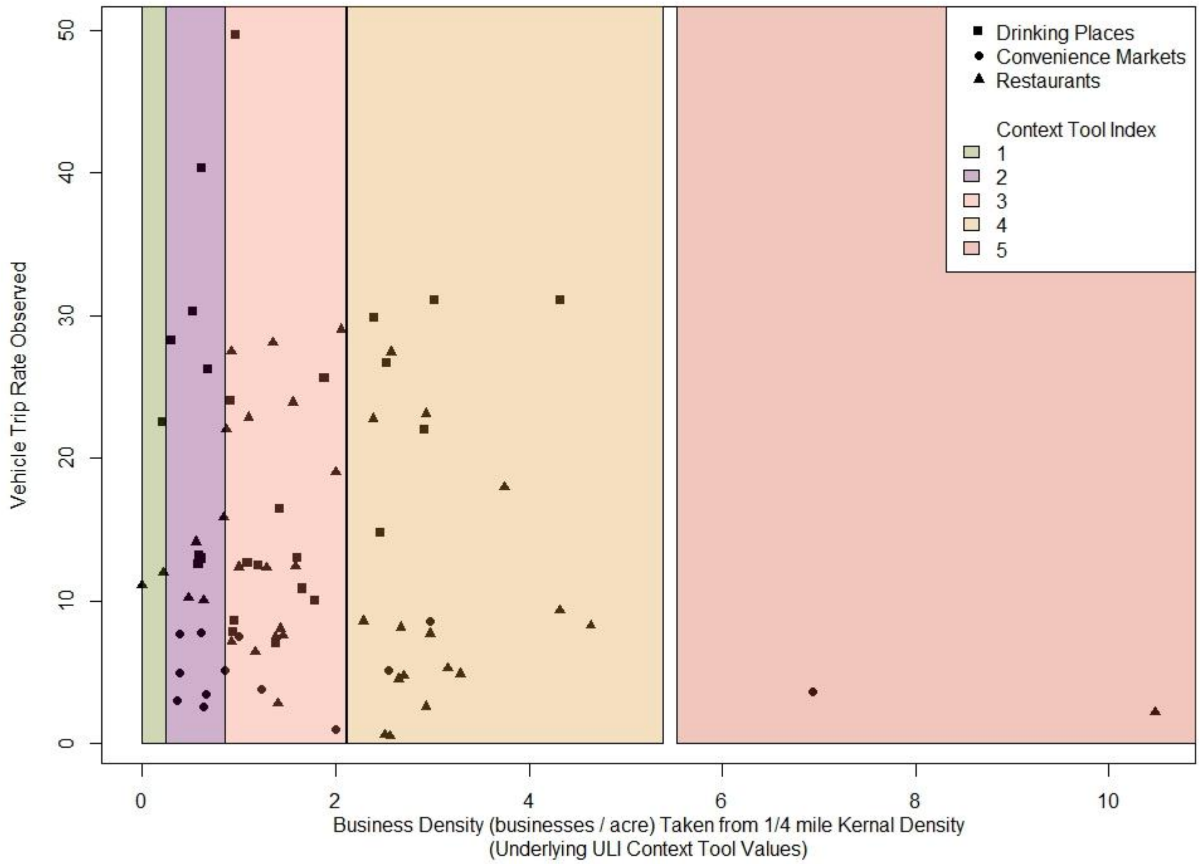


**Figure 3-6. Context Tool Index Ranges and Observed Vehicle Trip Rates: ULI Business Density**

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 3-7. The ULI score found at this establishment point is 3, while the average ULI score within the establishment buffer is 2.19.

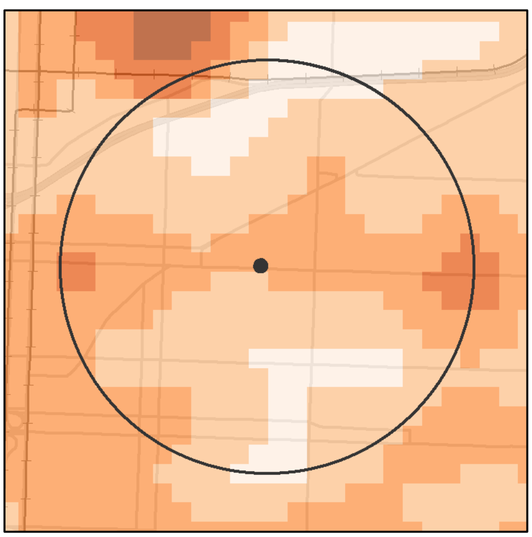

**Figure 3-7. Example Establishment with ½-mile Buffer and ULI Context Tool**

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 3-8 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.

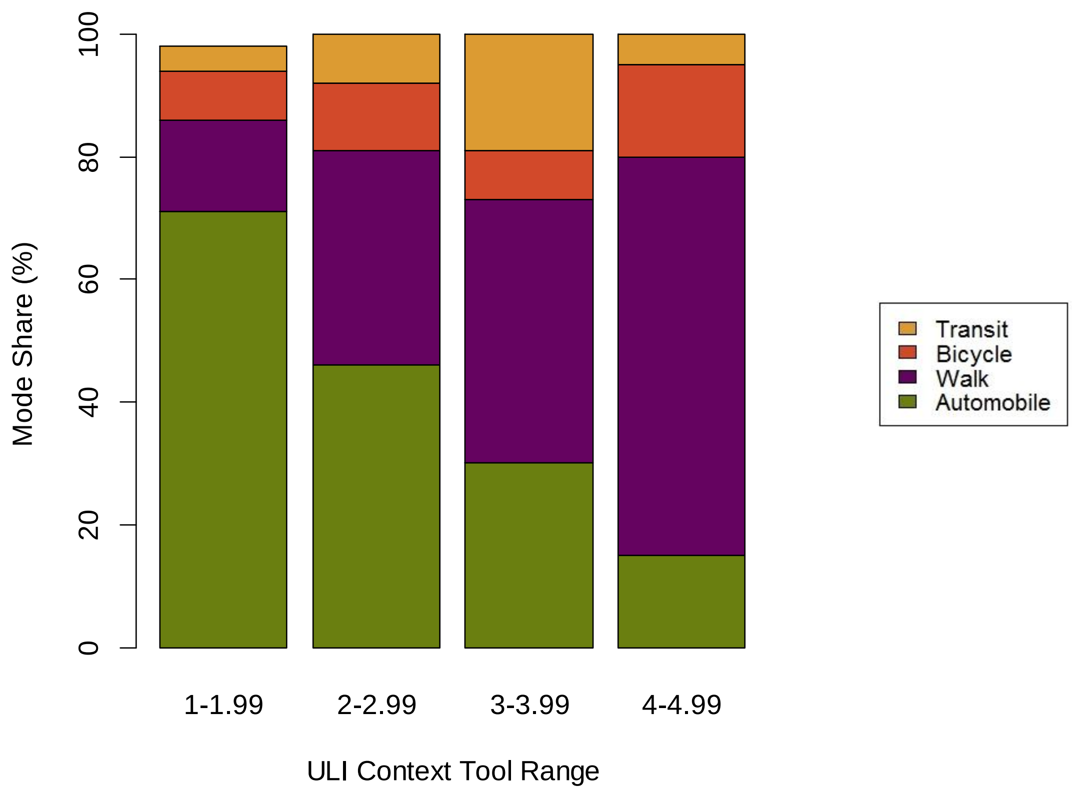


**Figure 3-8. Average Mode Share by ULI Range (Metro Context Tool)**

### 3.4.3 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 3-10 and are described below.

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

**Table 3-10. Built Environment Measures List and Data Source**

| Measure | Units | Data Source* | Average | Range | | |
|---|---|---|---|---|---|---|
| Number of Transit Corridors | Number of transit bus/rail lines within ½-mile | Light-rail and Bus Stop layer (RLIS, 2010) | 24 | 0 | to | 112 |
| People Density | Residents and employees per acre | ESRI Business Analyst (2010) and Multifamily/Household layers (RLIS, 2010) | 34 | 7 | to | 164 |
| Number of High-Frequency Transit Stops | Number of stops within ½-mile with headways under 15 Minutes | Bus Stop layer (RLIS, 2010) and TriMet schedules (2011) | 47 | 0 | to | 244 |
| Employment Density | Employees per acre | ESRI Business Analyst (2010) | 21 | 0.4 | to | 141 |
| Lot Coverage | Percent | Tax lot and Building Layers (RLIS, 2010) | 28% | 9% | to | 67% |
| Length of Bike Facilities | Miles | Bike Route layer (RLIS, 2010) | 6.7 | 0.2 | to | 13.8 |
| Access to Rail | Presence of rail station within ½-mile | Light-rail Stop layer (RLIS, 2010) | 45% | No | to | Yes |
| Intersection Density | Intersections per acre | Lines file (TIGER 2009) | 0.22 | 0.01 | to | 0.56 |
| Urban Living Infrastructure | Density index based on the number of retail & service establishments within ½ mile | Metro Context Tool, Portland Metro | 2.1 | 1.0 | to | 4.2 |

* RLIS: Regional Land Information System, Portland Metro. TriMet: Regional transit provider.

**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]

[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 PERSON TRIP RATE ASSUMPTION

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. See Figure 4-1 for an illustrated example. 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.

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. In every case, we failed to reject the null hypothesis (all p-values > 0.189); average person trip rates per building area were not significantly different across urban contexts. This result suggests that 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.

[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).

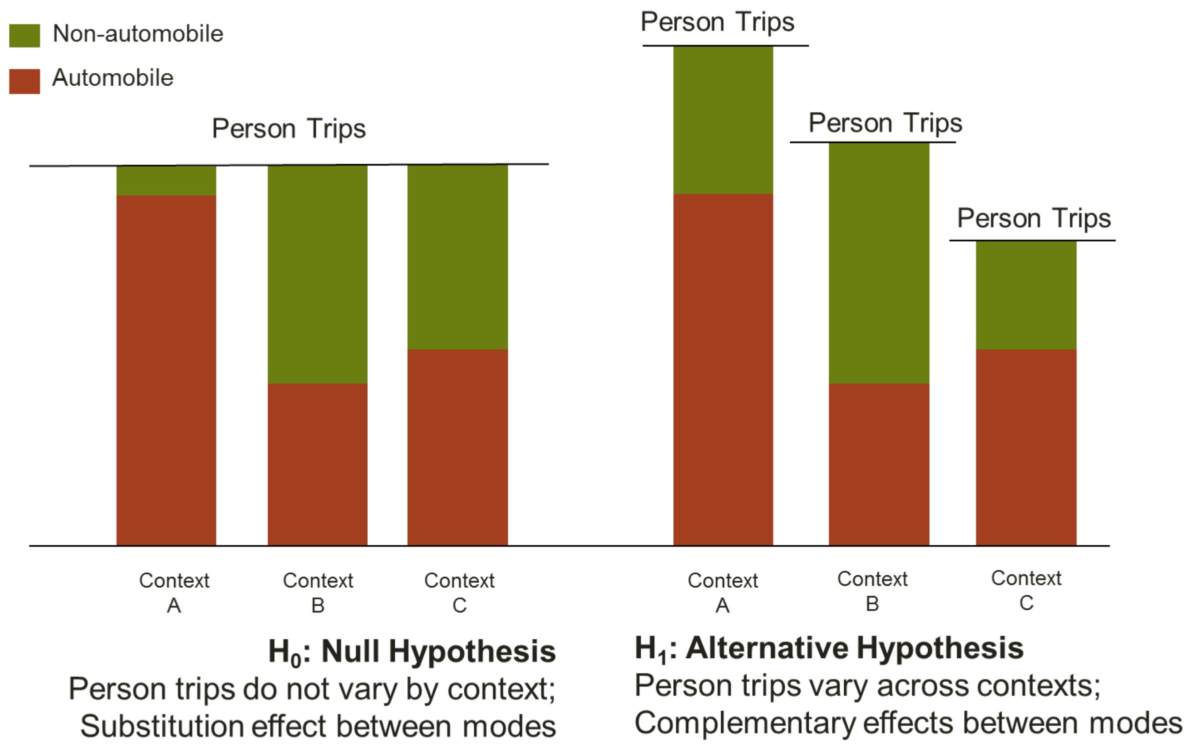


**Figure 4-1. Do Person Trip Rates Vary Across Contexts?**

## 4.2 COMPARISON OF OBSERVATIONS WITH ITE DATA

This section details a comparison between the Trip Generation Study (TGS) observations and the ITE Trip Generation vehicle trip rates (Institute of Transportation Engineers 2008) using the *ITE Trip Generation Handbook* methodology (Institute of Transportation Engineers 2004). To compare TGS observed 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**

$$VEH\ TRIP\ RATE_{TGS} = \frac{(P_{IN} + P_{OUT})_{TGS}(\%AUTO)_{TGS}}{VEH\ OCC_{TGS}} \times \frac{1}{1000\ Sq.Ft.Area}$$

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 vehicle trips 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

[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.

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 4-1 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 4-2). 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 4-1 and Table 4-2, 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 visitors 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.

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[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.

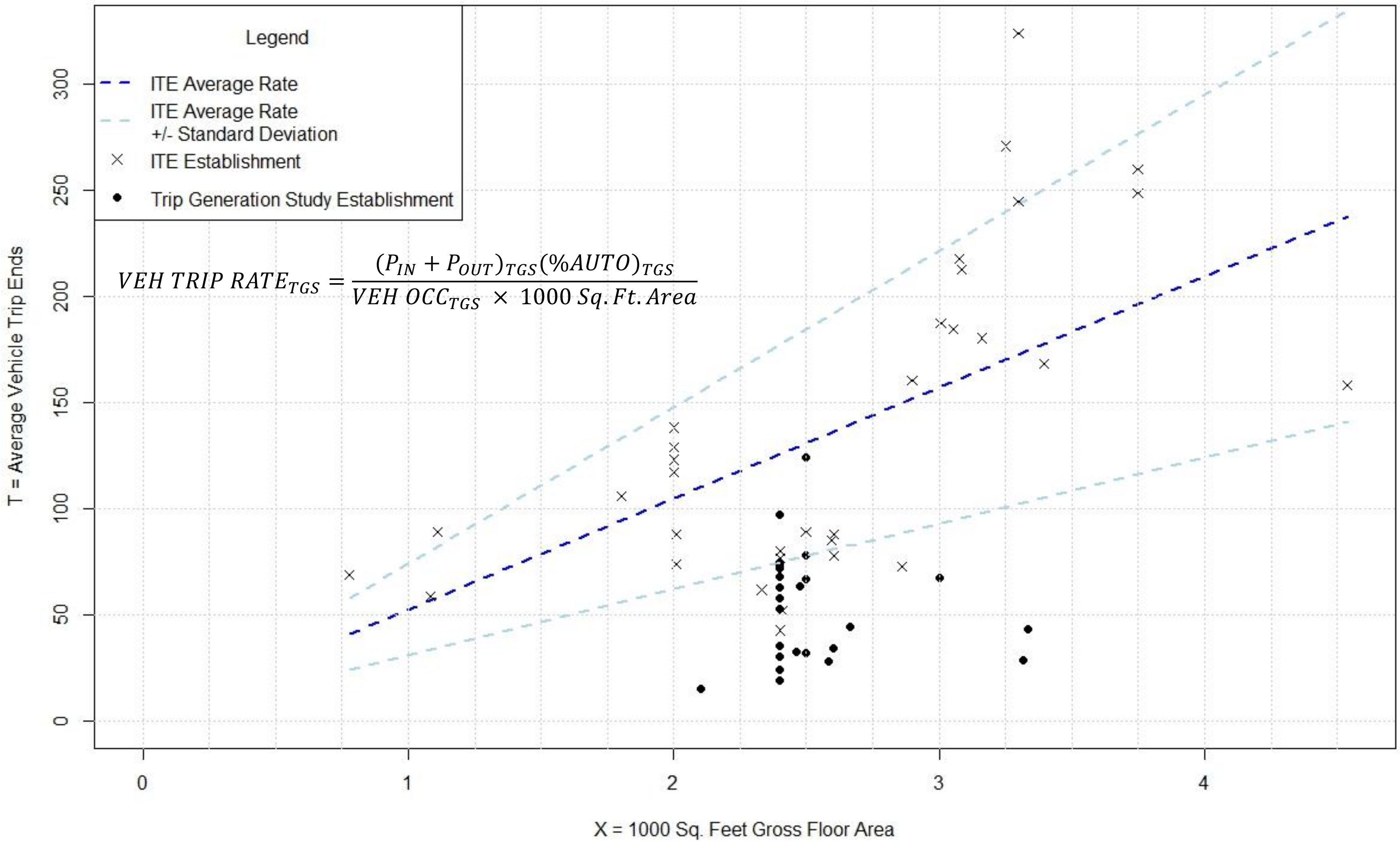


**Figure 4-2. Convenience Market (Open 24-hours) (LU 851): Weekday, Peak Hour of Adjacent Street Traffic, 4-6PM - TGS Vehicle Trips and ITE Vehicle Trip Rates Data**

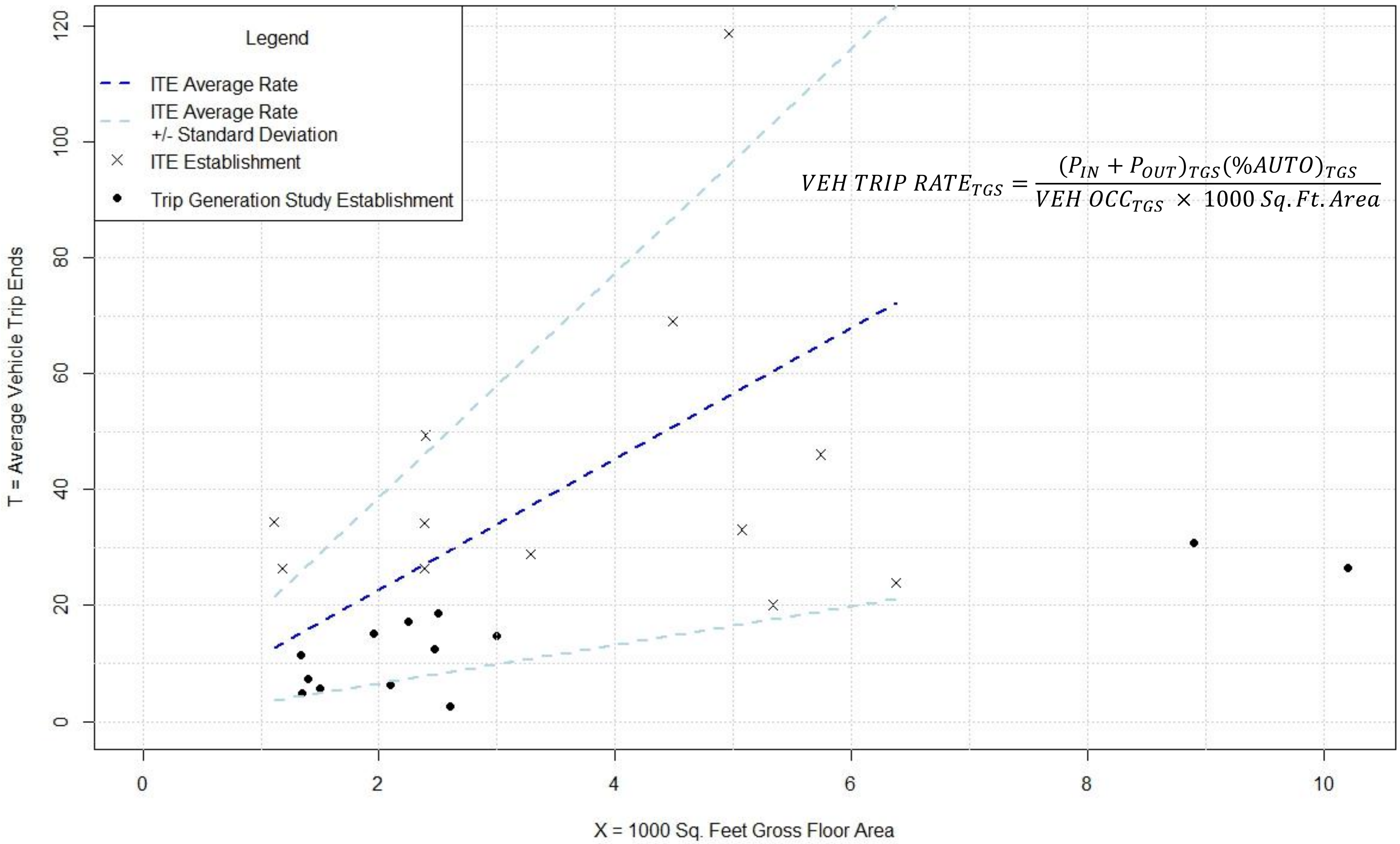


**Figure 4-3. Drinking Places (LU 925): Weekday, Peak Hour of Adjacent Street Traffic, 4-6PM - TGS Vehicle Trips and ITE Vehicle Trip Rates Data**

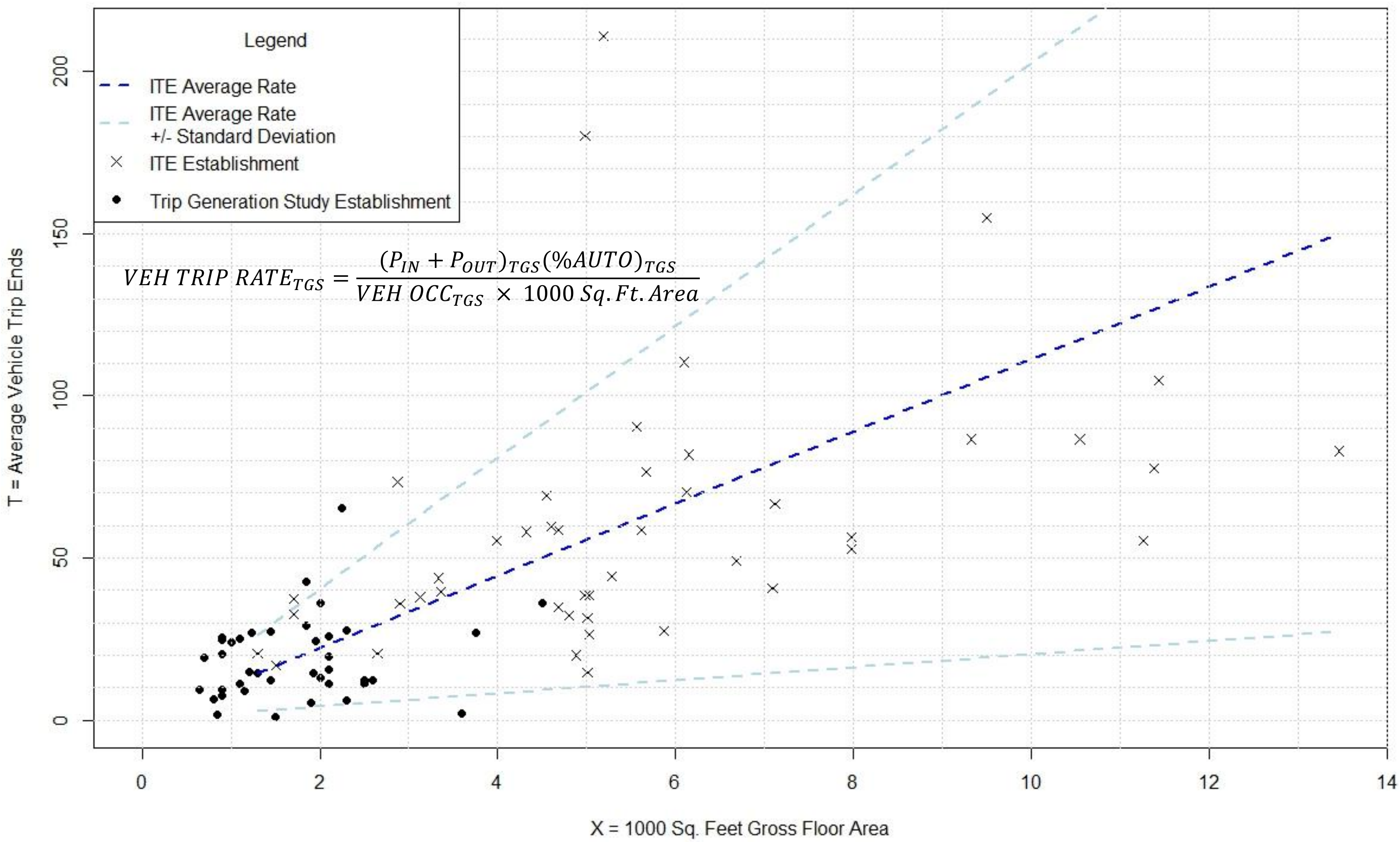


**Figure 4-4. High-Turnover (Sit-Down) Restaurants (LU 932): Weekday, Peak Hour of Adjacent Street Traffic, 4-6PM - TGS Vehicle Trips and ITE Vehicle Trip Rates Data**

**Table 4-1. 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 4-2. 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; <br><br> 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 that the criterion is met in this study.

## 4.3 URBAN CONTEXT ADJUSTMENT (UCA) MODEL

In this section, we introduce a method to estimate an Urban Context Adjustment (UCA) to ITE vehicle rates for the land uses: high-turnover (sit-down) restaurants (LU 932), convenience markets (LU 851), and drinking places (LU 925). 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 UCA vehicle trip rate for drinking places is significantly lower than the ITE vehicle trip rate and the average UCA trip rate for restaurants is higher than the provided ITE vehicle trip rate (see Table 4-1 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 UCA model below predicts the difference between ITE vehicle trip rates and UCA 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 UCA 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 UCA 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. Urban Context Adjustment Model**

$$\boldsymbol{ADJ} = 0.643 - 3.29 * \boldsymbol{ULI} + 7.41 * \boldsymbol{Restaurant} - 26.04 * \boldsymbol{Convenience}$$

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

$$\boldsymbol{ULI} \equiv \text{Average of ULI values within establishment buffer}$$

$$\boldsymbol{Restaurant} = \begin{Bmatrix} 1, \text{ if ITE Land Use} = 932\text{: High-Turnover (Sit-Down)Restaurant} \\ 0, \text{ if ITE Land Use} \neq 932\text{: High-Turnover (Sit-Down)Restaurant} \end{Bmatrix}$$

$$\boldsymbol{Convenience} = \begin{Bmatrix} 1, \text{ if ITE Land Use} = 851\text{:Convenience Market (Open 24-hours)} \\ 0, \text{ if ITE Land Use} \neq 851\text{:Convenience Market (Open 24-hours)} \end{Bmatrix}$$

$$\boldsymbol{Adjusted\ R^2} = 0.763$$

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 4-3 and Figure 4-5 provide some additional guidance on the range of observed values for which this equation is valid. Table 4-3 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 4-3. 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

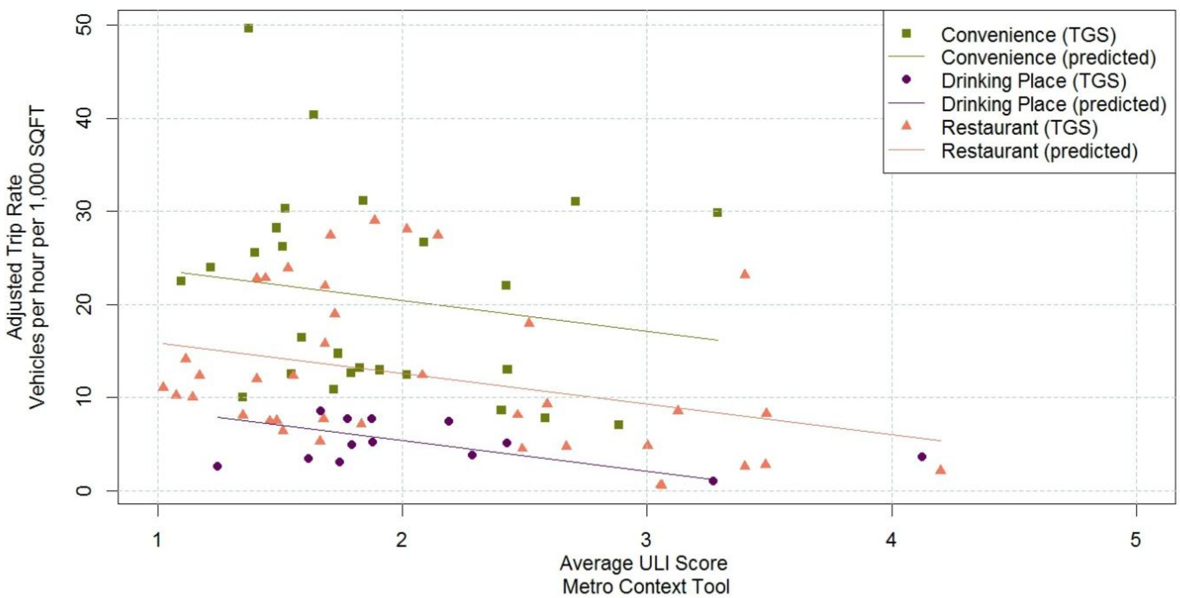


**Figure 4-5. Urban Context Adjustment to ITE Vehicle Trip Rate for the PM Peak Hour of the Facility by Average ULI Score[18]**

## 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 4-4 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 4-4. 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 acre) | 0.77 | 0.756 | -14.35** | -26.85*** | 6.47** | -2.20 |

***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 4-5). Additionally, Table 4-5 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 4-5. 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 4-6 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). The built environment measures shown here were calculated for all locations observed within the Metro Context Tool ULI Indicator – a grid of more than 383,000 locations covering the Metro area. This table shows the associated mean values of these other built environment attributes found in the same buffer.

For areas outside of the Portland area, where a measure of ULI may not be available, Table 4-6 is provided to assist in classifying the level of urbanization of an area. For example, if a planner desires a non-automobile mode share of approximately 66%, they may be looking at mode shares similar to an average ULI value range between 3 and 3.99 (see Figure 3-8). By using Table 4-6, the planner can assess the necessary built environment components to lay the ground work to achieve these high non-automotive mode shares, e.g. approximately 25 ± 10 transit corridors, 35 ± 6% lot coverage, or 103 ± 33 residents and employees per acre. Planners can then use these metrics to determine how they may be able to change the built environment to achieve the goals they set for the region.

Additionally, provided an absence of detailed local data on local business establishments to derive a regional ULI index in regions outside of Portland, Table 4-6 may also serve as a means for classifying the region into ULI categories for application of the UCA methodology.

**Table 4-6. Built Environment Measures Correlated with Observed Average ULI Score**

| Built Environment Measure | Average ULI Score | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 - 1.99 | | 2 - 2.99 | | 3 - 3.99 | | 4 - 4.99 | | ALL | |
| | N = 379832 | | N = 2907 | | N = 387 | | N = 95 | | N = 383221 | |
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| **Number of Transit Corridors (count)** | 1 | 2 | 9 | 6 | 25 | 10 | 34 | 4 | 1 | 2 |
| **People Density (residents and employees per acre)** | 4 | 5 | 31 | 16 | 103 | 33 | 161 | 13 | 4 | 7 |
| **Number of High-Frequency Transit Routes (count)** | 2 | 7 | 46 | 29 | 132 | 49 | 196 | 34 | 3 | 10 |
| **Employment Density (employees per acre)** | 1 | 2 | 19 | 16 | 81 | 35 | 141 | 14 | 1 | 5 |
| **Lot Coverage (%)** | 1.8 | 3.6 | 18.8 | 9.3 | 35.1 | 6.5 | 42.4 | 5.2 | 2.0 | 4.1 |
| **Length of Bike Facilities (mi.)** | 2.0 | 1.7 | 7.3 | 2.4 | 11.7 | 0.9 | 13.2 | 0.5 | 2.1 | 1.8 |
| Access to Rail Station (binary) | 4% | 20% | 66% | 47% | 100% | 0% | 100% | 0% | 5% | 21% |
| **Intersection Density (number per acre)** | 0.07 | 0.17 | 1.01 | 0.56 | 1.72 | 0.21 | 2.11 | 0.11 | 0.08 | 0.20 |

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

# 5.0 VERIFICATION OF METHODOLOGY

The purpose of this chapter is to test the methodology developed within this report and to verify the applicability of the TGS methodology. Additional data were collected at 47 establishment locations solely for verification. These sites were selected and studied subsequently to the UCA 78 establishments in the report.

## 5.1 DATA COLLECTION

The data collection for the verification effort included vehicle entering and exiting counts for the peak hour between 5-6PM for 47 additional establishment locations. For those locations with shared parking lots or for locations with on-street parking, persons leaving/returning to their vehicle were tracked to verify that their trip was tied to the establishment being surveyed. All 47 establishments include the three land uses considered in the TGS methodology: Land Use Code (LU851): Convenience Markets (Open-24 hours); (LU925) Drinking Places, (LU932) High-Turnover (Sit-Down) Restaurants. The verification data collection took place between April and May of 2012. Gross floor area in square feet was estimated using Google Earth.

Approximate temperature and rain were recorded. There were no vehicle counts taken on days of heavy rain or abnormally cool temperatures. Two sites had small construction occurring outside of the establishment, but neither limited the access to the location. Construction activity was not occurring during the PM peak hour studied. Sites with one or no vehicle trips observed during the peak hour were examined further for abnormalities at the establishment or location. Four sites were removed from the verification data set due to oddities in the location or of the establishment itself (e.g. newly established restaurant, misleading parking situation, etc.).

## 5.2 VERIFICATION

Of the total 47 establishments in the verification study, 34 fall within the bounds of the TGS methodology for establishment size and average ULI. Verification of the TGS methodology includes analysis on these 34 locations. The additional 12 locations were collected to examine the applicability of the TGS methodology beyond the bounds established by the UCA data collection. Table 5-1 Table 5-1shows the distribution of establishments across average ULI values for the UCA establishments in the study and the additional verification sites.

Table 5-2 and Table 5-3 compare estimated vehicle trips using the UCA to the observations from the 34 verification sites. Based on these results, convenience markets are the land use that benefits most from the UCA. For 6 of the 10 convenience markets included in the verification process, UCA overestimated vehicle trips by an average of 31%. While this is still an overestimation, it represents a significant improvement over ITE, which overestimates by 169% (see Table 5-3).

For 9 of the 12 drinking places, the UCA provides better estimates of vehicle trips than *ITE Trip Generation Handbook*. Although more drinking places are underestimated using UCA, the average rate of underestimation tends to be similar to that of the ITE methodology. We also observed an overall improvement in the mean squared error of vehicle trip rates between UCA estimates and observed verification data points compared with ITE.

Based upon this verification, the UCA provides a consistent, yet conservative, estimate of vehicle trips for all three land uses studied in this research. The UCA shows significant improvement to the *ITE Trip Generation Handbook methodology*, particularly for convenience markets (LU 850) and drinking places (LU 925). For restaurants, it appears that the UCA offers only marginal improvement over ITE.

**Table 5-1. Establishment Counts for UCA and Verification Data Collection, by Land-Use Type and Average ULI Range**

| | **Convenience Markets (Open 24-hours) (851)** | | **Drinking Places (925)** | | **High-Turnover (Sit-Down) Restaurants (932)** | | **Total** | |
|---|---|---|---|---|---|---|---|---|
| **Average ULI Range** | UCA | Verification | UCA | Verification | UCA | Verification | UCA | Verification |
| 1-1.99 | 17 | 7 | 8 | 8 | 22 | 8 | 47 | 23 |
| 2-2.99 | 8 | 3 | 3 | 4 | 8 | 4 | 19 | 11 |
| 3-3.99 | 1 | 0 | 1 | 0 | 8 | 0 | 10 | 0 |
| 4-4.99 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0 |
| **Total** | **26** | **10** | **13** | **12** | **39** | **12** | **78** | **34** |

**Table 5-2. Comparison of Vehicle Trip Rates – ITE and Urban Context Adjustment (UCA) rates to Observed Verification Data Collected[19,20]**

| | | Convenience Market (Open 24-hours) | | Drinking Place | | High-Turnover (Sit-Down) Restaurants | |
|---|---|---|---|---|---|---|---|
| | | **LU (851)** | | **LU (925)** | | **LU (932)** | |
| Sample Size | | 10 | | 12 | | 12 | |
| | | **Mean** | **St. Dev.** | **Mean** | **St. Dev.** | **Mean** | **St. Dev.** |
| Trip Rate | Observed | 19.4 | 6.1 | 6.9 | 3.3 | 12.0 | 5.9 |
| | UCA | 21.4 | 1.5 | 5.7 | 1.4 | 13.4 | 1.8 |
| | ITE | 52.4 | 21.4 | 11.3 | 8.0 | 11.2 | 9.1 |
| Difference to Observed | UCA | 2.0 | 6.2 | -1.1 | 3.0 | 1.4 | 5.4 |
| | ITE | 33.0 | 6.1 | 4.5 | 3.3 | -0.9 | 5.9 |
| Absolute Difference to Observed | UCA | 5.2 | 3.5 | 2.0 | 2.5 | 4.1 | 3.2 |
| | ITE | 33.0 | 6.1 | 4.9 | 2.7 | 4.4 | 3.2 |
| Mean Squared Error | UCA | 38 | | 10 | | 29 | |
| | ITE | 1120 | | 30 | | 33 | |
| Average Percent Error | UCA | 32% | | 31% | | 68% | |
| | ITE | 195% | | 119% | | 63% | |

**Table 5-3. Comparison of Vehicle Trip Rates – ITE and UCA rates to Verification Data Collection – Differences in Rates for Establishments Underestimated and Overestimated**

| | | Convenience Market (Open 24-hours) | | Drinking Place | | High-Turnover (Sit-Down) Restaurants | |
|---|---|---|---|---|---|---|---|
| | | **LU (851)** | | **LU (925)** | | **LU (932)** | |
| Sample Size | | 10 | | 12 | | 12 | |
| Number of times UCA is closer than ITE | | 10 (100%) | | 9 (75%) | | 7 (58%) | |
| | | **Average Difference in Trip Rates** | **Percent of Observed Trip Rate** | **Average Difference in Trip Rates** | **Percent of Observed Trip Rate** | **Average Difference in Trip Rates** | **Percent of Observed Trip Rate** |
| Underestimated | UCA | -4.0 | -21% | -2.7 | -40% | -4.5 | -38% |
| | ITE | --- | --- | -2.3 | -33% | -4.8 | -40% |
| Overestimated | UCA | 5.9 | 31% | 1.1 | 16% | 4.4 | 37% |
| | ITE | 33.0 | 169% | 5.1 | 74% | 4.7 | 39% |

Additionally, some of the establishments studied in the verification data collection and classified as drinking places may also qualify for classification as a restaurant. These locations are often referred to as "brew pubs". The composition of trip purposes for these types of establishments ranged from those observed at both drinking places and restaurants. By excluding the brew pub-

[19] The mean squared error is calculated by averaging the squared difference between all estimated and observed data values.
[20] The average percent error is calculated by taking the absolute difference between estimated and observed data values, dividing by the observed value and averaging across each land use.

style drinking places from comparison, the deviation between the TGS estimate and the observed trip rates improves further.

**Table 5-4. Comparison of Vehicle Trip Rates – ITE and TGS rates to Verification Data Collection – Differences between All Drinking Places and Non-Brew Pub Drinking Places**

| | | Drinking Place | | Drinking Place (without Brew Pub-style locations) | |
|---|---|---|---|---|---|
| Sample Size | | 12 | | 7 | |
| | | Average Difference in Trip Rates | Percent of Observed Trip Rate | Average Difference in Trip Rates | Percent of Observed Trip Rate |
| Overall | UCA | -1.1 | -17% | -0.4 | -7% |
| | ITE | 4.5 | 65% | 4.8 | 70% |
| Underestimated | UCA | -2.7 | -40% | -1.2 | -18% |
| | ITE | -2.3 | -33% | --- | --- |
| Overestimated | UCA | 1.1 | 16% | 0.6 | 8% |
| | ITE | 5.1 | 74% | 4.8 | 70% |

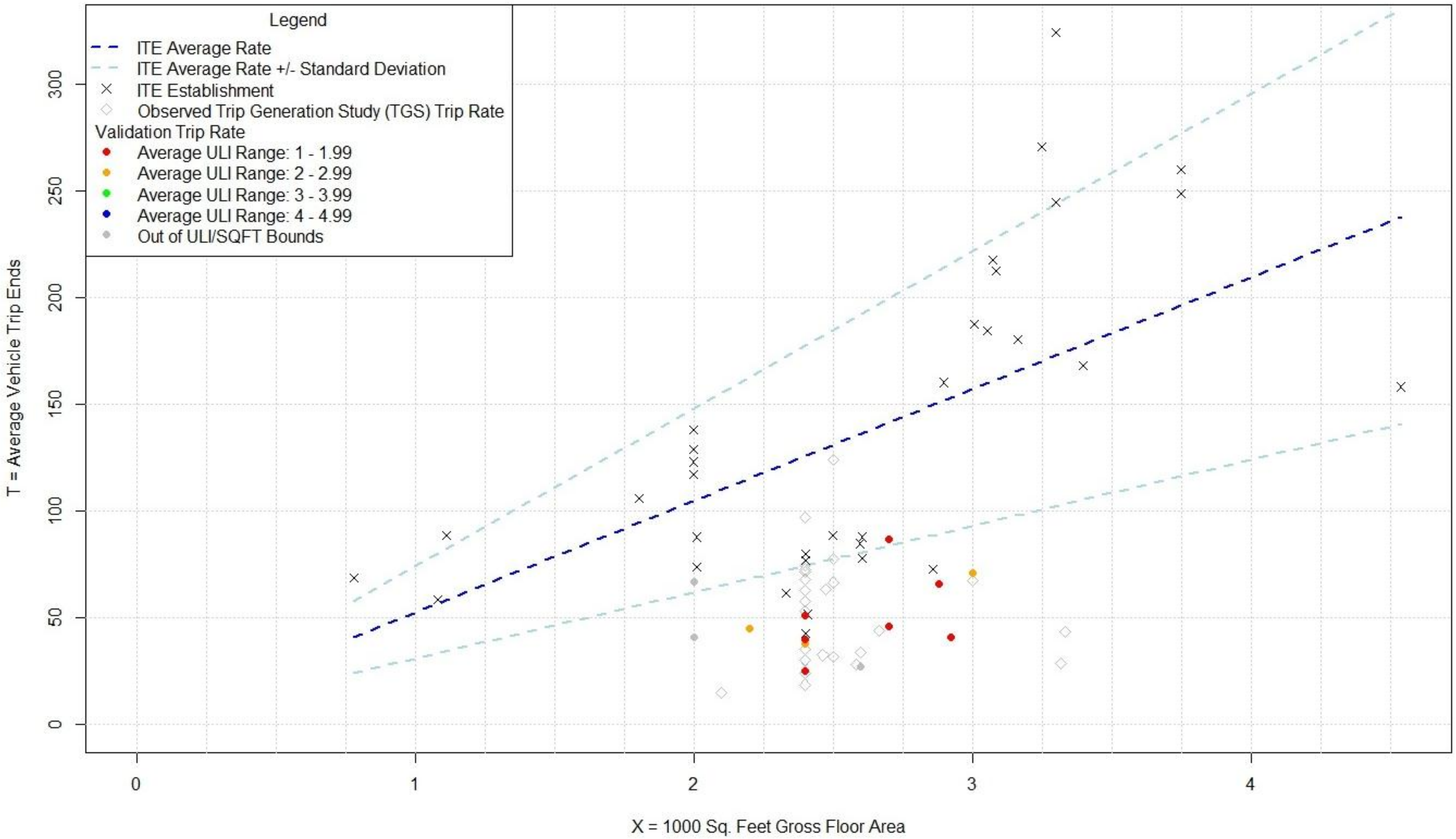


**Figure 5-1. Convenience Market (Open 24-hours) (LU 851): Weekday, Peak Hour of Adjacent Street Traffic, 4-6PM – Trip Ends Data from UCA TGS methodology development, Validation Data Collection and ITE Vehicle Trip Rates Data**

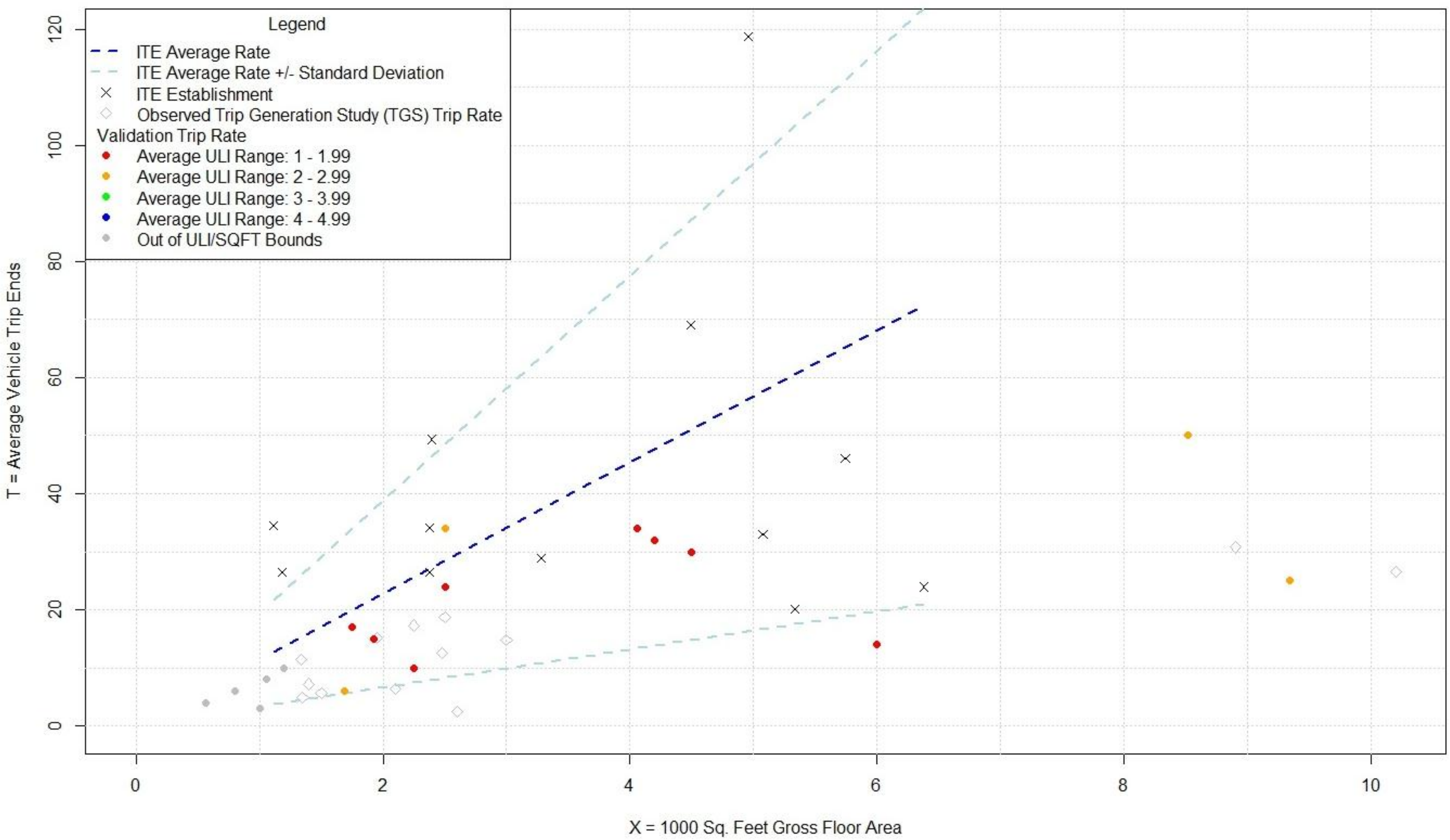


**Figure 5-2. Drinking Place (LU 925): Weekday, Peak Hour of Adjacent Street Traffic, 4-6PM – Trip Ends Data from UCA TGS methodology development, Validation Data Collection and ITE Vehicle Trip Rates Data**

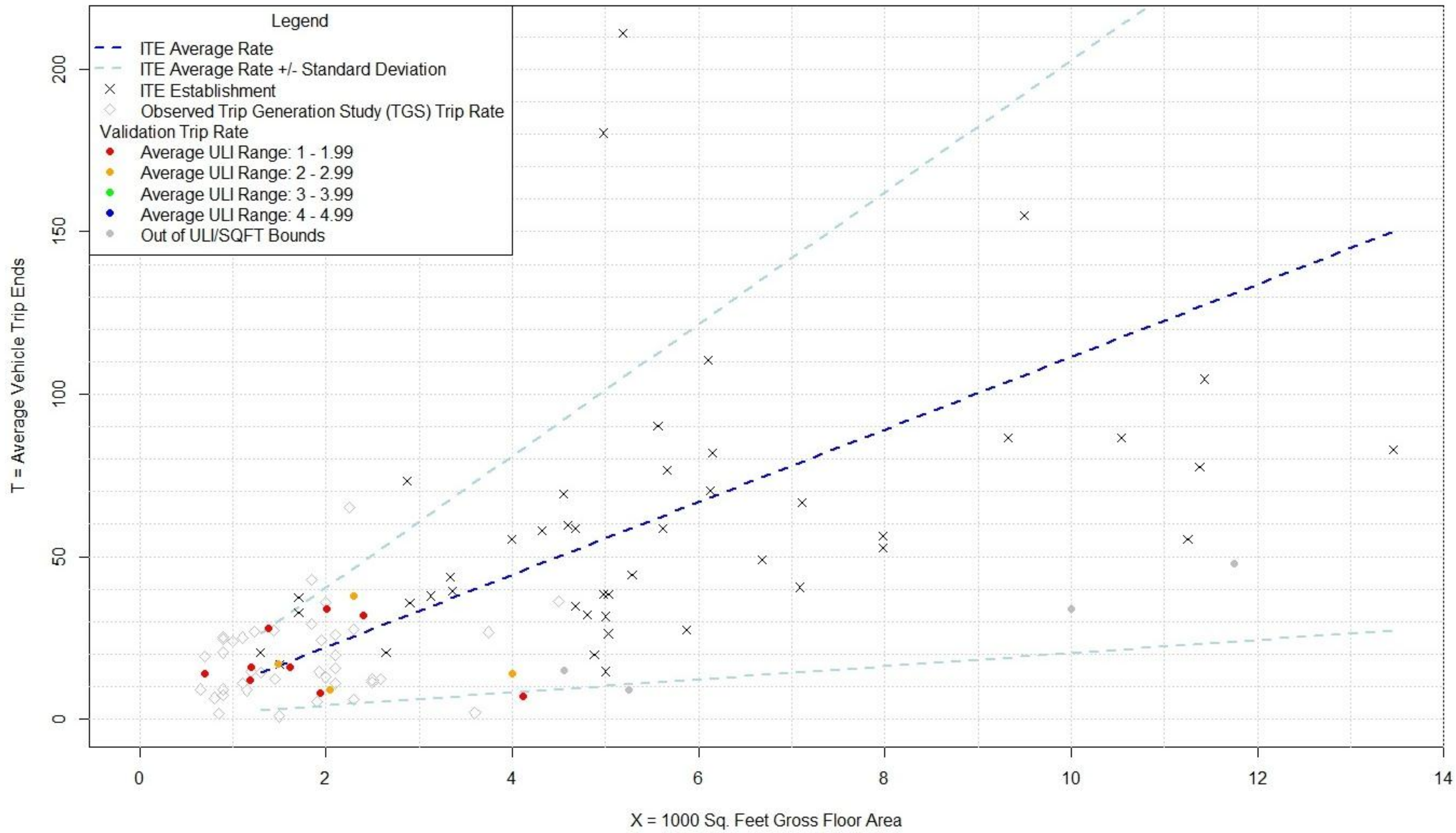


**Figure 5-3. High-Turnover (Sit-Down) Restaurant (LU 932): Weekday, Peak Hour of Adjacent Street Traffic, 4-6PM – Trip Ends Data from UCA TGS methodology development, Validation Data Collection and ITE Vehicle Trip Rates Data**

## 5.3 SUMMARY

This verification process demonstrates that TGS methodology provides reliable and accurate estimates all three land uses studied in this report. The TGS methodology shows significant improvement over ITE's rates, particularly for convenience markets (LU 850) and non-brew pub drinking places (LU 925). While the average error in estimation of high-turnover (sit-down) restaurants (LU 932) is similar between ITE and TGS methodology estimates, the number of underestimations occurring while using the TGS methodology is fewer than ITE.

For the locations that have an average ULI range of less than 3, the TGS methodology appears to be more accurate than ITE methodology for all land uses. For convenience markets, the ITE estimation consistently overestimates the vehicle trip rate significantly for Portland convenience markets. Application of the TGS methodology reduces the absolute difference in estimated vehicle trip rates from 33.0 to 5.2 vehicle trip ends per hour per 1,000 square foot gross floor area in the PM peak.

For drinking places, the TGS methodology tends to overestimate vehicle trips less often than the ITE methodology. Although the TGS methodology underestimated trip rates more frequently than the ITE methodology, the differences in trip rates tends to be closer to the observed rate 75% of the time. Additionally, the data suggest the need for future research identifying unique vehicle trip rates for brewpub-style drinking place establishments. Verification data collected at establishment sizes smaller than the TGS methodology bounds also suggest that drinking places with smaller square footages also tend to have vehicle trip rates below ITE trip rates.

High-turnover (sit-down) restaurants tend to be predicted similarly using ITE and TGS methodologies. However, the number of observed establishments underestimated by ITE is greater than TGS methodology estimates (54% versus 31%, N = 13). Moreover, establishments with large gross floor area suggest that larger restaurants may be over estimated by ITE in local context. Additional data for larger restaurants (gross floor area of greater than 4,500 square feet) are needed to confirm this observation.

The limitations of the verification analysis include the limited sample size and the range of contexts observed in the Metro area. Due to the nature of the verification data collection methodology, data from highly-urbanized locations with more difficult parking arrangements were not able to be collected by observation methods alone. They require person counts at the establishment and an intercept survey collecting trip modes and vehicle occupancy. Because of this limitation, we were not able to collect and verify the methodology in areas with average ULI values of greater than 3. These areas represent less than 0.1% of the total Metro area. From this verification process, we are not able to say to what degree the TGS methodology is conservative. However, these are the areas that pose the most difficulty in estimation of trip generation for infill developments.

# 6.0 CONCLUSIONS AND DISCUSSION

This study provides a means to adjust ITE's *Trip Generation Handbook* for urban context, a much needed gap in the state of the practice. The Urban Context Adjustment (UCA) method developed in this study is simple, straightforward, and consistent. It relies on one built environment measure as a proxy for urban context – 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 Portland region and can be computed for communities in other locations throughout the United States. The findings and methodology provided here can help communities assess the transportation impacts of new development and plan for desired long-term transportation outcomes for commercial centers, corridors, and transit oriented development.

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.

## 6.1 LIMITATIONS

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 greatest limitation of this study is the number of establishments and 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, visitors 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.

## 6.2 FUTURE WORK

There are several issues that merit consideration for future research and development. This section discusses plans for addressing additions to the project that would benefit our understanding of the contextual influences of trip generation.

### 6.2.1 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 includes potential ITE land uses (LU) for future data collection and analysis that are likely to occur in infill and TOD locations:

- 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)
- Retail uses, such as Specialty, Shopping Center, or Apparel (ITE LU 814, 820, or 876 respectively)

### 6.2.2 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. The ability to park at the destination end of a trip taken is often a key player in selecting a mode choice. Existing research shows 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), and free parking at work has been shown to reduce transit's share of commuters by 40% (Lund, Cervero and Willson 2004). To address this issue, 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.

### 6.2.3 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, it is necessary to validate these methods with data from other locations and contexts.

## 6.3 CONCLUSIONS

Results from this effort reveal a consistent trend: for all land uses tested here, vehicle trip rates decrease as the urban context becomes more urban. Specifically, findings strongly support the need for an urban context adjustment to the vehicle trip rates given in ITE's *Trip Generation Handbook*. While this study tested a limited number of land uses in one metropolitan region, it confirms that amendments to the long-term industry standards provided in ITE's *Trip Generation Handbook* are long overdue. We need methodologies backed by empirical evidence that provide planning support for the automobile as well as non-motorized and transit modes in urban environments.

Specifically, the methods and data provided by ITE need to move away from a focus on vehicle-trips towards a paradigm of collecting person-trip information and multi-modal travel. Transportation impact analyses can be important and powerful planning tools, but only if they reflect the multi-modal nature of urban environments. The analysis should provide a basis for how these person-trips are distributed across the various modes, as a function of site and urban context characteristics. To do this, data collection protocols and analytic methods may need to also move beyond the focus of the peak hour of the adjacent roadway in order to accommodate all transportation system users.

This study represents a first step in moving this bar forward and advancing national standards. Data for more land uses and covering a wider range of urban contexts are needed to inform a nationally relevant methodology. But, many communities across the country already have a great deal of information from their own local trip generation studies to inform a larger scale study and validate available methodologies for regional and urban context variations. The opportunity exists to make these data more readily available to researchers to help improve practice and create new professional standards that better reflect the multi-modal nature of our cities.

# 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:*<br>*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?* | ________________________________________ ____________<br>________________________________________ ____________<br>________________________________________ ____________ |
| 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,<br>[ ] Coffee shop, [ ] Service errand,<br>[ ] Other: ___________________ |
| Q8. Origin Mode | *How did you travel to [establishment]?*<br><br>**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:**<br>**Data entry name:** | | | | |

| Automobile/Bicycle Exit Tally Sheet | | |
|---|---|---|
| Date: | | |
| Location: | | |
| Name of Counter: | | |
| *(For visitors 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:**<br>**Data entry name:** | | |

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

# APPENDIX D. MODE SHARES

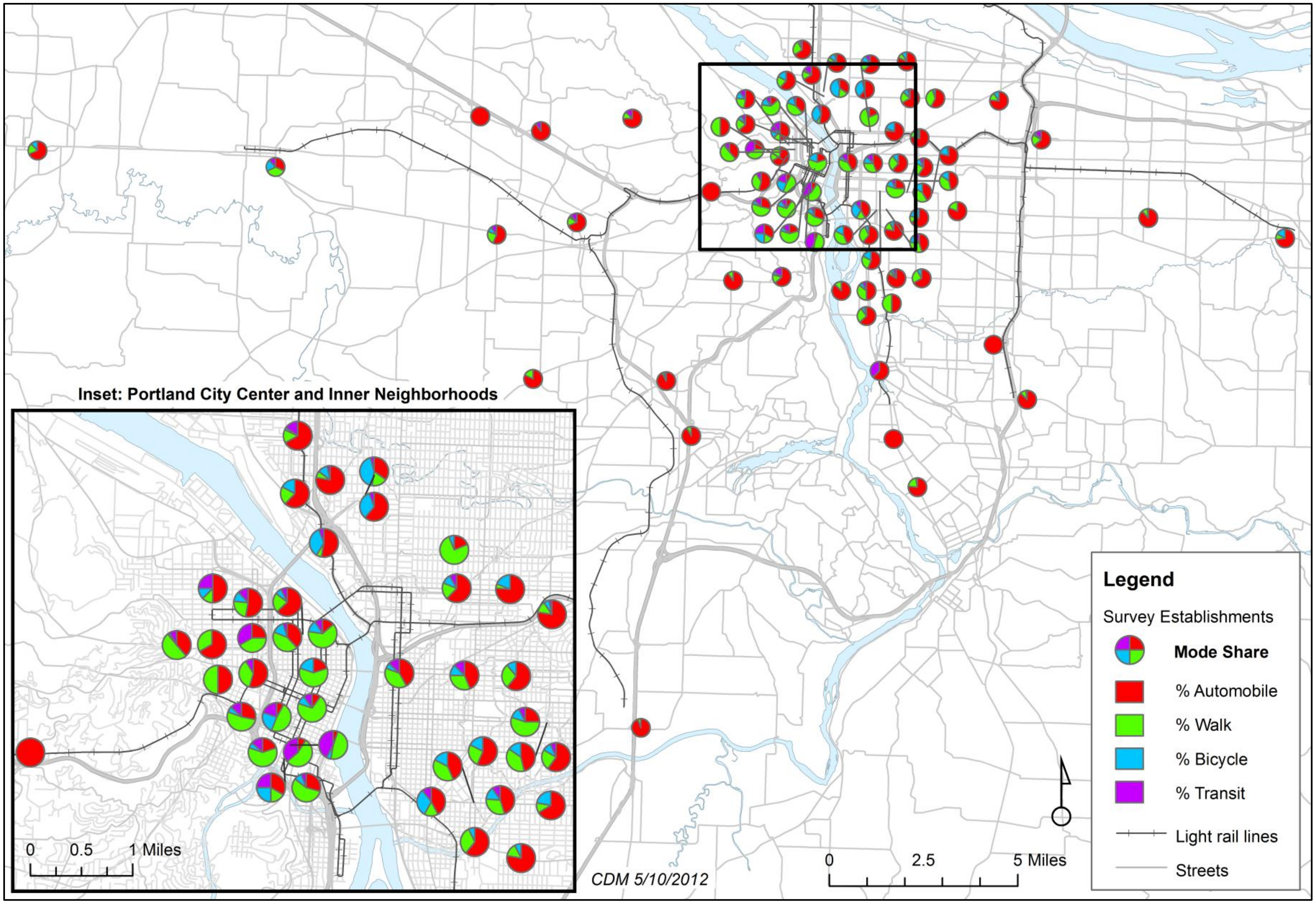


**Figure 6-1. Survey Establishment Mode Shares**

# 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 3-7 and Table 3-8**).**

## Vehicle trip estimation method to exiting trips

In Equation 6-1 we estimate vehicle trips exiting establishments.

**Equation 6-1. Conversion to vehicle trip equivalents method for exiting trips.**

$$VT_{CNTS,OUT} \approx VT_{EST,OUT} = \frac{(P_{OUT})(\%AUTO)}{V_{OCC}}$$

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 6-2. 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.

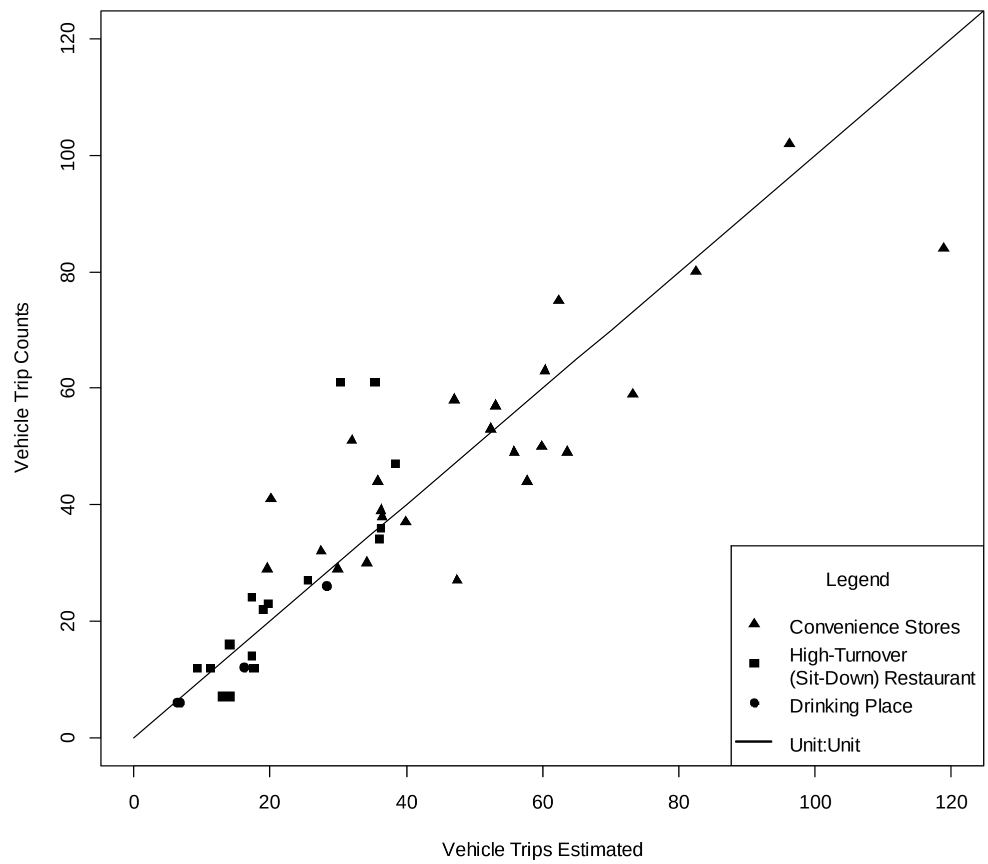


**Figure 6-2. Comparison of vehicle trip counts to calculated**

**Table 6-1. 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 6-1 shows the comparison between estimated exiting vehicle trips and observed exiting vehicle trips. Weighted averages indicate the accuracy of the estimation method (Equation 6-1). 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

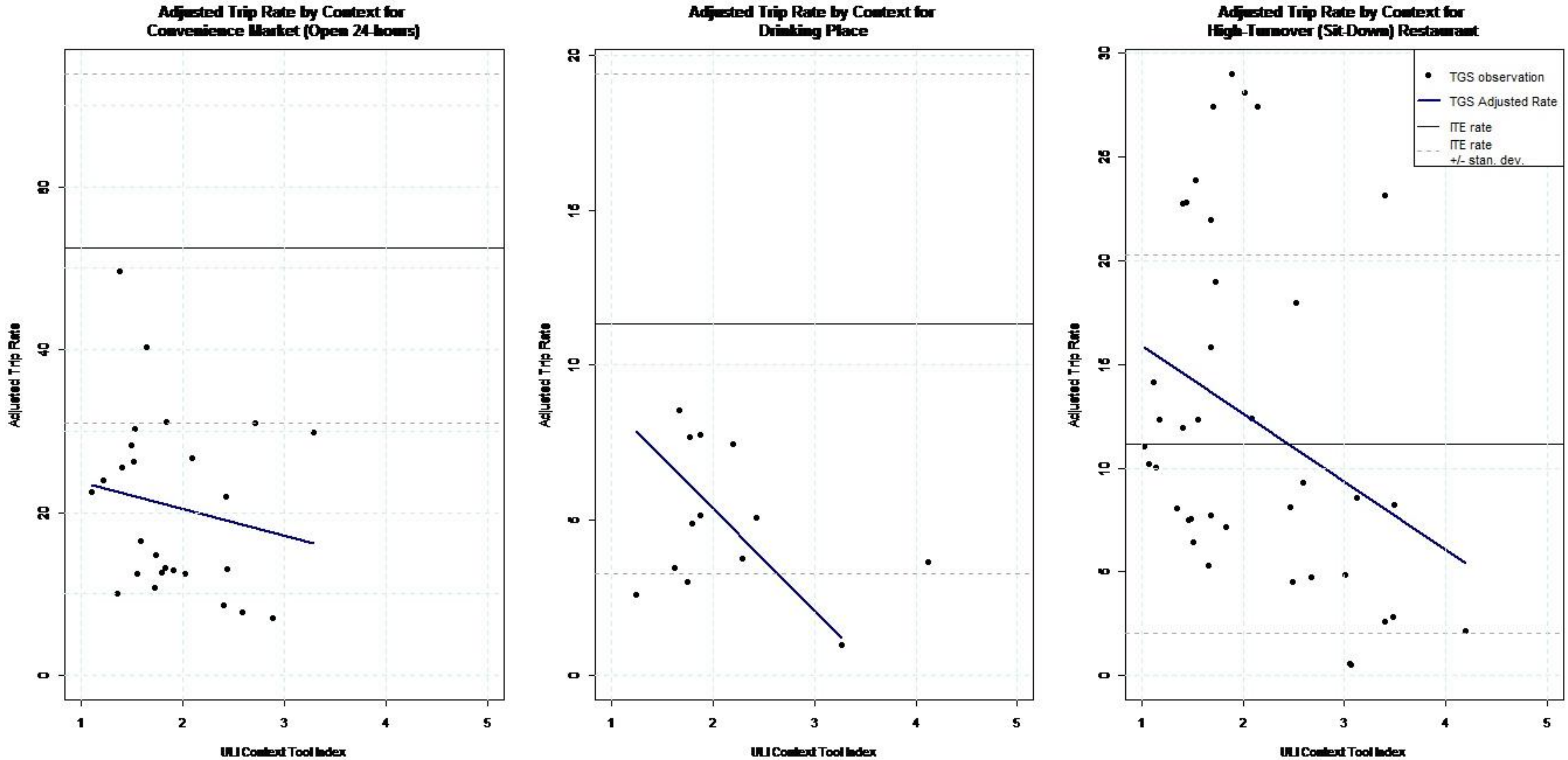


**Figure 6-3. Adjusted Vehicle Trip Rate by Average ULI Score and Land Use**

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