Adjusting ITE's *Trip Generation Handbook* for Urban Context

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Submitted for presentation to the *Transportation Research 92nd Board Annual Meeting*, August 2012

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Word count: 7,952 [words 5,952 +3 Figures x 250 + 5 Tables x 250]

ABSTRACT

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, 24-hour convenience markets, and drinking places. The Urban Context Adjustment (UCA) methodology was developed to adjust ITE vehicle trip rates based on the built environment.

The key measure representing urban context is an index of retail and service establishment density called the Urban Living Infrastructure (ULI) indicator provided by the Portland Metro Context Tool. ULI is highly correlated with other built environment measures such as person density, lot coverage, density, and accessibility to transit. The model developed for the UCA method has a good statistical fit and is easy to use in evaluating the impacts of new development. The approach is also useful in guiding future plans and policies as the ULI measure is correlated with other planning-relevant built environment measures. The UCA method was verified using data collected from an additional 34 establishments of the same land uses.

Overall, the UCA method improves estimation of vehicle trip rates for convenience markets and drinking places, over the rates estimated using data and methods from ITE's *Trip Generation Handbook*. The rates predicted by UCA for high-turnover (sit-down) restaurants tend to be similar to those estimated from ITE's approach. Further implications in planning and practice are discussed.

INTRODUCTION

The Institute of Transportation Engineer's (ITE) *Trip Generation Handbook* (*1*) and *Trip Generation: An ITE Informational Report* (*2*)[1] began collecting data on vehicle trip rates in the 1960s and focused on single-use, vehicle-oriented in suburban sites in the United States. Despite its wide-spread use, the ITE *Trip Generation Handbook* lacks the supporting information to apply these rates in across a range of urban contexts. Today, there is national interest in building evidentiary database that supports the estimation of trip generation for site-level analysis in transportation impact studies (TIAs) for new developments located in urbanized areas that support multimodal transportation options such as infill locations, transit-oriented developments (TODs), or mixed use developments (*3*, *4*). For locations that support greater non-automobile mode shares, ITE recommends that local rates be established via data collection: "If the site is located in a downtown setting, served by significant public transportation... the site is not consistent with the ITE data" (*1*). ITE acknowledges the limitations of the *Trip Generation Handbook* dataset in the omission of transit, non-motorized transportation facilities, mixed land uses, and density, but currently offers little guidance on how to address these shortcomings.

Collecting local data and calculating the impact of urban form on vehicle trip rates are expensive and time-consuming processes and planners are struggling to plan for the transportation needs of infill, mixed use, and TODs. Many jurisdictions ignore warnings on the limited applicability of the rates given in the ITE *Trip Generation Handbook* and apply them across urban contexts, including highly developed area with significant non-automobile use (*5*, *6*, *7*, *8*). Despite evidence that a more compact urban form, access to transit and a greater mix of uses generates fewer and shorter vehicle trips, local governments are often compelled to use current ITE trip generation rates to evaluate transportation impacts and calculate transportation system development charges. 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 may be vastly overestimated. High vehicle trip estimates increase the amount of vehicle-oriented development, necessitating other automobile priority measures. More vehicle use, greater capacity, abundant parking supply, faster travel times, and fewer automobile alternatives are all related to overestimating vehicle trip rates. Further, developers may shun locating new developments in infill or TOD areas because if the increased impact fees that may result from overestimation of vehicle trips.

Alternatively, some communities rely on the application of adjustments to the ITE rates for different contexts (e.g. a 10% reduction in ITE rates in areas with high-frequency transit service). However, these reductions are sometimes derived without empirical basis and applied arbitrarily. In these cases, unfounded adjustments may lead to the underestimation of vehicle trips, which has other consequences in the undersupply of automobile infrastructure. Thus, accurate estimation of vehicle trips for new development is important for both short-term accommodation

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[1] For the remainder of this paper, ITE's *Trip Generation Handbook* will refer to both the *Handbook* and the accompanying *Informational Report.*

of transportation system users as well as the planning for the maturity of urban developments over the long term.

This paper attempts to fill this need by presenting a method to adjust the *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 data (using counts and establishment surveys) on trip rates for a few specific land uses (restaurants, 24-hour convenience markets, and drinking places). These new trip rates were compared to the ITE rates for the same land use category and establishment size and from this, a methodology for adjusting the ITE rates was developed, referred to as the Urban Context Adjustment (UCA) method.

The remainder of this paper is organized as follows. The next section summarizes the state of the practice in how communities are estimating vehicle trip rates for different urban contexts. This is followed by a description of data collected in this study. The methods, the model estimation results and verification are presented. Finally the implications for planning and practice are discussed in the conclusions.

LITERATURE REVIEW

The ITE *Trip Generation Handbook*, and accompanying Informational Report, is the most commonly referenced and utilized practical guideline for predicting vehicle trip rates during the development process. ITE also recommends using an approach developed by JHK & Associates, et al (*9*) published in the *Trip Generation Handbook* (*1*) that reduces vehicle trip generation for locations in closer proximity to transit with supportive land uses, i.e. greater density, higher floor-to-area ratios, and available pedestrian and cycling facilities. This report was published as a draft and is only presented in the *Trip Generation Handbook* as a guide in procedure; it does not necessarily present reductions based on context. ITE has also supported Gard's approach for TODs (*10*) using multimodal information to provide development-wide reductions.

We reviewed 23 jurisdictional guidelines for local adjustment from around the United States and Canada (*11*, *12*, *13*, *14*, *15*, *16*, *17*, *18*, *19*, *20*, *21*, *22*, *23*, *24*, *25*, *26*, *27*, *28*, *29*, *30*, *31*, *32*, *33*, *34*). These guidelines originate from mega cities like New York City, New York to smaller cities like Bend, Oregon. These compiled guidelines identify trends in estimation of trip generation rates and traffic impact studies currently in practice. Of them, 22 reference ITE *Trip Generation Handbook* rates and methods as being appropriate in their local contexts as long as local rates or studies are not available, and the 23rd did not specify preference for or against ITE methods. Six jurisdictions provide local vehicle trip generation rates of some sort - these areas are highly urban or have large authority areas (*13*, *21*, *22*, *24*, *29*, *30*). From this evaluation of ITE *Trip Generation Handbook* methodology and excluding the most suburban and automobile-oriented sites, 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's rates, necessitating further investigation in area types other than highly suburban sites.

Beyond North America, similar methodologies to ITE exist for guidance on estimating vehicle trip generation rates. The Austrailian-based system "New South Wales Roads and Traffic Authority" (*35*) provides a dataset similar to ITE, but when land use trip rates are not available for Austrailia, the ITE Handbook is a recommended option. The UK and Ireland (*36*) and New Zealand (*37*) require multi-modal information for every submitted location, consider area type of the location, and remove data points older than 10 years. Urban context has been acknowledged in these places as an important factor to consider in using previously collected data to estimate vehicle trip generation rates.

Alternatives to the ITE *Trip Generation Handbook* methodology exist. In the US, several models and methods have been developed to approach various issues in estimating vehicle trips or adjustments to ITE methodologies. URBEMIS (*5*) is a pivot model that regionally adjusts ITE rates at single-use sites based on built environment features. INDEX (*38*) is a GIS-based post-processor which evaluates environmental impact based on regional travel model output and scenarios of policy changes to the built environment. At multi-use developments, methods to better account for internal capture (*39*) and better estimate trip generation at mixed-use sites (*40*) have been developed. However, the authors of a recent evaluation of available smart growth trip generation methodologies have acknowledged that "no clear *winner* emerges among currently available methods" (*3*). Few of these methods address urban context directly in their formulation. Additionally, no research has been done in the Portland area to address the adjustment of vehicle trip generation rates.

One critical issue is the lack of a functional definition of urban contexts. A vast body of research exists to confirm that various aspects of built environment are 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 (*41*, *42*, *43*, *44*, *45*, *46*, *47*). Area types, or urban contexts, encompass many individual built environments together to categorize places, and they are also significantly related to levels of automobile travel (*45*, *46*, *48*). 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, but suburban areas are not necessarily consistently predicted either. However, the issue of defining context in modeling applications is confounded by the high correlation between different measures of the built environment and aggregate indices, which perform better in models, lack the specificity needed to direct urban policy.

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 easy to use 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. This method also provides a basis for other regions to develop adjustments to ITE based on urban contexts.

DATA & METHODS

Data for this study were collected in 2011 from June through early October at 78 sites in the Portland, Oregon region. Because of the limited number of sites, the study controlled for weather conditions by only collecting data on days with favorable conditions. Data collection events occurred from 5 to 7 PM on Mondays, Tuesdays, Wednesdays, and Thursdays to overlap with the *Trip Generation Handbook* weekday, the evening peak hour (4 to 6 PM) as well as one of the peak hours of the generator.

Establishment Types & Site Selection

Land use (LU) types chosen for the study include (a) LU 932: High-Turnover (Sit-Down) Restaurants, (b) LU 851: Convenience Markets (Open 24-Hours) without gas stations and (c) LU 925: Drinking Places. These land uses were chosen because they exist throughout the region in all area types and in places where vehicle trip overestimation has proven most problematic: urban infill, mixed-use, and TOD areas.

Establishments (N=78) were selected for inclusion in the study based on characteristics of their surrounding built environment.[2] Individual establishments from across the region were recruited to participate in the study (see map and descriptive of establishment locations in Figure 1). The sample included overrepresentation of establishments in more urban area types as we hypothesize that these are likely to have fewer vehicle trips. Building square footage was collected from business managers at establishments where possible, and through Google Earth.

Most establishments in the study are regionally owned and operated franchises. Local establishments were more willing to participate in the study than national corporate franchises. As such, most establishments in the study were under 3,000 sq. ft. gross floor area, and may cater to a different market segment than patrons of national chains. This is one limitation of the study; on the other hand, these are more typical of the size and type of establishments that are located in infill developments.

Site Visitor Surveys

Surveys were administered by intercepting visitors as they left the establishment or site. A five-minute survey was administered using an electric handheld tablet (*49*). Key information relevant to this study included: demographics, travel mode(s), vehicle occupancy, trip origin and following destination, and locations of home and work. When visitors refused the long survey, a shorter version was offered that collected information on mode of travel and gender. An average of 24.2 surveys was collected at each establishment, for a total of 1887 surveys. The overall response rate was 52% for both surveys combined.

Demographic characteristics from this survey sample are compared to US Census data for the Portland Metropolitan Statistical Area. The survey sample appears to be representative of the area population based upon comparisons of household income, vehicle ownership, and household size.

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[2] To ensure representation of the entire spectrum of the urban landscape found in the Portland region, a preliminary analysis (for site selection purposes only) included the following measures in a factor/cluster analysis around establishments: 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. A k-means clustering analysis of the entire list of establishments considered for inclusion revealed five classifications of area-types that roughly corresponded to: Central Business District neighborhoods; Urban Core neighborhoods; Neighborhood and Regional Centers; Suburban Town Centers and Corridors; and Suburban Areas. However, these area types were not used as proxies for context in the subsequent analysis or estimation of adjustment models.

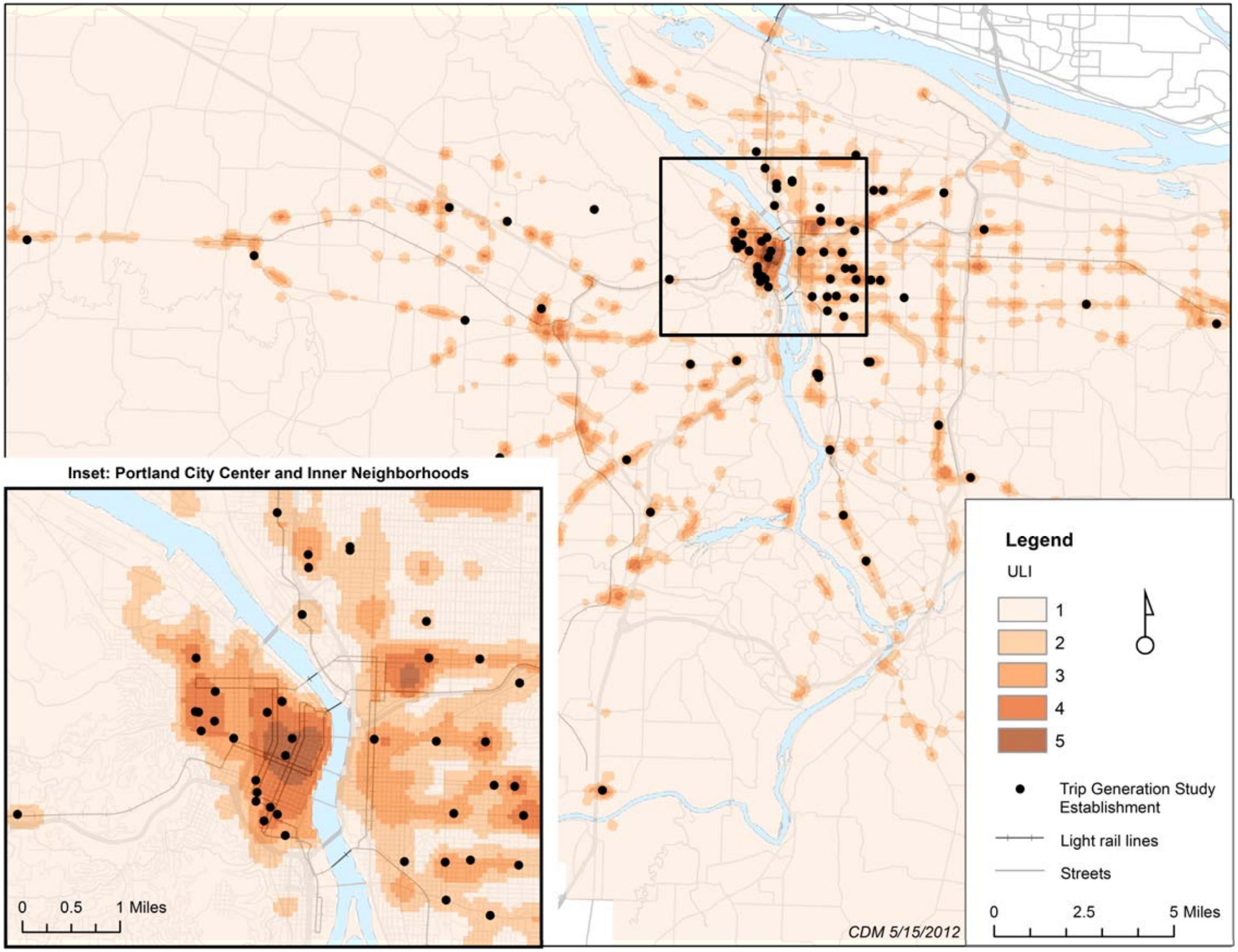
Person and Vehicle Counts

Surveyors also countered persons by gender entering and exiting every entrance to the establishments during the survey period using direct observations. Person count information is key to expanding the way that transportation impact analysis and trip generation studies are conducted to account for all modes of travel.

Likewise, counts of vehicles exiting the site were also observed when feasible, typically when the site had parking adjacent to the store entrance. Counts were not recorded for those vehicles entering the site because for multi-use sites, we needed to associate a vehicle with an observed trip to the specific establishment of interest. Many locations in very urban areas did not have adjacent parking lots and thus vehicle counts were not conducted.

Built Environment Data

In order to test a variety of measures associated with urban context, built environment information for each site was gathered from archived data sources within a buffer area of ½ mile radius (Euclidean distance) from each establishment. The measures that were included in this study were selected based upon their association with mode choices from the literature of travel behavior and the built environment. The measures are listed in Table 1 and the Urban Living Infrastructure (ULI) is described in more detail below, as it is a key to the method developed in the following sections.



1 **Figure 1. Urban Living Infrastructure Indicator from the Metro Context Tool**

Table 1. Built Environment Measures List and Data Source[3]

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.

ULI serves as a rasterized measure of the density and diversity of retail and service destinations. The measure is based on the different retail and service establishments that accommodate everyday non-work living needs, e.g. food or clothing stores, restaurants, laundry services, supply stores and bookstores. The ULI measure associated with each raster cell (264 by 264 feet) is computed by calculating the number of retail and service establishment within a ¼-mile and then classifying them into a 1-to-5 index using a Jenks' natural breaks algorithm. Figure 1 shows distribution of the ULI measure across the Metro region. Only a few areas in the Metro region besides downtown Portland have ULI values of 5, while the majority of the region has a ULI of 1. In this analysis, the average ULI measure across all of the raster cells within a half-mile radius of the establishment is used.

ANALYSIS

The aim here is to develop a consistent and reliable method for adjusting ITE trip generation estimates to control for urban context. The UCA is based on relationships between built environment characteristics and mode shares found from analysis of data collected from specific establishments across the Portland region. This section describes the data analysis and methodological development.

[3] "Access to Rail" is a binary variable and is reported in percent of establishments with access to rail within ½ mile Euclidian buffer.

Comparison of Urban Context Adjustment (UCA) Observations with ITE Trip Rates

This section details a comparison between the UCA observations and ITE *Trip Generation Handbook* trip rates for the establishments in this study. To compare observed UCA person trips to ITE vehicle trips for each establishment, we estimate vehicle trip rates from survey data as described in Equation 1:

Equation 1. UCA Vehicle Trip Rate

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

Where: P_{IN} = Person count entering the establishment,

P_{OUT} = Person count exiting the establishment,

$\%AUTO_{UCA}$= automobile mode share (from the visitor survey), and

$VEH\ OCC_{UCA}$ = Average vehicle occupancy (from the visitor survey)

Comparison of UCA vehicle trips to ITE vehicle trips for the weekday peak hour of the facility (5–6PM) is shown in **Error! Reference source not found.**. UCA vehicle trips are consistently below ITE rates and ITE data points for convenience stores and drinking establishments. For high-turnover (sit-down) restaurants, the UCA vehicle trips and ITE vehicle trips are similar.

ITE lists the criteria recommended to adopt the ITE *Trip Generation Handbook* methodology for local use and shown in Table 2. All criteria must be met to consider application of ITE *Trip Generation Handbook* data in local context. Otherwise, it is recommended that a local rate or equation be developed (*6*). Based upon these criteria, we recommend a local adjustment to ITE *Trip Generation Handbook* rates for convenience stores and drinking establishments. We do not have sufficient evidence to require adjusting ITE rates for high-turnover (sit-down) restaurants in the Portland region. Nonetheless because the establishment sample size is too small to estimate segmented models for each land use, we include restaurants in our adjustment methodology to increase the sample size used for model estimation.

We hypothesize that the differences between ITE and UCA observations are largely due to differences in the travel modes visitors use to access/egress these sites. As discussed the section previous, 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.

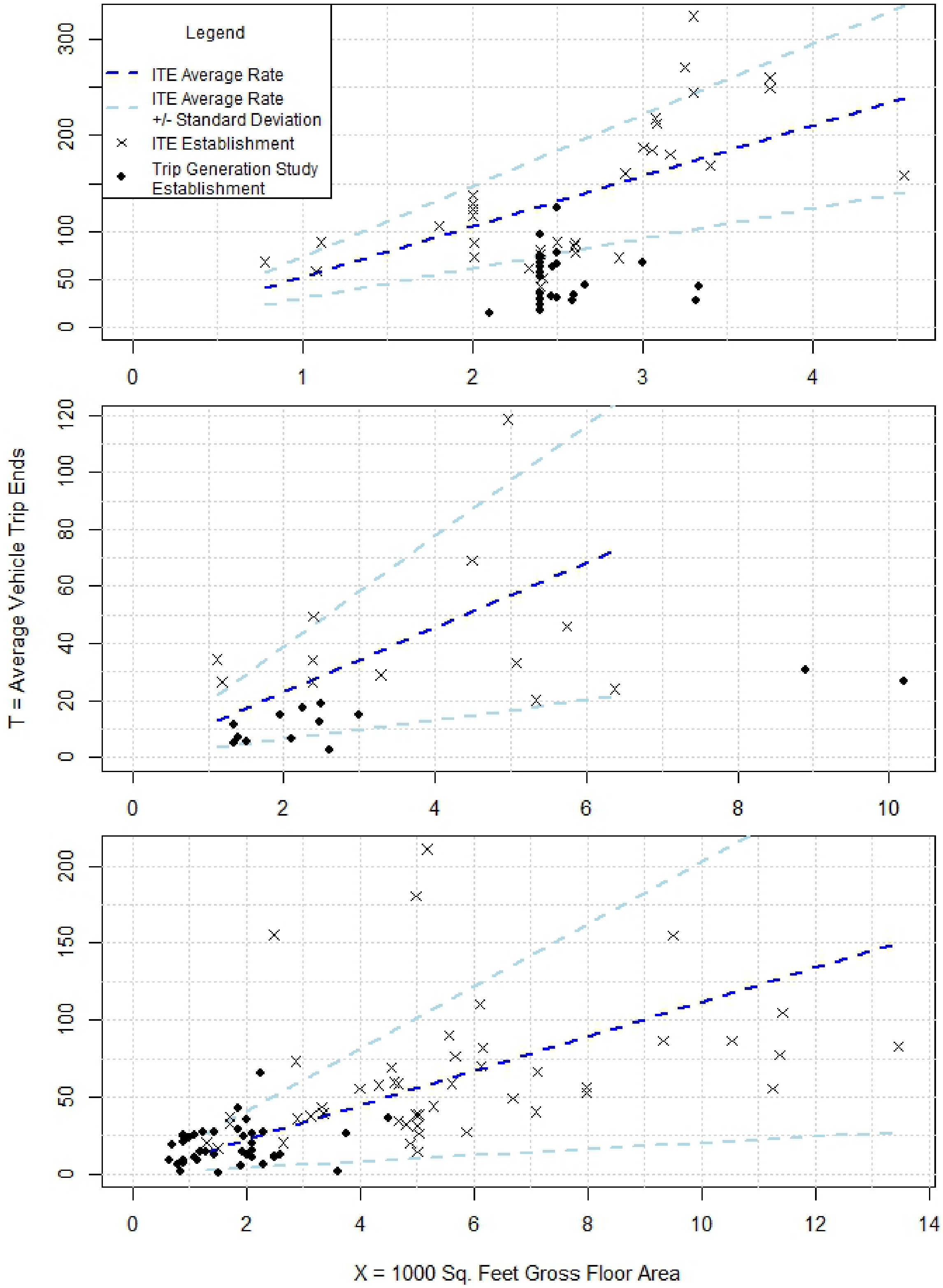


Figure 2. UCA Vehicle Trips and ITE Vehicle Trip Rates Data, in order from top: (a) LU 851, Convenience Markets (24-hours); (b) LU 925, Drinking Places; and, (c) LU 932, High Turnover (Sit-Down) Restaurants

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Table 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;	0 locations fall above, 26 location fall below	0 locations fall above, 13 locations fall below	**17 locations fall above, 22 locations fall below**
<u>OR</u>			
2.B.) All study locations fall within 15% of the ITE average rate or equation. ($(TGS_{RATE} - ITE_{RATE}) / ITE_{RATE}$) < ±15%	1 of 26 location falls within 15%	0 of 13 locations fall within 15%	7 of 39 locations fall within 15%
3.) Locally collected studies fall within the scatter of rates provided by ITE	Appear slightly below	Appear below	**Appear within scatter**
4.) "Common sense" indicates appropriate use of ITE rates for location application.	Vague	Vague	Vague
Conclusion	Local rate or adjustment is recommended.	Local rate or adjustment is recommended.	Use of ITE methods may be appropriate.

Note: bold indicates a met criterion

Urban Context Adjustment Models

Using the pooled data collected for all establishments for the weekday PM peak hour (5-6PM), several models of adjustments to ITE's vehicle trip rates for urban context are estimated using ordinary least squares multivariate regression. The dependent variable for all models is the difference between the UCA vehicle trip rate and the trip rate estimated using ITE's methods (*2*, *1*). In each of the models shown in Table 3, the independent variables include indicators of the land use type (drinking establishments are the base case) and a different built environment measures. This is done because each of these measures is highly correlated and thus cannot be used reliably in a statistical modal in this form. However, the authors do recognize that these various dimensions of the built environment work together to define urban context and influence travel choice.

All of these models perform quite well with adjusted R^2 ranging from 0.47 to 0.92. From the model coefficients, it is clear that 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 rates can be attributed to context.

The model estimated using the ULI measures, shown in the first row Table 3, is the one that has been selected for the UCA approach for the Portland area. This model has an adjusted R^2 of 0.76. This is consistent with a study that showed increasing shares of non-motorized travel as the density of discretionary businesses increases (*50*). From this table, we can see that the other built environment variables are highly correlated with ULI and that it serves as a suitable proxy for other measures of 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, resulting in a new vehicle trip rate of 15.2. The adjustment to convenience markets in the same area (with average ULI of 1.0) would be a reduction of 28.7 to the ITE trip rate; when applied to the ITE trip rate this results in 23.7 vehicle trips per PM peak hour per 1,000 sq. ft. (a 45% reduction from the ITE vehicle trip rate). The adjustment to drinking places in the same area (average ULI = 1.0) is a reduction of 2.6 to the ITE trip rate; the resulting trip rate would be 8.7 vehicle trips per hour per 1,000 sq. ft. (a 77% reduction from ITE).

Figure 3 shows the observed mode shares within average ULI ranges of survey establishments. ULI is strongly associated with locations with greater 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.

Table 3. ITE Rate Adjustment Models Using Built Environment Measures

Built Environment Measure (units)	Correlation with ULI	Adjusted R^2	Built Environment Coefficient	Convenience Market Coefficient	Restaurant Coefficient	Intercept Coefficient
Average ULI (count)		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***	7.15***	-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

NOTE: N = 78

***p-value ≤ 0.01

** p-value ≤ 0.05

*p-value ≤ 0.1

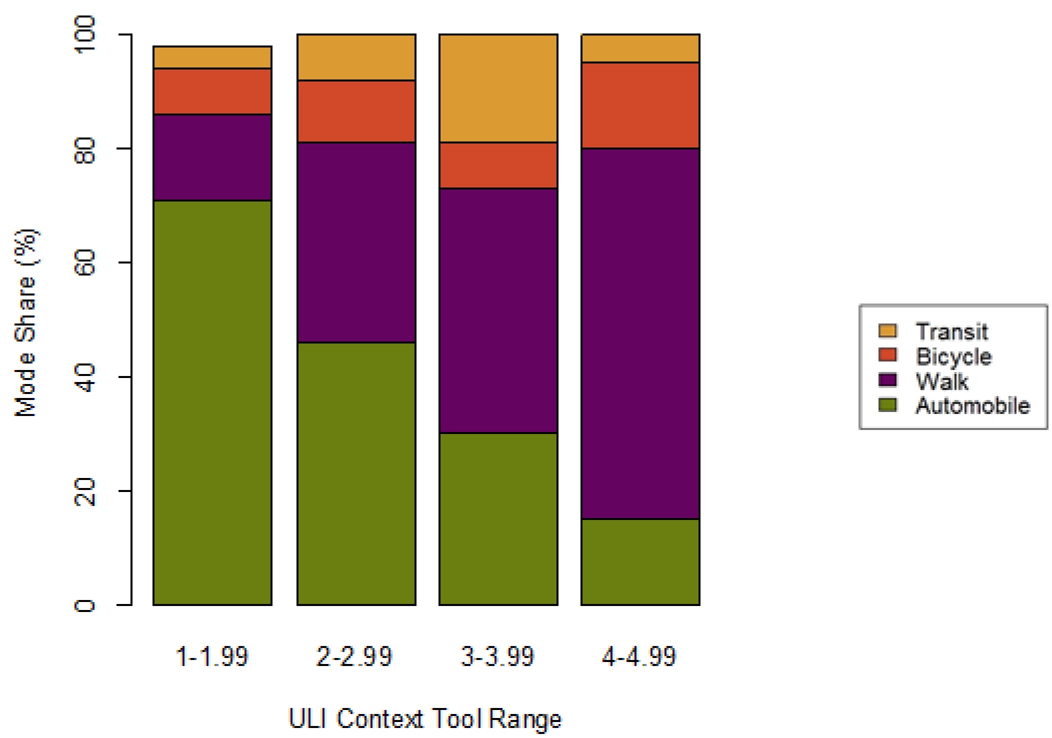

Figure 3. Average Mode Share by ULI

VERIFICATION OF METHODOLOGY

This section verifies the models estimated in this paper using independently collected data[4]. Vehicle count data were collected from 34 additional establishments for use in verification in April and May, 2012. For these sites, vehicle counts entering and exiting the locations were collected using the same methodology outlined above.

Table 4 compares 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%.

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.

[4] This section uses the word "verification" instead of "validation" due to sample sizes required to warrant statistical merit. Because of segmentations across different land uses and urban contexts, the verification sample would have needed to be increased fivefold to meet statistical requirements of a true validation effort.

Table 4. Comparison of Vehicle Trip Rates – ITE and Urban Context Adjustment (UCA) rates to Observed Verification Data Collected[5,6]

		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%	

APPLICATIONS IN PLANNING AND POLICY

As shown in Table 3, there are many measures of the built environment that performed well in the models. Average ULI was selected as the "urban context proxy" for the UCA model because it is a highly correlated with other measures of the built environment, more so than any of the other independent urban context variables, and has more explanatory power while remaining statistically significant. However, ULI is not necessarily sensitive to the full range of planning and policy decisions that a city might pursue to reduce automobile travel, as it represents a measures of density and diversity of retail and services. Thus, it is important to understanding how ULI relates to the other built environment characteristics that characterize urban context and have been shown in the literature to be associated with lower automobile use and/or higher non-automobile mode shares.

Table 5 summarizes measures of the built environment that are highly correlated with ULI and provides a range of values of each measure associated with average ranges of ULI, as observed across the entire Portland metropolitan area. These measures were calculated from a rasterized grid of more than 383,000 cell locations covering the entire metropolitan area, with each cell measuring 264 ft. by 264 ft. This table shows the associated average values of these other built environment attributes found in within a half-mile buffer.

[5] The mean squared error is calculated by averaging the squared difference between all estimated and observed data values.

[6] 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.

Additionally, for communities without the ability to calculate a similar ULI measure, Table 5, combined with Figure 3, may assist in classifying the level of urbanization needed at location to achieve a desired mode share. For example, if a non-automobile mode share of approximately 66% at an infill location is desired, the corresponding average ULI value range is between 3 and 3.99 as shown on Figure 3. By using Table 5, one can assess the necessary built environment components associated with this mode share (e.g. approximately 25 ± 10 transit corridors, 35 ± 6% lot coverage, or 103 ± 33 residents and employees per acre). These metrics can then be used as planning targets needed to achieve the goal of a particular mode share.

Table 5. 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 = 379,832		N = 2,907		N = 387		N = 95		N = 38,3221	
	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** (%)	2%	*4%*	19%	*9%*	35%	*7%*	42%	*5%*	2%	*4%*
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*

*Pearson's correlation with ULI > 0.4

**Pearson's correlation with ULI > 0.6

DISCUSSION AND RECOMMENDATIONS

The methods developed in this paper fill a gap by providing a means to adjust ITE's *Trip Generation Handbook* for urban context. 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.

Results from this paper 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 vehicle-trip based data and methods to one that focuses on person-trip information and multi-modal travel. Traffic 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.

ACKNOWLEDGEMENTS

This project was sponsored by a grant from the Oregon Transportation Research and Education Consortium (OTREC) with assistance from: Portland Metro; ODOT; City of Hillsboro; City of Lake Oswego; City of Milwaukie; and City of Tigard.

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