MAPC Literature REVIEW: Trip Generation White Paper

Renaissance Planning

November 12, 2019

Introduction and Objective

The relationship between travel behavior and the built environment has been explored by researchers for decades. Over time, a broad consensus has emerged indicating that the built environment factors, including land use diversity, density, design, and access to destinations, influences vehicle miles traveled (VMT) and mode choice.[1] A smaller body of research explores the relationship between built environment factors and total person trips by all modes. Within this body of research, one recent publication noted the emergence of two diverging narratives, with some studies identifying a significant relationship and other finding no significance.[2] The purpose of this literature review is to explore research around trip generation and the built environment, focusing specifically on studies exploring the relationships between total person trip generation (regardless of travel mode) and its relationship to variables related to density, diversity, design, and destination accessibility (sometimes described as the four "Ds").

Summary of Findings

Literature exploring person trip frequency and the built environment can be divided into one of two categories: 1) analyses of travel surveys as they relate to context, and 2) site-specific counts of person trips as they relate to the urban context of the site. Findings both within and between these categories do vary, but in broad terms, this review identified that most site-specific studies find that urban context does not influence total person-trip generation. Although travel behavior can also be measured using other methods such as workplace surveys, intercept surveys,[3] cell phone data, and GPS-based approaches [4], this review found little relevant evidence around total person tripmaking and the built environment using these data collection methods.

Findings in research exploring travel surveys and total person trips are murkier, particularly when researchers control for various household and socioeconomic factors. In general, researchers typically find relationships between person trip frequency and the built environment after controlling for household and socioeconomic factors, although the effect on the number of person-trips generated is generally minor, and the relationship is only sometimes statistically significant. The influence, when found, is also noted to be secondary to household and socioeconomic variables. In studies that do not control for these factors, or report uncontrolled findings, trip frequency appears to stay nearly constant across urban contexts. The

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[1] Ewing, R., & Cervero, R. (2001). Travel and the Built Environment: A Synthesis. *Transportation Research Record*, *1780*(1), 87–114. https://doi.org/10.3141/1780-10

[2] Zhang, Qin, et al. "Household Trip Generation and the Built Environment: Does More Density Mean More Trips?." *Transportation Research Record* (2019): 0361198119841854.

[3] Koppelman, F. S., & Bhat, C. (2006). A self instructing course in mode choice modeling: multinomial and nested logit models.

[4] Chen, C., Ma, J., Susilo, Y., Liu, Y., & Wang, M. (2016). The promises of big data and small data for travel behavior (aka human mobility) analysis. Transportation research part C: emerging technologies, 68, 285-299.

following paragraphs summarize the most notable findings, followed by a more detailed tabulation of literature sources reviewed.

The comprehensive synthesis of previous research published in 2001 by Reid Ewing and Robert Cervero set the stage for further research, noting that "trip frequencies appear to be primarily a function of the socioeconomic characteristics of travelers and secondarily a function of the built environment," although this synthesis focused on vehicle trips and VMT without making conclusions regarding the significance of the secondary effects on person-trip frequency.[5]

For example, a 2016 nationwide study conducted by a team from UCLA and Rutgers that evaluated numerous factors related to the built environment with National Household Travel Survey (NHTS) data and found that that average total household trips remained nearly constant across urban contexts. But when these values were controlled for household and socioeconomic factors, built environment characteristics and neighborhood typologies revealed a small but statistically significant relationship.[6] This study appears to be the most robust source of information considering both its use of authoritative nationwide data (as contrasted with locally targeted surveys) and its relative currency. The uncontrolled reported effects on person-trip frequencies is shown in Figure 1. The paper notes that "the median number of survey-day trips is consistent across neighborhood types, with any differences staying within the 95 percent confidence intervals".

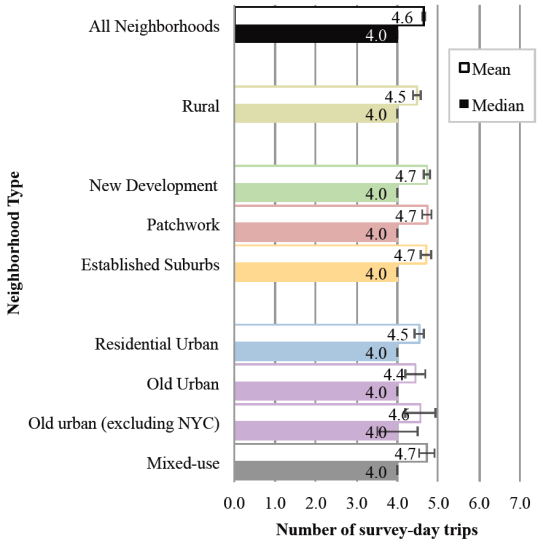

Figure 1. UCLA/Rutgers study finding on neighborhood effect on person-trip generation

In another recent publication, Zhang, Clifton, et al examined Oregon statewide travel survey data to evaluate the impact of the built environment on several travel behavior metrics, including person trips, considering a measure of the 4Ds described as urban living infrastructure. They found that the inclusion of the urban living infrastructure (ULI), a measure of local accessibility, showed an increase in total person tripmaking, although with a relatively low (80%) significance level and low resulting coefficient. The researchers noted that ULI had the greatest impact on shopping-related trips. Household density within one mile was also tested and found to be statistically significant. [7]

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[5] Ewing, R., & Cervero, R. (2001). Travel and the Built Environment: A Synthesis. *Transportation Research Record*, *1780*(1), 87–114. https://doi.org/10.3141/1780-10

[6] Voulgaris, C. T., Taylor, B. D., Blumenberg, E., Brown, A., & Ralph, K. (2016). Synergistic neighborhood relationships with travel behavior: An analysis of travel in 30,000 US neighborhoods. Journal of Transport and Land Use, 10(1). https://doi.org/10.5198/jtlu.2016.840

[7] Zhang, Qin, et al. "Household Trip Generation and the Built Environment: Does More Density Mean More Trips?." *Transportation Research Record* (2019): 0361198119841854.

Representing the alternative narrative of the relationship between tripmaking and the built environment in travel surveys, a 1996 paper by Ewing, R., Deanna, M., & Li, S.-C explored travel survey data across Florida. The researchers tested the effects of several built environment factors on household trip frequencies, including density, jobs-housing balance. The researchers concluded that "after controlling for sociodemographic variables, residential density, mixed use, and accessibility do not have significant, independent effects on household trip rates." [8]

In her recent doctoral dissertation and associated journal article, Currans noted that most site-level studies and tools used to assess the effects of the built environment on adjusting vehicle trip rates published by the Institute of Transportation Engineers (ITE) make an assumption that the built environment does not affect person trip generation (but does affect trip distribution and mode choice).[9]

The 10th Edition of the ITE Trip Generation Handbook, published in 2017, was the first edition to segregate vehicle trip rates by urban context for the two land uses (mid-rise multifamily housing and general office) where sufficient observed samples were available (notably, some of the samples included non-vehicular travel modes). From that information ITE reported, person-trip generation rates appear consistent across urban and suburban contexts for the residential uses but noted a difference in center city core person-trip rates from office uses for which more data would be needed to derive a useful fitted curve.[10]

From the preponderance of the evidence, based largely on the findings of current practitioners, our conclusion is that the development of a regional accessibility-based model can reasonably assume that person-trip generation is unaffected by the built environment context and that our focus should be on the trip distribution and mode choice affects for which solid evidence exists regarding the influence of the built environment.

[8] Ewing, R., Deanna, M., & Li, S.-C. (1996). Land Use Impacts on Trip Generation Rates. Transportation Research Record, 1518(1), 1–6. https://doi.org/10.1177/0361198196151800101

[9] Currans, K. M. (2017). Issues in Trip Generation Methods for Transportation Impact Estimation of Land Use Development: A Review and Discussion of the State-of-the-art Approaches. Journal of Planning Literature, 32(4), 335–345. https://doi.org/10.1177/0885412217706505

[10] Institute of Transportation Engineers. (2017). Trip generation. Washington, D.C.

Summary Table of Findings

Article Summary Legend

Study did not explore the relationship between total trips (all modes) and factor(s) related to the 4Ds or results were missed or inconclusive.	Study found relationship between total trips (all modes) and factor(s) related to the 4Ds.	Study found or relies on basis of no relationship between total trips (all modes) and factor(s) related to the 4Ds.

Article Summaries: Trip Generation at Site Level

Publication Title	Findings Relating to Trip Generation and Context	Data Analyzed	Authors	Publication Type	Year
Issues in Urban Trip Generation	The most commonly used methods to adjust ITE trip rates for urban areas rely on the assumption that person trip rates are not impacted by urban context. The author's literature review on this topic concluded that, "few studies have focused on understanding the overall demand for travel (e.g., total trips or activity)—or rather the joint effects of land use upon mode-choice and trip frequency—potentially leading to over- and underestimation of overall activity."	Literature Review of Site Count Methodologies	Currans, K. M.	Dissertation for Doctor of Philosophy in Civil and Environmental Engineering, Portland State University	2017

Publication Title	Findings Relating to Trip Generation and Context	Data Analyzed	Authors	Publication Type	Year
ITE Trip Generation 10th Edition	Peak hour person trip rates were compiled from observed data for mid-rise multifamily residential and general office uses in three urban contexts: general urban/suburban, dense multi-use urban, and center city core. The person trip rates for the three urban contexts were essentially identical (0.52 to 0.54) for all three residential uses. The city center core office buildings had notably lower person trip generation rates (1.24) than the other two contexts (1.42 and 1.44), although the data relationships for the 13 center city core sites did not permit development of a fitted curve with a reasonable R-square value.	Site Count, All Modes	Institute of Transportation Engineers	Reference manual	2017
Varying Influences of the Built Environment on Household Travel in 15 Diverse Regions of the United States	Researchers only looked at mode-specific trip rates, and not total trips by person or household.	Travel Survey, All Modes	Reid Ewing, Guang Tian, JP Goates, Ming Zhang, Michael J Greenwald, Alex Joyce, John Kircher, William Greene	Peer-reviewed Journal Article	2015
Adjusting ITE's Trip Generation Handbook for Urban Context	This study, which proposes a method to adjust ITE trip generation rates based on urban context, included site surveys of 78 high-turnover facilities in Portland, Oregon. Sites were classified into a series of different urban contexts based on an array of built environment variables. Researchers reported finding that person trip rates did not vary significantly across the urban contexts.	Site Count, All Modes	Clifton, K., Currans, K., & Muhs, C.	Peer-reviewed Journal Article	2015

Publication Title	Findings Relating to Trip Generation and Context	Data Analyzed	Authors	Publication Type	Year
Trip Generation and Data Analysis Study (DDOT Phase I-II)	Researchers collected trip data from urban sites in Washington D.C. The authors explored adding contextual variables, including multi-modal accessibility, to improve trip generation models. However, they did not find a significant relationship between person trips and multi-modal accessibility when it was added to the base models that included building square footage. It is important to note that the data collected comprised of urban location in Washington, D.C., and was not intended to cover a spectrum of urban context.	Site Count, All Modes	Porter, C., Hardy, D., Goldstein, J., Schiesel, R. B., Kaufmann, P., Cambridge Systematics, Weinberger, R., Ricks, K., Schrieber, J., Cohen, L., & Symmetra Design, L. L. C.	Report produced by consultants for District Department of Transportation (DDOT).	2014-2015

Article Summaries: Trip Generation and Travel Surveys

Publication Title	Findings Relating to Trip Generation and Context	Data Analyzed	Authors	Publication Type	Year
Household Trip Generation and The Built Environment: Does More Density Mean More Trips?	Researchers concluded that built environment variables (urban living infrastructure, a local accessibility measure, and household density) have significant and positive influences on trip generation, especially for total number of trips, total number of tours, and home-based shopping-related trips. The authors note that "local accessibility (ULI) matters the most for shopping-related trips among the five observed trip purposes."	Travel Survey, All Modes	Qin Zhang, Kelly Clifton, Rolf Moeckel, Jaime Orrego-Oñate	Peer-reviewed Journal Article	2018
Synergistic neighborhood relationships with travel behavior: An Analysis of Travel in 30,000 US Neighborhoods	Researchers found very little overall variation between daily trips between neighborhood types. However, when controlled for socioeconomic variables, researchers found that built-environment variables did show some relationship to total trips.	Travel Survey, All Modes	Carole Turley Voulgaris, Brian D. Taylor, Evelyn Blumenberg, Anne Brown, Kelcie Ralph	Peer-reviewed Journal Article	2016
Comparing the Influence of Land Use on Nonwork Trip Generation and Vehicle Distance Traveled: An Analysis using Travel Diary Data	Researchers used travel diary data to identify the impacts of the built environment on non-work vehicle trips and VMT. Researchers found that land use variables and sociodemographic variables had similar impacts on VMT and vehicle trip generation. Since the researchers did not review non-vehicle travel, the results do not include the impacts on total trips.	Travel Survey, Vehicle Trips	Boarnet, M. G., Nesamani, K. S., & Smith, S.	Peer-reviewed Journal Article	2013
Travel and the Built Environment: A Meta-Analysis	This meta-analysis found a relationship between VMT and mode choice and the built environment. It did not explore total trips and the built environment.	Travel Survey, All Modes	Reid Ewing, Robert Cervero	Peer-reviewed Journal Article – Meta Analysis	2010

Publication Title	Findings Relating to Trip Generation and Context	Data Analyzed	Authors	Publication Type	Year
Travel and the Built Environment: A Synthesis	Researchers noted that "trip frequencies appear to be primarily a function of the socioeconomic characteristics of travelers and secondarily a function of the built environment." However, they note that in poorly controlled or uncontrolled studies, trip frequencies did not vary, echoing the findings from more recent research.	Travel Survey and Site Count, Mixture of Modes in Studies Included	Reid Ewing, Robert Cervero	Peer-reviewed Journal Article – Synthesis	2001
Land Use Impacts on Trip Generation Rates	Researchers did not find independent effects on trips rates for residential density, mixed use, and accessibility after controlling for after controlling for household variables.	Travel Survey	Ewing, R., Deanna, M., & Li, S.-C.	Peer-reviewed Journal Article	1996

Detailed Literature Review Findings by Article

Article Title	**HOUSEHOLD TRIP GENERATION AND THE BUILT ENVIRONMENT: DOES MORE DENSITY MEAN MORE TRIPS?**
Citation	Zhang, Qin, et al. "Household Trip Generation and the Built Environment: Does More Density Mean More Trips?." *Transportation Research Record* (2019): 0361198119841854.
Research Objective	Researchers seek to identify if variables related to the built environment impact household trip generation, and if these variables also impact trip generation purpose. Researchers use data from the Portland, Oregon metropolitan area and develop models to estimate trip generation across all modes at the household level.

Research Findings	The researchers found that "the built environment does have significant and positive influences on trip generation, especially for total number of trips, total number of tours, and home-based shopping-related trips." The authors highlighted that" local accessibility (ULI) matters the most for shopping-related trips among the five observed trip purposes. Statistical tests indicated that built environment variables, when added to base models, significantly improve model outputs. The researchers recommend improving the sensitivity of transportation demand models to variables that reflect the built environment.

TABLE 2 Total household trip generation estimation results of the negative binomial model

Independent variables	Base model		Expanded model with BEs[1]	
	Estimate	Pr(>|z|)	Estimate	Pr(>|z|)
Model 1: Dependent variable - number of trips per household				
Intercept	1.039	<0.001 ***	-1.275	0.058 .
Number of workers	2.854	<0.001 ***	2.830	<0.001 ***
Number of non-workers	2.213	<0.001 ***	2.223	<0.001 ***
Number of teleworkers	0.410	0.029 *	0.403	0.032 *
Number of children under 6 years	1.501	<0.001 ***	1.475	<0.001 ***

	Number of school students 2.324 <0.001 *** 2.327 <0.001 *** Number of vehicles 0.141 0.116 0.244 0.009 ** Medium-high income household (Yes) 0.946 <0.001 *** 0.965 <0.001 *** Ln(household density within one mile) - - 0.326 <0.001 *** Urban living infrastructure - - 0.002 0.212 *AIC* *25098* *25086* *Log likelihood ratio test* *16.359 **** Model 2: Dependent variable - number of tours per household Intercept 0.154 0.026 * -0.914 <0.001 *** Number of workers 1.097 <0.001 *** 1.085 <0.001 *** Number of non-workers 0.883 <0.001 *** 0.887 <0.001 *** Number of children under 6 years 0.251 0.021 * 0.238 0.028 * Number of school students 0.878 <0.001 *** 0.879 <0.001 *** Number of vehicles 0.026 0.396 0.072 0.020 * Medium-high income household (Yes) 0.303 <0.001 *** 0.311 <0.001 *** Ln(household density) - - 0.151 <0.001 *** Urban living infrastructure - - 0.001 0.120 *AIC* *16377* *16351* *Log likelihood ratio* *30.167**** Model 3: Dependent variable - average number of trips per tour at the household level Intercept 3.271 <0.001 *** 3.454 <0.001 *** Number of workers -0.184 <0.001 *** -0.183 <0.001 *** Number of non-workers -0.143 <0.001 *** -0.143 <0.001 *** Number of children under 6 years 0.425 <0.001 *** 0.427 <0.001 *** Number of school students 0.040 0.336 0.040 0.338 Number of vehicles 0.046 0.071 . 0.039 0.135 Medium-high income household (Yes) 0.065 0.209 0.064 0.215 Ln(household density) - - -0.027 0.312 Urban living infrastructure - - n.s.[2] n.s.[2] *AIC* *15076* *15077* *Log likelihood ratio* *1.024 (not significant)* Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 [1]BE refers to the Built Environment [2]n.s. refers to not significant (>0.5), which was not estimated in the model
Literature Review Findings	The literature review portion notes that in general, there is a lack of census around the impact that the built environment has on trip generation rates. Further, the paper notes that research in this specific area of built environment and trip generation is dated, with most research focused on specific modes. While the researchers note that there is a well-established link in research established on the broader topic of the built environment and travel behavior, they note that most of this research is around VMT and mode choice.
URL	https://journals.sagepub.com/doi/abs/10.1177/0361198119841854

Article Title	ISSUES IN URBAN TRIP GENERATION
Citation	Currans, K. M. (2017). Issues in Trip Generation Methods for Transportation Impact Estimation of Land Use Development: A Review and Discussion of the State-of-the-art Approaches. Journal of Planning Literature, 32(4), 335–345. https://doi.org/10.1177/0885412217706505
Research Objective	The purpose of this article is to review the latest methods for estimating the transportation impacts of site-level development in urban environments. The author notes that "the main objective is to identify the largest and potentially problematic gaps in methods available for practice in order to allow researchers, agencies, and practitioners to both be aware of these limitations and forge forward new innovations to solve these ongoing problems."
Research Findings	The paper finds that the most dominant source for estimating transportation impacts in the United States is The Institute of Transportation Engineers (ITE) Trip Generation Handbook. The author identified 13 methods to predict urban vehicle trip generation impacts. Of these, the most common method is to adjust ITE rates. However, the author identifies three methods that directly estimates person trips based on agency-collected data. The most common method is to "adjust ITE's Trip Generation Handbook vehicle trip generation rates based on assumed mode share and vehicle occupancy rates for ITE's study sites." These adjustments are made by either directly reducing vehicle trip rates by adjustments for urban contexts, or through identifying a baseline person-trip rate derived from the suburban ITE rates. The author notes that the second method relies on the assumption that person-trip rates are not impacted by urban context. In exploring this topic in literature, the author identifies that "few studies have focused on understanding the overall demand for travel (e.g., total trips or activity)—or rather the joint effects of land use upon mode-choice and trip frequency—potentially leading to over- and underestimation of overall activity." The paper notes that there is a shift in research towards identifying multi-modal trip generation data, and to this end identifies studies that are underway, the author finds that practitioners "continue to struggle estimating the impacts of urban development.".
URL	https://journals.sagepub.com/doi/abs/10.1177/0885412217706505?journalCode=jplb and https://pdfs.semanticscholar.org/56a4/140b084919beead7e96c356103d46ddec481.pdf

Article Title	**SYNERGISTIC NEIGHBORHOOD RELATIONSHIPS WITH TRAVEL BEHAVIOR: AN ANALYSIS OF TRAVEL IN 30,000 US NEIGHBORHOODS**
Citation	Voulgaris, C. T., Taylor, B. D., Blumenberg, E., Brown, A., & Ralph, K. (2016). Synergistic neighborhood relationships with travel behavior: An analysis of travel in 30,000 US neighborhoods. Journal of Transport and Land Use, 10(1). https://doi.org/10.5198/jtlu.2016.840
Research Objective	The researchers developed neighborhood typologies and explored the relationship between these designations and travel behavior. To do this, they utilize variables from the EPA Smart Location Database and the US Census to create seven neighborhood typologies that represent the "3 Ds." The researchers then developed models to evaluate these typologies against data from the National Household Travel Survey (NHTS), conducted in 2009, which includes respondents from all 50 states.

Research Findings	The researchers found very little variation between daily trips between neighborhood types, when New York City Old Urban areas were removed. However, they did find substantial variation in PMT and mode choice by neighborhood type.

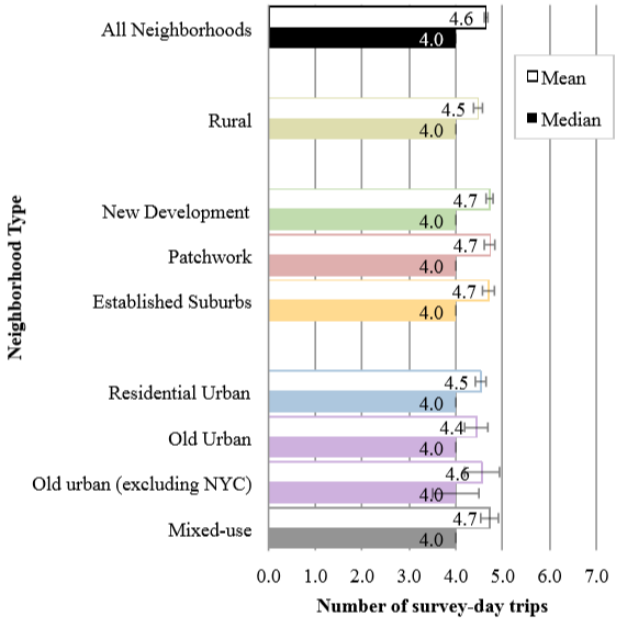


Figure 8: Mean and median number of survey-day trips by neighborhood type, with error bars indicating 95 percent confidence intervals

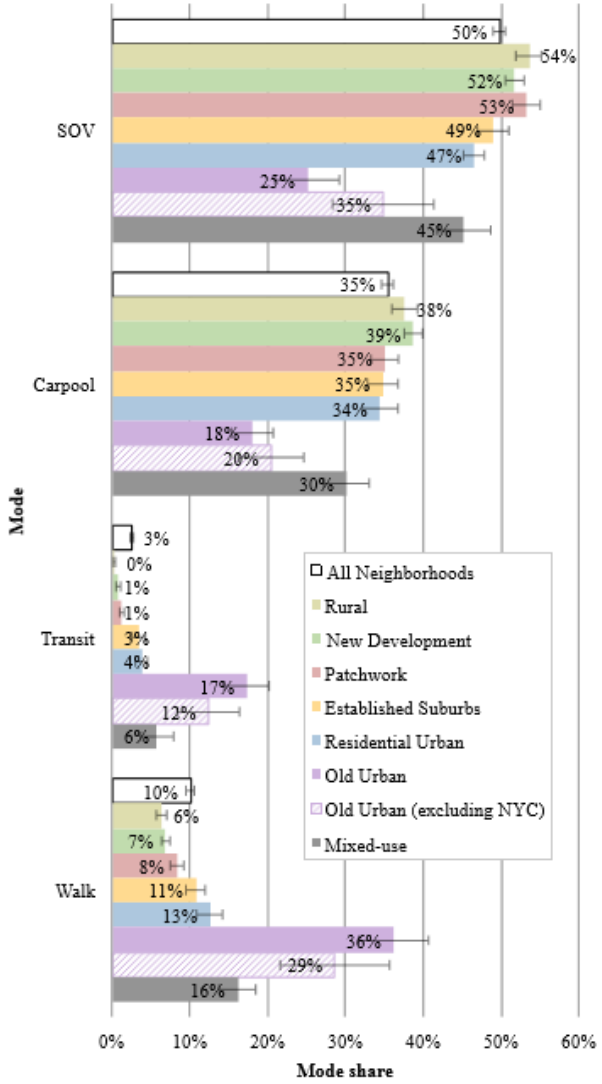


Figure 9: Percentage of survey-day trips by each mode, by neighborhood type, with error bars indicating 95 percent confidence intervals

In developing models, researchers did find a relationship between the neighborhood types and total trips. Table 6 reviews these findings. The report makes the following observations.

- "Controlling for individual and household characteristics (Model A), respondents in all non-rural neighborhoods except Old Urban neighborhoods made more trips than those in Rural neighborhoods, despite traveling far fewer miles on average"
- "Surprisingly, despite the much higher destination accessibility in Old Urban neighborhoods relative to Rural neighborhoods (see Table 4), the number of daily trips made by Old Urban residents is no different than the number of daily trips made by Rural residents."

- "In fact, when we control for built-environment characteristics, such as density and diversity in Model B, we find that residents of the Old Urban and Mixed-Use neighborhoods actually make fewer trips, on average, than their more rural counterparts."
- "When we include individual factor score in the model without including neighborhood type (Model C), the effects of the factor scores are of a similar magnitude to those in Model B. Of the three models, Model B best fits the data, as indicated by the Akaike Information Criterion (AIC)."

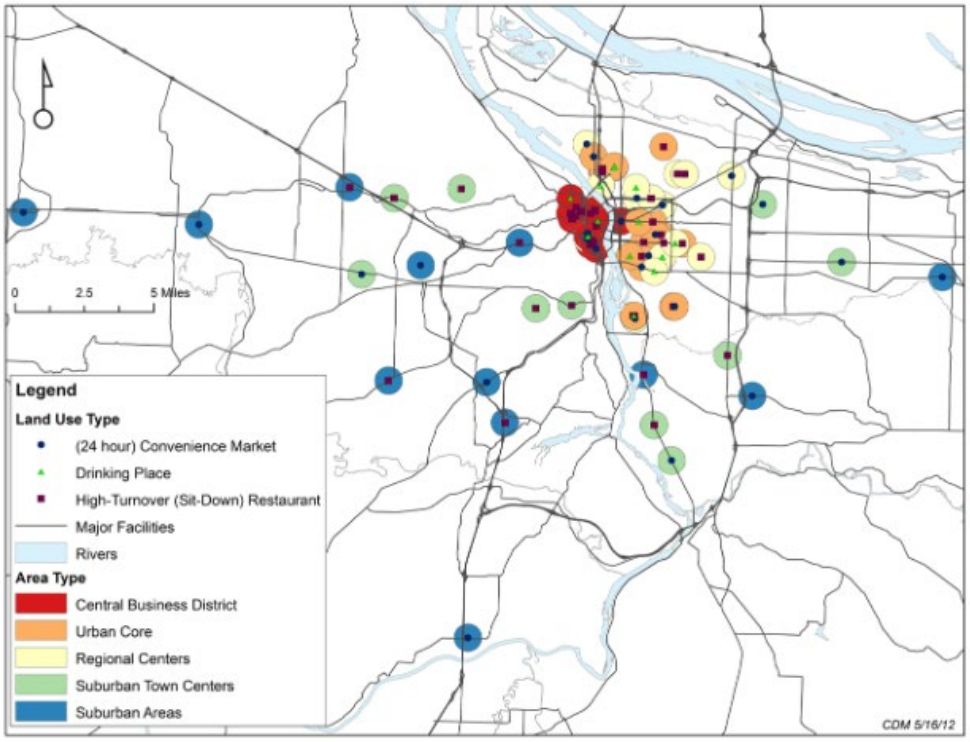
Table 6: Results of negative-binomial regression models for number of survey-day trips

	Model A		Model B		Model C	
AIC*	529,301		529,110		529,127	
Variable	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
Personal Characteristics						
Age	<0.01	<0.001	<0.01	<0.001	<0.01	<0.001
Sex (Base: Male)						
Female	0.08	<0.001	0.08	<0.001	0.08	<0.001
Race/ethnicity (Base: Non-Hispanic White)						
Non-Hispanic Black	-0.01	0.374	-0.01	0.240	-0.01	0.245
Non-Hispanic Asian	-0.12	<0.001	-0.12	<0.001	-0.12	<0.001
Hispanic	-0.01	0.156	-0.02	0.044	-0.02	0.036
Other	-0.02	0.077	-0.02	0.072	-0.02	0.066
Employment (Base: Employed)						
Not employed	-0.11	<0.001	-0.11	<0.001	-0.11	<0.001
Internet use (Base: Daily)						
Less than daily	-0.08	<0.001	-0.08	<0.001	-0.08	<0.001
Household characteristics						
Education (Base: Less than high school)						
High school	0.12	<0.001	0.12	<0.001	0.12	<0.001
Some college	0.20	<0.001	0.20	<0.001	0.20	<0.001
Four-year degree	0.25	<0.001	0.25	<0.001	0.25	<0.001
Graduate degree	0.27	<0.001	0.27	<0.001	0.27	<0.001
Income ($10,000s)	0.01	<0.001	0.01	<0.001	0.01	<0.001
Number of HH adults	-0.04	<0.001	-0.04	<0.001	-0.04	<0.001
Number of HH children	0.08	<0.001	0.08	<0.001	0.08	<0.001
Neighborhood characteristics						
Factor scores						
Dense	-	-	0.03	<0.001	0.04	<0.001
Diverse	-	-	0.02	<0.001	0.01	<0.001
Transient	-	-	0.01	0.004	<0.01	0.729
Established	-	-	0.03	<0.001	0.02	<0.001
Accessible	-	-	>-0.01	0.882	-0.01	0.66
Neighborhood type (Base: Rural)						
New development	0.03	<0.001	0.03	0.002	-	-
Patchwork	0.08	<0.001	0.01	0.460	-	-
Established suburb	0.01	<0.001	0.01	0.324	-	-
Urban residential	0.08	<0.001	0.01	0.600	-	-
Old urban	0.03	0.060	-0.08	0.001	-	-
Mixed-use	0.07	<0.001	-0.04	0.019	-	-

Statistically significant results (at a 95-percent confidence level) in black; non-significant results in grey.
*The Akaike Information Criterion (AIC) indicates goodness of fit, where a lower AIC value indicates a better fit to the data.

Literature Review Findings	The researchers report a body of evidence linking land use and urban form to travel behaviors. In general, they describe the relationship between travel behavior to be more closely related to socioeconomic factors than built-environment factors. Although they found research suggesting that combined built-environment factors could have a greater impact than when evaluated individually, the researchers found little work comparing the travel impacts of a comprehensive built environment factor to travel behavior.
URL	https://www.jtlu.org/index.php/jtlu/article/view/840

Article Title	**ITE TRIP GENERATION, 10TH EDITION**
Citation	Institute of Transportation Engineers. (2017). Trip generation. Washington, D.C.
Research Objective	The 10th edition includes a chapter that provides guidance for estimating the number of person trips generated at the site level based on a specific land use type and urban context.
Research Findings	Peak hour person trip rates were compiled from observed data for mid-rise multifamily residential and general office uses in three urban contexts: general urban/suburban, dense multi-use urban, and center city core. The person trip rates for the three urban contexts were essentially identical (0.52 to 0.54) for all three residential uses. The city center core office buildings had notably lower person trip generation rates (1.24) than the other two contexts (1.42 and 1.44), although the data relationships for the 13 center city core sites did not permit development of a fitted curve with a reasonable R-square value.
URL	https://www.ite.org/technical-resources/topics/trip-and-parking-generation/trip-generation-10th-edition-formats/

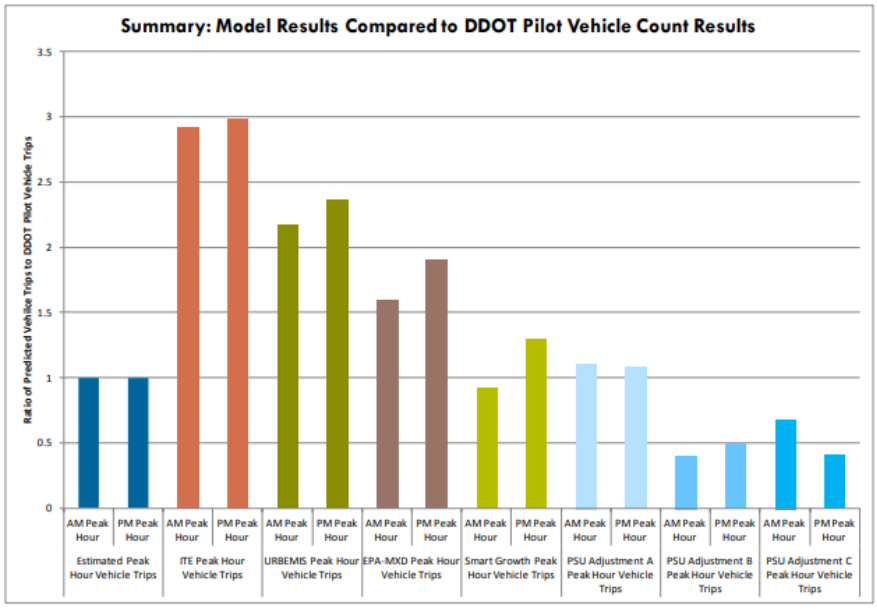
Article Title	**ADJUSTING ITE'S TRIP GENERATION HANDBOOK FOR URBAN CONTEXT**
Citation	Clifton, K., Currans, K., & Muhs, C. (2015). Adjusting ITE's Trip Generation Handbook for urban context. Journal of Transport and Land Use, 8(1), 5-29. Retrieved from http://www.jstor.org/stable/26202699
Research Objective	The purpose of this study is to explore how urban context affects trip generation rates across three land use types in Portland, Oregon and to identify an approach for adjusting ITE trip rates that can be useful for other communities seeking to develop local adjustments. As part of their research, data was collected at 78 establishments, focusing on high-turnover restaurants, convenience markets, and drinking establishments. Sites were selected to cover a broad range of urban environments in the region. To accomplish this, researchers identified a ½ mile straight line buffer around each establishment and identified the block size, percent of dwellings that are single-family detached, percent of retail employment, and percent of lot building coverage. The researchers used a k-means clustering analysis to divide the establishments into five built-environment typologies: business district neighborhoods, urban core neighborhoods, neighborhood and regional centers, suburban town centers and corridors, and suburban areas.  **Figure 1:** Site location map.

Research Findings	The ITE adjustment methodology relies on the assumption that person trip rates remain constant across urban contexts. The researchers tested this hypothesis against a variety of local urban context variables, including number of transit corridors, person density, number of high-frequency transit stops, employment density, lot coverage, length of bike facilities, retail and service employment index, access to rail, intersection density. Researchers found that "the average person trip rates per building area are not significantly different across urban contexts. This result suggests that our assumption appears to be applicable and person trips do not vary significantly for establishments of specific size and type."
Literature Review Findings	The paper's literature review component notes that numerous studies have explored predicted ITE trip generation rates versus observed rates. The authors write that the greatest range of error occurs in central business districts/urban core/downtown area, as well as in mixed-use development. The authors discuss methods that are available for agencies to adjust ITE rates.
URL	https://www.jstor.org/stable/26202699?seq=8#metadata_info_tab_contents

Article Title	**TRIP GENERATION AND DATA ANALYSIS STUDY (DDOT PHASE II)**
Citation	Porter, C., Hardy, D., Goldstein, J., Schiesel, R. B., Kaufmann, P., & Systematics, C. (2015). Trip generation and data analysis study.
Research Objective	This report, which builds on Phase I, looked at how specific land use types in urban settings influence trip generation. Phase II included a pilot of the trip generation data collection methodologies developed in Phase I, and included a portion analyzing these data.
Research Findings	In analyzing trip generation data collected at the site, the report explored relationships between these data and contextual variables. In general, the researchers found that "the relationship between total estimated person-trips was found to have the strongest relationship to the number of dwelling units (DU) plus the retail square footage (expressed as thousands of retail square feet, or KGSF. Researchers tested adding several environmental variables with the model, but determined that "environmental variables did not have a strong causative relationship as measured by t-statistics or p-values." Specific variables that were tested included, multi-modal accessibility (MMA), residential proximity, and auto ownership.
URL	https://www.alexandriava.gov/uploadedFiles/DDOT_TripGen_Report_Oct15%20(002).pdf

Article Title	TRIP GENERATION DATA COLLECTION IN URBAN AREAS (DDOT PHASE I)
Citation	Weinberger, R., Ricks, K., Schrieber, J., Cohen, L., & Symmetra Design, L. L. C. (2014). Trip generation data collection in urban areas (No. DDOT-RDT-14-01). District of Columbia. Dept. of Transportation.
Research Objective	The report found that limited data on trip generation at the site level exists for urban environments. The purpose of this report, which is the first phase of a multi-phase project, is to develop and test a protocol for generating trip data in urban environments at the site level.
Research Findings	The researchers found that their work confirmed that existing methodologies are inadequate for "predicting multimodal trip generation in urban contexts." The report developed a data collection methodology for addressing this gap in data. In reviewing pilot data generated as part of this study, the report found that ITE Trip Generation rates would in general overestimate vehicle trips and underestimate non-vehicle modes. Specific to total trip generation, the report found that ITE approaches underestimated person trips. The report reviews alternative methods for predicting trip generation, and while they found some improvement over the ITE approach, the authors suggest the need for more data and a new approach.

Literature Review Findings	The researchers reviewed methodologies for identifying trip generation rates at the site level. The researchers applied these models and compared site level count results to estimates developed from the models. Below is a brief summary of the alternative methodologies the report includes, including a chart that indicates how the model compared to survey data in Washington, D.C. **ITE Trip Generation Manual –** Document containing vehicle counts across the United States. Crowd-sourced, and focused on single-use, low density sites. **URBEMIS** –The California Air Resources Board developed the urban emissions model that quantifies emissions from development. Largely based on conversion of VMT to trips. The output is a reduction credit applied to ITE trip estimates that account for development context. **EPA-MXD** – This spreadsheet tool is based on the 2010 paper, "Travel and the Built Environment," which is summarized separately in this white paper, and observations of 239 mixed-use urban developments. The spreadsheet tool uses land use modifiers, such as intersection density and jobs-housing balance, to adjust ITE estimate and estimate trips by mode. **Smart Growth Trip Generation (SGTG)** – Based on data collected at California smart growth sites, this spreadsheet tool estimates vehicle, transit, and walking trip generation rates by adjusting ITE rates using a linear regression. Tool inputs include population, jobs, distance to CBD, setback, parking costs, transit service frequency, and percent parking of area. **PSU Models** – This includes three model developed by Clifton and Currans adjusts ITE trip generation rates based on simple land use categories and trip characteristics. Model A uses density within a half mile buffer to estimate mode share. Model B predicts auto share by intersection density. And Model C predicts auto share by distance from CBD and nearness of TOD. This report found that model A provided the closest estimates to count data.

	Figure 32. Ratio of Model Results to DDOT Estimated Vehicle Trips 
URL	https://nelsonnygaard.com/wp-content/uploads/2014/04/2014-01_Urban-Trip-Generation-Final-Report.pdf

Article Title	**COMPARING THE INFLUENCE OF LAND USE ON NONWORK TRIP GENERATION AND VEHICLE DISTANCE TRAVELED: AN ANALYSIS USING TRAVEL DIARY DATA**
Citation	Boarnet, M. G., Nesamani, K. S., & Smith, S. (2003). Comparing the Influence of Land Use on Nonwork Trip Generation and Vehicle Distance Traveled: An Analysis using Travel Diary Data.
Research Objective	Researchers used travel diary data to identify impacts of the built environment on non-work vehicle trips and VMT.
Research Findings	The authors found that land use variables and sociodemographic variables had similar impacts on VMT and vehicle trip generation. The researchers did not review non-vehicle travel, and therefore the results do not inform the impact of the built environment on total trip generation. Income was determined to be the "primary determinant of both trip frequency and VMT, but that land use exerts an influence that is on par with other sociodemographic characteristics after the primary role of income is considered."
Literature Review Findings	The researcher's review of literature found that research around the relationship between land use and non-work travel. The authors summarize research findings that indicate some level of connection, with studies finding differing levels of impact.
URL	https://escholarship.org/content/qt4xf6r519/qt4xf6r519.pdf

Article Title	TRAVEL AND THE BUILT ENVIRONMENT: A META-ANALYSIS
Citation	Reid Ewing & Robert Cervero (2010) Travel and the Built Environment, Journal of the American Planning Association, 76:3, 265-294, DOI: 10.1080/01944361003766766
Research Objective	The authors conducted a meta-analysis of studies that explored the relationship between the built environment and travel behavior. Their intent was to identify "generalizable conclusions for practice."
Research Findings	The meta-analyses looked at VMT, walking, and transit use, and therefore a relationship to trips was not explored. The researchers found that "travel variables are generally inelastic with respect to change in measures of the built environment. Of the environmental variables considered here, none has a weighted average travel elasticity of absolute magnitude greater than 0.39, and most are much less. Still, the combined effect of several such variables on travel could be quite large." The meta-analyses did not explore the relationship between trips and the built environment.
Literature Review Findings	The paper's literature review section notes that trip frequency, trip length, mode choice, and VMT were the most commonly modeled outcomes in research. With respect to trip frequency, the authors found that "trip frequency is primarily a function of socioeconomic characteristics of travelers and secondarily a function of the built environment."
URL	https://www.tandfonline.com/doi/abs/10.1080/01944361003766766

Article Title	**TRAVEL AND THE BUILT ENVIRONMENT: A SYNTHESIS.**
Citation	Ewing, R., & Cervero, R. (2001). Travel and the Built Environment: A Synthesis. *Transportation Research Record*, *1780*(1), 87–114. https://doi.org/10.3141/1780-10
Research Objective	The authors conduct a literature review of 50 recent empirical studies to identify the impacts of the built environment on trip frequency, trip length, mode choice, VMT, and VHT.
Research Findings	Generalizing across all studies in the synthesis, the authors write that trip frequency is "primarily a function of socioeconomic characteristics of travelers and secondarily a function of the built environment." The study includes summaries of findings around trip frequency based on the the aspect of the built environment that the underlying research explored. Regarding neighborhood and activity center design, the researchers concluded that "trip frequencies differ little, if at all, between built environments. Three studies showing lower trip rates in traditional urban neighborhoods failed to control for income or household size differences, which could easily account for the lower rates." However, they also note that in "more carefully controlled studies, it appears that overall trip frequencies depend mainly on household socioeconomic characteristics and that travel demand is inelastic with respect to accessibility" Summarizing studies that explored land use patterns, researchers report that "trip frequencies appear to be largely independent of land use variables, depending instead on household socioeconomic characteristics. Any drop in automobile trips with greater accessibility, density, or mix is roughly matched by a rise in transit or walking-biking trips."
URL	https://journals.sagepub.com/doi/10.3141/1780-10

Article Title	LAND USE IMPACTS ON TRIP GENERATION RATES
Citation	Ewing, R., Deanna, M., & Li, S.-C. (1996). Land Use Impacts on Trip Generation Rates. Transportation Research Record, 1518(1), 1–6. https://doi.org/10.1177/0361198196151800101
Research Objective	The researchers tested the effects of density, jobs-housing balance, and accessibility on household trip frequencies. Researchers used travel data from travel surveys across Florida to test for a relationship.
Research Findings	Relating to trip rates, the researchers found a negligible impact from the variables they tested. They concluded, "after controlling for sociodemographic variables, residential density, mixed use, and accessibility do not have significant, independent effects on household trip rates."
Literature Review Findings	The article's literature review finds that while theory suggests that accessibility would impact trip rates, studies of trip data have resulted in mixed findings on the relationship.
URL	https://journals.sagepub.com/doi/abs/10.1177/0361198196151800101