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Incorporating the 10th Edition Institute of Traffic Engineers (ITE) Trip Generation Rates Into Virginia Department of Transportation Guidelines

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Incorporating the 10th Edition Institute of Traffic Engineers (ITE) Trip Generation Rates Into Virginia Department of Transportation Guidelines

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16. Abstract:
The Institute of Transportation Engineers (ITE) released the *Trip Generation* (TG) 10th edition in 2017, which significantly updated its database, and some of its trip generation rates were substantially lower than those of earlier editions. This study aims to investigate the applicability of the TG 10th edition in various Virginia contexts and to recommend how to incorporate the TG 10th edition into state guidelines. The research team surveyed 31 state transportation agencies to obtain a clear understanding of current practices in the adoption of trip rates and trip estimation approaches. We systematically compared trip rates of TG 9th and 10th editions using hypothesis tests and identified land uses with significant rate reduction. Trip generation data were collected from 37 sites in Virginia during weekday PM peaks for the mixed-use sites and single-use sites with significantly reduced 10th edition rates (multi-family low-rise and general office). To investigate the use of trip rates in different settings, general offices in both general urban/suburban and dense multi-use urban were considered. For mixed-use developments, we explored the combinations of four internal trip capture models and TG rates of 9th and 10th editions to identify the best trip estimation approach. Given that all trip data were collected after the outbreak of the COVID-19 pandemic, Streetlight data were used to adjust trip counts to account for the impacts of COVID. This study recommends that the VDOT Office of Land Use: 1) accept the TG 10th edition for the development of a Traffic Impact Analysis (TIA) should the 8th or 9th edition rates show a TIA is required and select 10th edition trip rates according to settings; and 2) accept the methodology presented in Trip Generation Handbook 3rd edition to estimate internal trip capture for mixed-use developments. This project will provide benefits to VDOT by improving the estimation of trip generation, which is critical in determining charges to developers for transportation improvements and making decisions concerning the modification of existing facilities and the design of new facilities.

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FINAL REPORT

INCORPORATING THE 10th EDITION INSTITUTE OF TRAFFIC ENGINEERS (ITE) TRIP GENERATION RATES INTO VIRGINIA DEPARTMENT OF TRANSPORTATION GUIDELINES

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ABSTRACT

The Institute of Transportation Engineers (ITE) released the *Trip Generation* (TG) 10th edition in 2017, which significantly updated its database, and some of its trip generation rates were substantially lower than those of earlier editions. This study aims to investigate the applicability of the TG 10th edition in various Virginia contexts and to recommend how to incorporate the TG 10th edition into state guidelines. The research team surveyed 31 state transportation agencies to obtain a clear understanding of current practices in the adoption of trip rates and trip estimation approaches. We systematically compared trip rates of TG 9th and 10th editions using hypothesis tests and identified land uses with significant rate reduction. Trip generation data were collected from 37 sites in Virginia during weekday PM peaks for the mixed-use sites and single-use sites with significantly reduced 10th edition rates (multi-family low-rise and general office). To investigate the use of trip rates in different settings, general offices in both general urban/suburban and dense multi-use urban were considered. For mixed-use developments, we explored the combinations of four internal trip capture models and TG rates of 9th and 10th editions to identify the best trip estimation approach. Given that all trip data were collected after the outbreak of the COVID-19 pandemic, Streetlight data were used to adjust trip counts to account for the impacts of COVID. This study recommends that VDOT's Office of Land Use provide guidance to VDOT districts to accept traffic impact analysis reports using ITE's 10th Edition *Trip Generation* and the 3rd Edition of the *Trip Generation Handbook*. It is further recommended that the Office of Land Use provide guidance to the districts to accept traffic impact analysis reports prepared using the methodology presented in the 3rd edition of the *Trip Generation Handbook* to estimate internal capture for mixed-use developments.

TABLE OF CONTENTS

FINAL REPORT

INCORPORATING THE 10th EDITION INSTITUTE OF TRAFFIC ENGINEERS (ITE) TRIP GENERATION RATES INTO VIRGINIA DEPARTMENT OF TRANSPORTATION GUIDELINES

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INTRODUCTION

Transportation agencies require developers to evaluate the traffic impacts of proposed land use developments to prevent or mitigate traffic congestion. *Trip Generation* (TG), a manual developed by the Institute of Transportation Engineers (ITE), has been widely used by US practitioners to estimate trip generation, an essential component of traffic impact studies. Underestimating generated trips could contribute to traffic congestion, while overestimating generated trips could result in unfair high charges to developers for unnecessary improvements to transportation infrastructure. However, the TG database may be insufficient or outdated for some types of land use: ITE has traditionally collected most data for TG from suburban, single land use and automobile-oriented environments. Moreover, the ITE methodology for trip generation estimation may not always be applicable given the vastly diverse development contexts across the US. As such, ITE's TG has not always delivered satisfactory estimates of trip generation (Clifton et al., 2015).

ITE released its 10th edition of the TG in 2017, and changes from the 9th edition include an updated database which excludes pre-1980 data and incorporates 1,700 new sites. Further, 22 new land use types were added, bringing the total number of land use types to 176. The TG 10th edition also features a revised methodology for estimating trip generation for mixed-use developments and offers direct calculation of person trips to input into the modal split step. In addition, for the first time, the TG designates each data point as one of four setting types: center city core, dense multi-use urban, general urban/suburban or rural. In the 10th edition, the ITE also permits users to have direct access to its data points, which provides the flexibility to identify data points with similar contextual factors to the proposed land use development. These updated features may offer useful insights for improved trip generation and warrant an investigation of how the TG 10th edition might inform Virginia Department of Transportation (VDOT) guidelines.

PURPOSE AND SCOPE

The purpose of this research is to investigate the applicability of the ITE TG 10th edition to Virginia and to make recommendations on how to incorporate the TG 10th edition into state guidelines. More specifically, the objectives of this project are to:

- Examine other states' trip generation practices, especially regarding adoption of the TG 10th edition.
- Assess the impacts of the COVID-19 pandemic during the study period could affect the accuracy of trip generation estimates for different setting types in Virginia.
- Determine the most suitable trip generation rates for various Virginia contexts. Trip generation rates vary by TG versions (e.g., 9th edition vs 10th edition), and setting types (i.e., center city core, dense multi-use urban, general urban/suburban, and rural).
- Determine which of three options is most suitable for mixed-use developments in Virginia: (1) using the rates in the TG 9th edition and trip reduction factors (e.g., for internal capture); (2) using the rates in the TG 10th edition without trip reduction factors; or (3) using the rates in the TG 10th edition with trip reduction factors.
- Recommend updates for VDOT *Administrative Guidelines for the Traffic Impact Analysis Regulations.*

METHODS

Overview

The following tasks were conducted to achieve the study objectives:

1. Review the Literature
2. Summarize Changes in Trip Generation Rates
3. Survey State Agencies
4. Identify Criteria for Setting Classification
5. Collect and Analyze Virginia-Specific Data
6. Account for COVID-19 Impacts
7. Analyze Trip Data

Review the Literature

The research team conducted a literature review that included practical applications, referred regulations, case studies, and government reports. The main purpose of the literature review was to investigate the applicability of ITE trip generation rates in various contexts and the use of trip reduction approaches. Major works referenced in the literature review included the TG 9th edition (ITE, 2012) and TG 10th edition (ITE, 2017b), Trip Generation Handbook (TGH) 2nd edition (ITE, 2004) and TGH 3rd edition (ITE, 2017a), the EPA/SANDAG MXD model (United States Environmental Protection Agency), National Cooperative Highway Research Program (NCHRP) Report 684 (Bochner et al., 2011), and NCHRP Report 758 (Daisa et al., 2013). The TGH 3rd edition was published along with the TG 10th edition.

Summarize Changes in Trip Rates

The ITE's addition of new data, elimination of older data, and re-examination of existing data produced changes in the trip generation rates in the TG 10th edition. The task compared TG 10th and 9th editions using hypothesis tests and identified land uses with significant rate reductions for further investigation. Following the review of various trip estimation approaches (e.g., TG 10th and 9th editions, NCHRP Report 684 and NCHRP Report 758, and the EPA/SANDAG MXD model), the research team compared trip generation rates of all the land use types that appear in these approaches, such as office, retail, service, residential and industrial. The team also compared the rates of other typical land use types such as institutional, lodging, and recreational. ITE collected the trip rates during five different time periods: Weekday, Weekday AM Peak Hour of Adjacent Street Traffic, Weekday PM Peak Hour of Adjacent Street Traffic, Weekday AM Peak Hour of Generator, Weekday PM Peak Hour of Generator. Note that "Adjacent Street Traffic" includes site-generated traffic and traffic on the adjacent street, while "Generator" only includes traffic entering and exiting the site.

The comparison includes evaluations of both the practical significance and the statistical significance of the trip rate change. Results are practically significant when the change is large enough to be meaningful in real life. The metric for practical significance is rate change in percentage (% change).

$$\%\ Change = \frac{\overline{X_1} - \overline{X_2}}{\overline{X_2}} \times 100\% \qquad (1)$$

where, $\bar{X}_1, \bar{X}_2$ are the means of trip generation rates of the TG 10th and 9th editions, respectively. The statistical significance of the trip rate change is measured through Welch's t-test, which assumes unequal sample distribution variance.

$$t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}} \qquad (2)$$

where t is the test statistic in the Welch's t-test; s_1, s_2 are the standard deviations of trip generation rates of 10^{th} and 9^{th} editions of TG, respectively; and N_1, N_2 are sample sizes of the trip generation data of 10^{th} and 9^{th} editions of TG respectively.

Survey State Agencies

This task sought a clear understanding of other states' current practices in incorporating the 10^{th} edition ITE TG into guidelines. The research team carefully reviewed jurisdictional guidelines for trip generation prior to comprehensively exploring practices among state agencies. An online questionnaire attached in Appendix A was designed by the research team, and it covers the critical questions related to the following:

- Adoption of the ITE TG 10^{th} edition
- Guidelines for the use of ITE's database
- Criteria used to identify setting types of developments
- Approaches to estimate internal capture in mixed use development
- Approaches to estimate external walk/bike trips
- Approaches to estimate external transit trips
- Trip reductions based on demand management (e.g., increased parking fees and the implementation of HOV lanes)
- Alternative approaches for trip estimation (e.g., applying region-specific adjustment, incorporation of local trip generation data, household surveys and travel demand models)

The Social Science Research Center (SSRC) at Old Dominion University distributed the questionnaire, coordinated the correspondence, and summarized the survey results. State representatives were identified via AASHTO Planning Committee. Email invitations to participate in the survey were sent to identified state representatives in early June 2020. Reminders were sent a week later followed by phone calls to non-respondents. A final reminder was sent in the end of June.

Identify Criteria for Setting Classification

The TG 10^{th} edition defines four setting types for trip data points collected: center city core, dense multi-use urban, general urban/suburban and rural. One land use type can be associated with multiple trip generation rates, depending on the setting. If data for a specific setting are available, those data should be used for trip generation. If data for a specific setting are unavailable, ITE approaches should be used to adjust general urban/suburban trip generation rates for a particular location application. The research team carefully reviewed the TG's descriptions of specific setting types and the relevant literature, and summarized the classification criteria based on density, land use diversity, public transit, pedestrian facility, and parking.

Collect Virginia-Specific Data

This task sought to collect trip generation data for land uses of interest across a variety of contexts in Virginia, an essential step in evaluating the applicability of the ITE 10th edition. The following procedure describes our approach to this task:

- Step 1. Select land use types of interest. We focused on mixed-use sites and single-use sites with significant rate reductions, including multi-family low-rise and general office. To investigate the use of rates in different settings, general office is considered in the settings of both general urban/suburban and dense multi-use urban.

- Step 2. Identify representative sites for each land use type based on their definitions and feasibility to collect data. According to TG, a multi-family low-rise housing should contain at least four dwelling units and have one or two floors, a general office building should house multiple tenants with a gross floor area over 5,000 square feet, and a mixed-use development is a single real-estate development that consists of two or more ITE land use types with a gross floor area from 100,000 to 2 million square feet.

- Step 3. Conduct onsite data collection in compliance with the guidance provided in the Virginia Traffic Impact Statement (VDOT, 2008). Instances such as holidays, inclement weather, and special events were avoided. For each site, external trips by mode (e.g., passenger vehicle, transit, walk, bike) during weekday PM peak hour of adjacent street traffic (peak hour between 16:00 and18:00 by default) were counted. The data collection form is attached in Appendix B. Ten data collectors attended a training session prior to field data collection.

Due to constraints of time and budget, 37 representative sites were selected for this study, as summarized in Table 1. An online interactive map for these sites was created and a snapshot of that map is shown in Figure 1. The data collection schedule is shown in Table 2.

Table 1. Sites for Field Data Collection

Land Use	Setting	Sites
Multi-Family Low-rise	General Urban/Suburban	R1[a]: Grace Hill, Virginia Beach, VA 23455
		R2: Traditions, Virginia Beach, VA 23455
		R3: Woodland Park, Virginia Beach, VA 23462
		R4: Princess Ann Square, Virginia Beach, VA 23462
		R5: Providence Point, Chesapeake, VA 23325
		R6: South Hampton, Virginia Beach, VA 23456
		R7: Columbus Station, Virginia Beach, VA 23462
		R8: Columbus Station East, Virginia Beach, VA 23462
		R9: St. Andrews, Virginia Beach, VA 23320
		R10: Wimbledon Chase Condos, Virginia Beach, VA 23703
		R11: Ashley Park, Richmond, VA 23225
		R12: Ridgecrest Dr., Charlottesville, VA 22902
General Office	General Urban/Suburban	O1: The Language Group, etc., Virginia Beach, VA 23462
		O2: RE/MAX Alliance, etc., Virginia Beach, VA 23462
		O3: East Coast Trial Lawyers, Virginia Beach, VA 23462
		O4: Southern Trust Mortgage, etc., Virginia Beach, VA 23462
		O5: The Cooper Law Firm, etc., Virginia Beach, VA 23462
		O6: Professional Financial Services, Virginia Beach, VA 23462
		O7: Hook Law Center, Suffolk, VA 23435
		O8: Advisor Mortgage, Virginia Beach, VA 23462
		O9: UST Global, etc., Virginia Beach, VA 23462
		O10: IT Dojo, etc., Virginia Beach, VA 23452
General Office	Dense Multi-Use Urban	O11: AECOM, etc., Norfolk, VA 23510
		O12: Kass Law Firm, etc., Portsmouth, VA 23704
		O13: Ciniva, etc. Norfolk, VA 23510
		O14: Dominion Enterprises, Norfolk, VA 23510
		O15: Zak Investment, Norfolk, VA 23510
Mixed-Use	General Urban/Suburban	M1: Haygood Shopping Center, Virginia Beach, VA 23455
		M2: Hilltop Marketplace, Virginia Beach, VA 23451
		M3: Fairfield Shopping Center, Virginia Beach, VA 23455
		M4: Providence Square Shopping Mall, Virginia Beach, VA 23464
		M5: Kemps River Crossing Shopping Mall, Virginia Beach, VA 23464
		M6: Parkway Market Place, Virginia Beach, VA 23464
		M7: Pembroke Meadows Shopping Center, Virginia Beach, VA 23455
		M8: Cypress Point Shopping Center, Virginia Beach, VA 23455
		M9: Loehmann's Plaza, Virginia Beach, VA 23452
		M10: Todd Center, Virginia Beach, VA 23666

[a] Letter and number combinations (e.g., R1, R2, O3) are site labels.

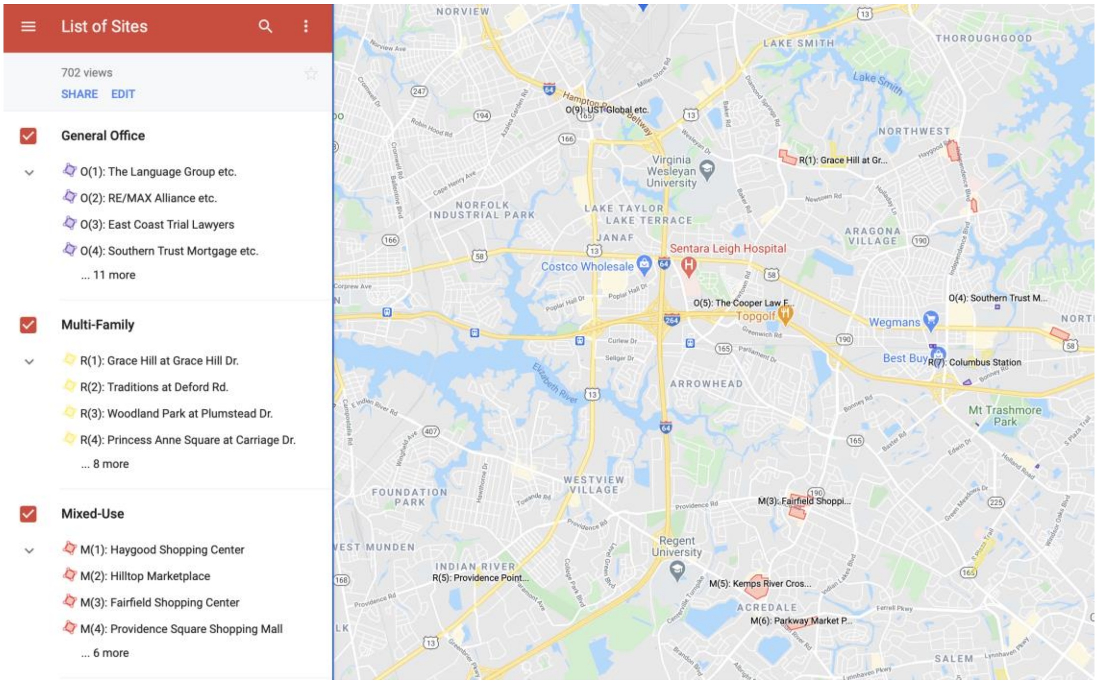


Figure 1. Map of Sites (Xie & Dong), Map Data © 2021 Google

Table 2. Study Data Collection Schedule in 2020

Nov 9	**Nov 10**	**Nov 13**	**Nov 16**	**Nov 17**	**Nov 18**
R5[a], R3, R9, R10	R6, R1	R8, O1, O2, O3	O4, O9	O6, O5	O7, O8, O15
Nov 19	**Nov 20**	**Nov 30**	**Dec 1**	**Dec 2**	**Dec 3**
O10, M8	O12, M5	M4	O13	M2	M6
Dec 4	**Dec 7**	**Dec 8**	**Dec 9**	**Dec 10**	
M10	M3	M9	M7	O11, O14, O16	

[a] Letter and number combinations (e.g., R1, R2, O3) are site labels defined in Table 1.

Account for COVID-19 Impacts

In response to the COVID-19 pandemic, the Commonwealth of Virginia issued a stay-at-home order on March 30, 2020. Parr et al. (2020) found that the COVID-19 pandemic significantly influenced subsequent travel demand. In this study, all trip generation data were collected after the outbreak of the pandemic, and thus it is critical to account for the impacts of COVID-19. Streetlight data were used to quantify the impacts of COVID-19 for each land use type. Site-specific trip estimates during weekdays of November and December in 2019 and 2020 were used to conduct before-after comparisons. To minimize bias from the different algorithms/data sources, we did not use Streetlight data earlier than 2019. The pass-through gateways were set across adjacent streets to obtain entering and exiting trips for each investigated site. An example of gateway setup for Haygood Shopping Center is illustrated in Figure 2.

Figure 2. Setup of Gateways for Haygood Shopping Center

We used the change rate and COVID adjustment factor to measure the impact of the pandemic as follows:

$$Change\ Rate = \frac{ST_{2020} - ST_{2019}}{ST_{2019}} \times 100\% \qquad (3)$$

$$COVID\ Adjustment\ Factor = \frac{ST_{2020}}{ST_{2019}} \times 100\% \qquad (4)$$

where ST_{2019} and ST_{2020} are estimated mean trips for a specific land use by Streetlight during the weekday PM peak in 2019 and 2020, respectively.

Analyze Trip Data

If there were no COVID-19, the trip count in the counterfactual scenario (Adjusted Trip Count) can be estimated by:

$$Adjusted\ Trip\ Count = \frac{Observed\ Trip\ Count}{COVID\ Adjustment\ Factor} \qquad (5)$$

We computed the observed and adjusted trip rates for multi-family low-rise and general office by dividing the observed and adjusted trip counts by independent variables (e.g., dwelling unit for multi-family low-rise and gross floor area for general office). The observed and adjusted trip rates were then compared with the trip rates of the TG 9th and 10th editions.

For mixed-use developments, we explored the combinations of four internal trip capture models and TG rates of 9th and 10th editions to identify the best trip estimation approach for Virginia's context. These four internal trip capture models include 1) no internal capture applied; 2) the approach presented in VDOT Traffic Impact Analysis (TIA) Regulations; 3) the MXD method, which is currently adopted by VDOT; and 4) the approach presented in the TGH 3rd edition (published along with the TG 10th edition), which is most widely adopted by state agencies according to survey results. The estimates of all approaches were compared with the observed and adjusted trip counts of the mixed-use developments investigated.

RESULTS

Review the Literature

Despite being accepted as an industry standard, ITE TG has long been criticized for failing to provide accurate the trip generation rates in urban, mixed-use and transit-oriented contexts and for land use types with insufficient and outdated data. Clifton et al. (2015) conducted travel surveys at 78 establishments in Portland and showed that TG (9th edition) significantly overestimated vehicle trips in an urban context because of factors such as accessible public transit, facilities available for pedestrians and cyclists, and high activity density. Lee et al. (2011) indicated that ITE provided a methodology to capture internal trips of mixed-use developments, but this method was shown to be less effective than other alternatives (e.g., EPA/SANDAG MXD and URBEMIS) developed to estimate vehicle trip generation rates. Ewing et al. (2017) examined five transit-oriented development (TOD) cases in the US and found that vehicle trip generation rates were about half or less of what was predicted using the ITE rates. In addition, Palakurthy et al. (2017) collected vehicle trip generation data at 40 park-and-ride facilities in Denver with regional bus and light rail transit service and indicated that ITE failed to provide accurate representations because of the small sample sizes and outdated trip generation data used for park-and-ride land use. Currans (2013) summarized the results of 13 studies performed to compare the ITE predicted vehicle trip rates with observed ones and found significant differences for developments in CBD/urban core/downtown areas and mixed-use developments.

To provide local developers with more accurate trip rates, a few jurisdictions collected locality-specific trip generation data and developed their own procedures for trip generation estimation, such as San Diego (Handy et al., 2013), San Francisco (Rahaim et al., 2019) and New York City (NYC, 2020). Clifton et al. (2015) reviewed 23 jurisdictional guidelines for local adjustment of trip generation rates and found that 14 of them allowed adjustment for transit, walking and biking or mixed-use development, but there was no consensus across the jurisdictions on how to quantify the adjustment. For single-use developments, alternative approaches to ITE methodology included URBEMIS (Nelson\Nygaard Consulting Associates, 2015) that regionally adjusted ITE rates according to built environment features and INDEX (Hagler Bailly Services Inc. & Criterion Planners/Engineers, 1999) that estimated trip generation based on regional travel model outputs and policies. For multi-use development, trip reduction should be considered due to internal trip capture. ITE provided a procedure to estimate the internal capture at mixed-use developments but it has been shown to be less effective than other alternatives (Lee et al., 2011). NCHRP Report 684 (Bochner et al., 2011) expanded the ITE procedure to cover AM, PM peak hours, mix of up to six primary land uses and to consider the effect of proximity, resulting in more precise estimates of internal capture. It is worth mentioning that the recommended methodology in the TGH 3rd edition was based on the procedure presented in NCHRP Report 684 (Bochner et al., 2011). The EPA/SANDAG MXD method (United States Environmental Protection Agency) accounted for elasticities and impacts of contextual factors (e.g., geographic, demographic, and land use characteristics) to estimate internal capture of trips, as well as walking and transit use in mixed-use developments. This method is currently adopted by several regions in California, Washington, and New Mexico, and is accepted as an alternative to ITE approaches in Virginia. In addition, NCHRP Report 758 (Daisa et al., 2013) developed procedures for trip generation estimation of infill developments by applying adjustment factors of mode share and vehicle occupancy. This study detailed two ways for deriving the adjustment factors, 1) collecting empirical data from proxy sites located in environments that represent the future context of the project being analyzed, and 2) extracting contextual factors (e.g., mode splits, car ownership, etc.) from household travel surveys. Clifton et al. (2012) and Currans and Clifton (2015) also proposed to use household travel surveys to adjust ITE trip generation rates based on known contextual vehicle mode splits.

In summary, a review of the literature reveals ITE does not always provide accurate vehicle trip estimates given the vast diversity of local contexts. Also, there is no consensus across jurisdictions on alternative procedures for estimating trip generation when ITE fails to deliver satisfactory estimates. There is limited work comparing the estimates of the ITE TG 10th edition with observed trip rates, since it was released fairly recently (2017).

Summarize Changes in Trip Rates

We compared the trip generation rates of the TG 9th and 10th editions for typical land use types, with results reported in Table 3. There are several land use types with trip generation rates that significantly decline in all five time periods, including general industrial, warehousing, mini-warehousing, university/college, general office, multi-family low-rise, and drive-in bank. For weekday AM peak hour of adjacent street traffic, there are land use types of industrial, university/college, hotel, general office, multi-family-low-rise, drive-in bank, quality restaurant, fast-food-restaurant with drive-through-window, and gas/service station for which the rates decline. When comparing the rates generated during the weekday PM peak hour of adjacent street traffic, the10th edition rates of land use types such as general industrial, manufacturing, mini-warehousing, university/college, medical-dental office, general office, single family, multi-family-low-rise, supermarket, and drive-in bank were lower than the 9th edition rates. The rates of general office and drive-in bank in the 10th edition were significantly lower when compared to the 9th edition with respect to all independent variables, such as gross floor area and employees.

Table 3. Comparisons of Trip Generation Rates between the Trip Generation 10th Edition and the Trip Generation 9th Edition

Land Use Type		10th Code	9th Code	Independent Variable	Weekday	Weekday AM Adjacent	Weekday PM Adjacent	Weekday AM Generator	Weekday PM Generator
Industrial	General Industrial	110	110	1000 Sq. Feet Gross Floor Area	-28.84%***	-23.91%***	-35.05%***	-8.91%***	-23.15%***
				Employees	15.89%[a]	18.18%***	16.67%***	39.58%***	33.33%***
	Manufacturing	140	140	1000 Sq. Feet Gross Floor Area	2.88%**[b]	-15.07%***	-8.22%***	2.53%	5.33%**
				Employees	15.96%***	-7.50%***	-8.33%***	10.26%***	12.50%***
				Acres	-9.93%**	-37.90%***	-45.63%***	-26.02%***	-20.41%***
	Warehousing	150	150	1000 Sq. Feet Gross Floor Area	-51.12%***	-43.33%***	-40.63%***	-47.62%***	-46.67%***
				Employees	29.82%***	19.61%***	11.86%***	23.64%***	17.24%***
	Mini-Warehousing	151	151	1000 Sq. Feet Gross Floor Area	-39.60%***	-28.57%**	-34.62%***	-28.57%***	-31.03%***
				1000 Sq. Feet Net Rentable Area	0.00%	0.00%	0.00%	0.00%	0.00%
Institutional	University/College	550	550	Students	-8.77%***	-11.76%***	-11.76%***	-7.14%***	-6.67%***
				Employees	N/A	0.00%	0.00%	-3.80%***	-4.71%***
	High School	530	530	Students	18.71%***	20.93%***	7.69%***	N/A	13.79%***
				1000 Sq. Feet Gross Floor Area	9.15%***	10.46%***	0.00%	N/A	1.42%
				Employees	12.72%***	14.53%***	4.52%**	N/A	2.17%*
	Middle School	522	522	Students	31.48%***	7.41%**	6.25%***	N/A	16.67%***
				1000 Sq. Feet Gross Floor Area	46.37%***	N/A	0.00%	N/A	32.14%***
				Employees	53.45%***	N/A	0.00%	N/A	24.58%***
	Elementary School	520	520	Students	46.51%***	48.89%***	13.33%***	N/A	21.43%***
				1000 Sq. Feet Gross Floor Area	26.51%***	34.04%***	13.22%**	N/A	1.61%
				Employees	33.67%***	35.27%***	1.14%	N/A	4.69%*
Lodging	Hotel	310	310	Rooms	2.33%*	-11.32%***	0.00%	3.85%*	0.00%
				Occupied Rooms	N/A	-7.46%***	4.29%*	1.56%	-1.35%
				Employees	0.00%	-2.90%	11.25%***	-5.06%	10.00%***

Land Use Type		10th Code	9th Code	Independent Variable	Weekday	Weekday AM Adjacent	Weekday PM Adjacent	Weekday AM Generator	Weekday PM Generator
Office	Medical-Dental	720	720	Employees	-2.36%	**28.30%*** **	**-8.49%** **	**33.75%*** **	**18.56%** **
				1000 Sq. Feet Gross Floor Area	**-3.68%*** **	**16.32%*** **	-3.08%	0.86%	-3.98%
	General Office	710	710	1000 Sq. Feet Gross Floor Area	**-13.81%*** **	**-25.64%*** **	**-22.82%*** **	N/A	N/A
				Employees	**-1.20%* **	**-22.92%*** **	**-13.04%*** **	N/A	N/A
Recreational	Health/Fitness Club	492	492	1000 Sq. Feet Gross Floor Area	N/A	-7.09%	-2.27%	-2.10%	-3.45%
Residential	Single-Family	210	210	Dwelling Units	**-0.84%*** **	**-1.33%*** **	**-1.00%* **	**-1.30%* **	**-1.96%*** **
				Residents	**3.92%*** **	0.00%	0.00%	0.00%	**3.70%**
				Vehicles	**5.65%*** **	**-1.96%* **	**2.99%*** **	**-1.96%* **	**2.99%*** **
	Multi-Family-Low-Rise	220	221	Occupied Dwelling Units	**-4.25%*** **	**-15.22%*** **	**-10.34%*** **	**-11.76%*** **	**-6.45%*** **
				Residents	N/A	N/A	N/A	0.00%	-3.03%
	Multi-Family-Mid-Rise	221	223	Dwelling Units	N/A	**20.00%*** **	**12.82%* **	-8.57%	-6.82%
	Multi-Family-High-Rise	222	222	Dwelling Units	**5.95%*** **	3.33%	2.86%	0.00%	-2.50%
Retail	Shopping Center	820	820	1000 Sq. Feet Gross Leasable Area	**-11.59%*** **	**-2.08%* **	**2.70%*** **	N/A	N/A
	Supermarket	850	850	1000 Sq. Feet Gross Floor Area	4.44%	**12.35%** **	**-2.53%* **	-5.66%	**-9.20%** **
	Convenience Market with Gasoline Pumps	853	853	1000 Sq. Feet Gross Floor Area	**-26.18%*** **	-0.81%	-3.20%	-1.56%	**-20.74%*** **
				Vehicle Fueling Station	**-40.56%*** **	**25.29%*** **	**20.82%*** **	**20.67%** **	**21.37%*** **

Land Use Type		10th Code	9th Code	Independent Variable	Weekday	Weekday AM Adjacent	Weekday PM Adjacent	Weekday AM Generator	Weekday PM Generator
Services	Drive-in Bank	912	912	1000 Sq. Feet Gross Floor Area	**-32.48%*** **	**-21.36%*** **	**-15.84%*** **	**-16.51%*** **	**-24.84%*** **
				Drive-in Lanes	N/A	-4.95%	**-18.32%** **	-18.90%	**-24.34%*** **
				Employees	N/A	-10.65%	**-26.20%*** **	N/A	N/A
	Walk-in Bank	911	911	1000 Sq. Feet Gross Floor Area	N/A	N/A	0.00%	N/A	N/A
	Quality Restaurant	931	931	1000 Sq. Feet Gross Floor Area	-6.79%	-9.88%	**4.14%*** **	**-19.75%* **	-8.20%
				Seats	**-9.09%*** **	**-33.33%*** **	**7.69%** **	-6.25%**	-3.33%
	Fast-Food Restaurant without Drive-Through Window	933	933	1000 Sq. Feet Gross Floor Area	N/A	N/A	8.37%	N/A	-7.06%
	Fast-Food Restaurant with Drive-Through Window	934	934	1000 Sq. Feet Gross Floor Area	-5.07%	**-11.51%* **	0.06%	-4.92%	**8.58%* **
				Seats	0.00%	3.15%	2.11%	**-8.72%* **	0.62%
	Gasoline/Service Station	944	944	Vehicle Fueling Station	2.05%	**-15.46%*** **	1.15%	**-16.30%*** **	-7.92%
	Gasoline/Service Station with Convenience Market	945	945	1000 Sq. Feet Gross Floor Area	N/A	-7.48%	-9.36%	7.69%	0.54%
				Vehicle Fueling Station	**26.16%*** **	**22.74%*** **	3.55%	**29.36%*** **	**16.95%** **
	Automobile Care Center	942	942	1000 Sq. Feet Gross Floor Area	N/A	0.00%	0.00%	0.00%	0.00%

[a] Percentages were calculated using equation (1).
[b] Significance levels: * for $0.01 \leq$ p-value < 0.05; ** for $0.001 \leq$ p-value < 0.01; *** for p-value < 0.001.

Survey State Agencies

The state agency survey questionnaire is included in Appendix A, and the survey questions are summarized below:

- **Question 1**: Has your state updated or is your state updating its regulations (or guidelines) for trip generation estimation based on the 10th edition of the Trip Generation?

- **Question 2**: Trip generation rates for some land use types (e.g., general office, drive-in bank, etc.) provided in the 10th edition are substantially lower than those of previous editions of Trip Generation. Those lower rates may already reflect the effect of internal capture and modal split. Does your state recommend further applying trip reduction approaches in addition to those lower trip generation rates?

- **Question 3**: The 10th edition provides a new Trip Generation web application - ITE TripGen. This new application allows electronic access to the entire Trip Generation database with filtering capabilities including region (e.g., Pacific Coast, Southeast, etc.), age of data, and development size. Does your state provide any guidelines for using the database to customize trip generation rates?

- **Question 4**: The 10th edition has defined four settings for developments including center city core, dense multi-use urban, general urban/suburban, and rural for the first time. Has your agency adopted the criteria provided by the 10th edition to classify development settings?

- **Question 5**: Please select all the versions of ITE Trip Generation that provide trip generation rates accepted by your state.

- **Questions 6-9**: When estimate Internal Capture Trips, External Walk/Bike Trips, External Transit Trips, and Pass-by/Diverted Trips, which method would you choose?

- **Question 10**: Has your state adopted any approach to adjust trip estimation based on transportation demand management strategies such as increasing parking fees and providing a public transit subsidy?

- **Question 11**: Does your state recommend any alternative approach to estimate trip generation? Examples might include applying region-specific adjustment factors, incorporating local trip generation data, use of household travel survey data, or use of travel demand models.

Survey responses were received from 30 states and District of Columbia. In some cases, more than one survey was completed per state, and for those states, the most comprehensive response was selected for this analysis. The responses for Questions 1-4 are shown in Figure 3. About 40% (12 out of 31) of responding states indicate that their states have updated or are updating state regulations/guidelines based on the 10th edition of TG. For Question 2, there are responses from six states showing that they would recommend further applying trip reduction approaches in addition to those lower trip generation rates in the 10th edition. Wisconsin DOT noted the lower trip generation rates might be caused by a decrease in travel demand (e.g., electronic banking and telecommuting make some trips unnecessary) rather than internal capture or modal split. Connecticut allows an additional reduction to a maximum of 20% if the proposed development is within one mile of a transit center (bus or train). As for the new Trip Generation web application, more than 80% of responding states reported they have not developed any guidelines for using the database to customize trip generation rates. The 10th edition has defined four settings including center city core, dense multi-use urban, general urban/suburban, and rural for the first time, and 67% of responding states have adopted these criteria to classify development settings. California's Smart Mobility Framework (Greenberg et al., 2010) introduced place types (e.g., urban centers, close-in compact communities, suburban communities, etc.), which use similar concepts of settings.

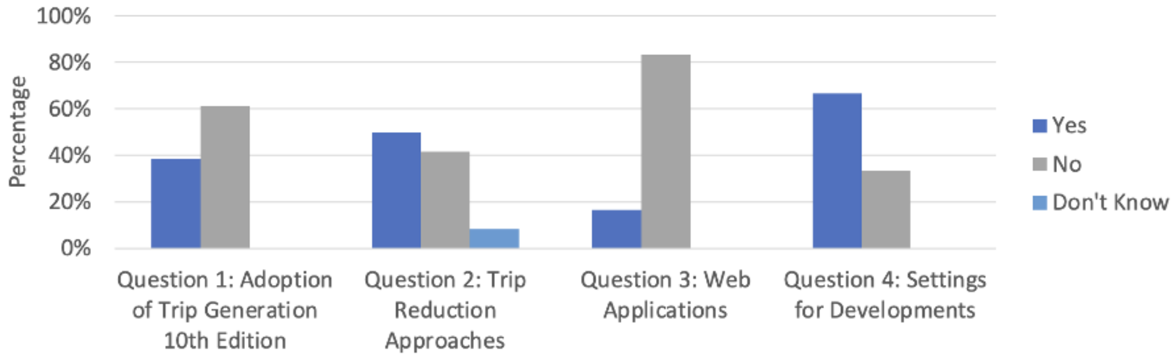


Figure 3. Adoption of the Trip Generation 10th Edition and Its New Features (Questions 1-4)

The responses for Question 5 are shown in Figure 4. Trip rates of the TG 10th edition are the most widely accepted according to the survey results, with more than 80% (25 out of 31) adoption rate among responding states. There are other states which adopted state-specific trip generation rates. Oregon calculates the rates for each project because the rates vary by location. The state of Maine has rates adopted after special studies. Texas uses rates from Texas Survey data and National Household Travel Survey (NHTS) data instead of ITE rates. Oregon has state-specific rates (in addition to 10th edition ITE rates), but they are not published. Alaska uses travel survey rates for parts of the state and 7th edition ITE rates for areas not covered by survey.

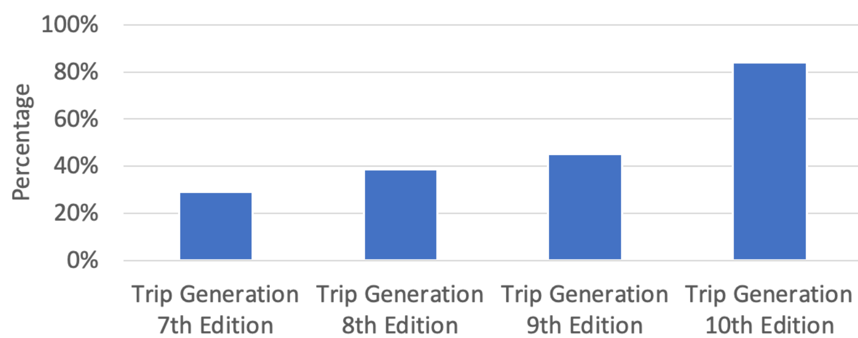


Figure 4. Adoption of Trip Generation Rates (Question 5)

The responses for Question 6 to Question 9 are shown in Table 4. More than 60% (20 out of 31) of responding states have adopted the approaches presented in the TGH 3rd edition to estimate the internal capture trips for mixed-use developments. Wisconsin has developed its own guidance on mixed-use development and acceptable reduction for pass-by trips. Connecticut allows a maximum of 10% internal capture. The District of Columbia uses Census data, household survey data and local studies for local mode split. Oregon uses a travel demand model (four-step or activity-based models) to estimate external walk/bike and transit trips. In California, varied approaches are used, depending on traffic operations/engineering branches.

Table 4. Adoption of Trip Estimation Approaches (Questions 6-9)

	Question 6. Internal Capture Trips	**Question 7. External Walk/Bike Trips**	**Question 8. External Transit Trips**	**Question 9. Pass-by/Diverted Trips**
ITE Trip Generation Handbook 2nd Edition	35.5% [a] (11) [b]	29.0% (9)	29.0% (9)	35.5% (11)
ITE Trip Generation Handbook 3rd Edition	64.5% (20)	58.1% (18)	45.2% (14)	61.3% (19)
NCHRP Report 684				
NCHRP Report 758 (for infill developments)		29.0% (9)	29.0% (9)	
EPA/SANDAG MXD method	12.9% (4)	16.1% (5)	6.5% (2)	

[a] Percentage of responding states that accept the corresponding approach
[b] Number of responding states that accept the corresponding approach

The responses to Questions 10-11 are shown in Figure 5. The majority of responses indicate no approach is used to adjust trip estimation rates based on the use of transportation demand management (TDM) strategies such as increasing parking fees and providing a public transit subsidy. However, Vermont provides detailed guidance, which allows trip reductions for TDM. The District of Columbia considers TDM effects in the mode split and allows for a vehicle trip generation cap if a project has a low parking ratio. Massachusetts recommends TDM as a mitigation strategy in its TIA guidelines but doesn't quantify its impact. Nonetheless, more than half of the states replied that their states recommend alternative approaches to estimate trip generation when TDM measures are used. The District of Columbia recommends an allowance for vehicle trip reductions for sites with greatly reduced parking and waives full traffic impact studies for projects without any off-street parking. Responses from Arizona, Alaska, Michigan, Oregon, Mississippi, South Dakota, Kansas, and Idaho stated they use travel demand models to estimate trip generation. West Virginia, Arizona, Oregon, and Texas mentioned the use of household travel survey data, while Michigan, Vermont, Wisconsin, South Dakota, and Kansas use local trip generation data.

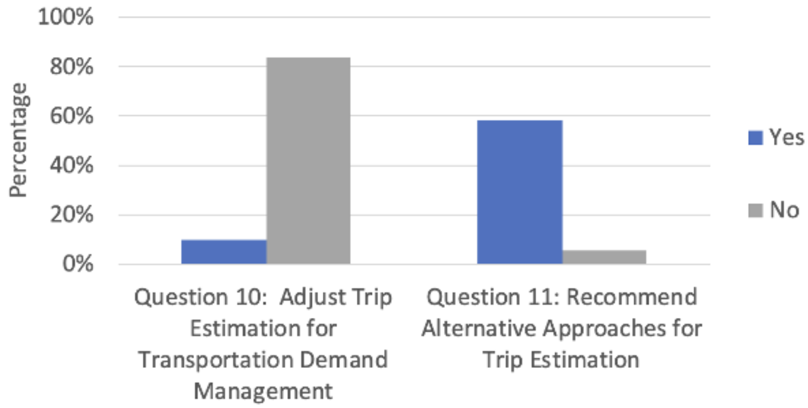


Figure 5. Adjustments of Trip Generation (Questions 10-11)

Identify Criteria for Setting Classifications

The TG 10th edition provides a detailed description of each setting type. For instance, a dense multi-use urban setting is described as a well-developed urban area outside a major metropolitan downtown or a moderate size urban area downtown. Residential uses are typically multi-family or single-family on lots no larger than one-fourth of an acre. It is an area served by significant transit (either rail or bus) that enables a high level of transit usage. At the same time, it is an area with good pedestrian facilities, on-street parking, and off-street public parking. The general urban/suburban area is associated with almost homogenous vehicle-centered access, low transit accessibility, few pedestrian facilities and sufficient parking spaces. Its land use diversity is a mix of residential and commercial uses, where the commercial land uses are concentrated at intersections or spread along commercial corridors surrounded by low-density residential development. Using the TG's descriptions, we summarized the setting classification criteria according to development density, land use diversity, public transit, pedestrian facility, and parking as shown in Table 5. California's Smart Mobility Framework (Greenberg et al., 2010) introduced "place types", a similar concept to setting that uses criteria including community design, regional accessibility, and pedestrian facility (summarized in Appendix C).

Table 5. Setting Classifications Criteria of the Trip Generation 10th Edition

	Center City Core	Dense Multi-Use Urban	General Urban/Suburban	Rural
Description	The downtown area for a major metropolitan region	A well-developed urban area outside a major metropolitan downtown or a moderate size urban area downtown	An area associated with almost homogeneous vehicle-centered access	Agricultural or undeveloped areas except for scattered parcels
Development Density	High density, multi-storied buildings	The residential uses are typically multi-family or single-family on lots no larger than one-fourth acre.	Fully developed (or nearly so) at low-medium density	Very low densities
Land use diversity	A wide range of land uses	Diverse and interacting complementary land uses	A mix of residential and commercial uses. The commercial land uses are typically concentrated at intersections or spread along commercial corridors, often surrounded by low-density, almost entirely residential development.	Low land use diversity
Public transit	Focal point of a regional light- or heavy-rail transit system	Convenient and frequent transit. Served by significant transit (either rail or bus) that enables a high level of transit usage to and from area development	A mix of residential and commercial uses. The commercial land uses are typically concentrated at intersections or spread along commercial corridors, often surrounded by low-density, almost entirely residential development.	Lack of transit facilities
Pedestrian facility	Extensive pedestrian facilities	Good pedestrian facilities	Few pedestrian facilities	Lack of pedestrian facilities
Parking	Shared and priced parking	There typically is on-street parking and often off-street public parking	Sufficient parking spaces	Sufficient parking spaces
Others	Typically, an employment destination. The area also includes the immediate vicinity of the commercial core.	The motor vehicle still represents the primary mode of travel to and from the area	A retail land use may focus on serving a regional clientele whereas a service land use may target motorists or pass-by vehicle trips for its customers.	

Collect Virginia-Specific Data

A total of 37 sites in Virginia were selected for field data collection. For each site, external trips by mode were counted and recorded at every 15-minute interval from 16:00 to 18:00. The PM peak for each site was identified by maximizing the summation of four consecutive 15-minute intervals. Examples of data collection results during PM peaks for sites with single access and multiple accesses are demonstrated in Figure 6 and Figure 7. The PM peak identified for Grace Hill is 16:45-17:45 and for Haygood Shopping Center is 16:30-17:30. It should be noted that the trip rates reported in TG are based on vehicle (personal passenger vehicle and truck) trips only. For example, the total vehicle trip count for Grace Hill in Figure 6 is 24 (entering vehicle trips) and 24 (exiting vehicle trips) equals to 48. The total vehicle trip count for Haygood Shopping Center in Figure 7 is the summation of all vehicle trip counts for all accesses and equals to 1,314.

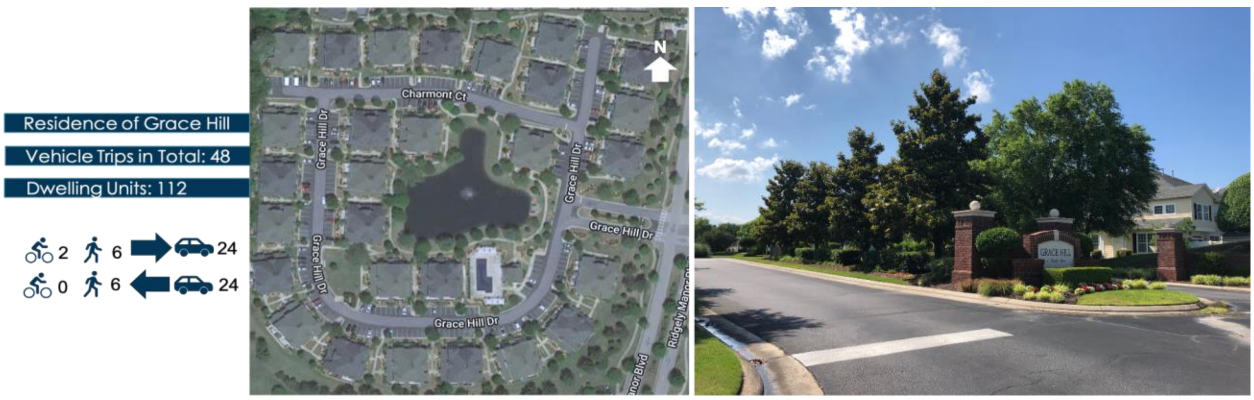


Figure 6. Data Collection Results (Left, Map Data © 2021 Google) and An Onsite Photo (Right) of One Multi-Family Low-Rise Site (R1. Grace Hill)

Figure 7. Data Collection Results (Left, Map Data © 2021 Google) and An Onsite Photo (Right) of One Mixed-Use Site (M1. Haygood Shopping Center)

If not specified, the trip count in this report refers to vehicle trip count. Trip rates are equal to trip count divided by the independent variable (e.g., dwelling unit for multi-family low-rise and gross floor area for general office). Observed trip counts and trip rates for multi-family low-rise, general office (in settings of general urban & suburban and dense multi-use urban), and mixed-use are reported in Tables 6 to 9.

Table 6. Observed Trip Data for Multi-Family Low-Rise in Weekday PM Peak

Site	Dwelling Unit	Observed Count	Observed Rate
R1	112	48	0.43
R2	116	71	0.61
R3	125	56	0.45
R4	80	35	0.44
R5	130	63	0.48
R6	78	30	0.38
R7	124	51	0.41
R8	132	73	0.55
R9	136	38	0.28
R10	160	68	0.43
R11	224	115	0.51
R12	118	67	0.57
Mean	**127.92**	**59.58**	**0.47**

Table 7. Observed Trip Data for General Office (General Urban and Suburban) in Weekday PM Peak

Site	Area (1,000 Sq. Ft.)	Observed Count	Observed Rate
O1	31.72	25	0.79
O2	31.68	43	1.36
O3	7.18	8	1.11
O4	59.93	16	0.27
O5	22.63	11	0.49
O6	27.00	35	1.30
O7	29.94	55	1.84
O8	31.25	63	2.02
O9	82.89	61	0.74
O10	10.64	21	1.97
Mean	**33.49**	**33.8**	**1.01**

Table 8. Observed Trip Data for General Office (Dense Multi-Use Urban) in Weekday PM Peak

Site	Area (1,000 Sq. Ft.)	Observed Count	Observed Rate
O11	276.5	40	0.14
O12	77.3	35	0.45
O13	54.1	6	0.11
O14	336.4	7	0.02
O15	52.3	8	0.15
Mean	**159.33**	**19.2**	**0.12**

Table 9. Observed Trip Data for Mixed-Use in Weekday PM Peak

Site	Area (1,000 Sq. Ft.)	Observed Count	Observed Rate
M1	166.54	1,314	7.89
M2	118.17	708	5.99
M3	202.94	1,127	5.55
M4	132.14	1,103	8.35
M5	227.65	1,236	5.43
M6	200.58	548	2.73
M7	62.88	500	7.95
M8	54.57	216	3.96
M9	103.16	382	3.70
M10	234.25	895	3.82
Mean	**150.29**	**802.9**	**5.34**

Account for COVID-19 Impacts

Streetlight data were extracted for the 37 selected sites. The change rate and COVID adjustment factor were computed for each land use type using equations (3) and (4) and are shown in Table 10.

Table 10. Use Streetlight Data to Account for COVID-19 Impacts on Trips by Context

	Number of Sites	Vehicle Trip Count in Weekday PM Peak			Change Rate [a]	COVID Adjustment Factor [b]
		Streetlight 2019	Streetlight 2020	Observed 2020		
Multi-Family Low-Rise	12	1,766	1,223	715	-30.73%	69.27%
General Office (General Urban & Suburban)	10	507	400	338	-21.20%	78.80%
General Office (Multi-Use Urban)	5	286	95	96	-66.90%	33.10%
Mixed-Use	10	20,825	19,283	8,029	-7.40%	92.60%
Total	37	23,384	21,001	9,178	-10.19%	89.81%

[a] Change Rate was estimated by equations (3).
[b] COVID Adjustment Factor was estimated by equation (4).

The change rates indicate that compared with 2019, Streetlight trip counts in 2020 for multi-family, general office in general urban & suburban, general office in multi-use urban, and mixed-use setting dropped by 30.73%, 21.20%, 66.90%, and 7.40%, respectively. The general office in multi-use urban setting experienced the greatest drop (66.90%) in trips, likely due to the increase in remote work during the pandemic. Mixed-use sites had the slightest decrease (7.40%) in trips, possibly because most trips were for essential travel such as shopping for food and household supplies.

Analyze Trip Data

Multi-Family Low-Rise

For the multi-family low-rise in a general urban & suburban setting, we computed the adjusted trip count using equation (5) and then divided it by dwelling unit to obtain the adjusted trip rate. Observed, adjusted, and TG trip rates for the 9th and 10th editions are reported in Table 11. The comparisons of these rates are also visualized in Figure 8. The mean observed trip rate for all sites is 0.47, which is closer to that of the TG 10th edition. After applying the COVID adjustment factor of 69.27%, the mean adjusted trip rate increases to 0.67. The absolute difference of the adjusted trip rate and TG 9th edition rate (0.11) is almost the same as that of the TG 10th edition rate.

Table 11. Comparisons of Trip Rates for the Land Use of Multi-Family Low-Rise (General Urban and Suburban Setting)

Site	Dwelling Unit	Observed Count	Adjusted Count	Observed Rate	Adjusted Rate	9th Rate	10th Rate
R1	112	48	69	0.43	0.62	0.78	0.56
R2	116	71	102	0.61	0.88	0.78	0.56
R3	125	56	81	0.45	0.65	0.78	0.56
R4	80	35	51	0.44	0.63	0.78	0.56
R5	130	63	91	0.48	0.70	0.78	0.56
R6	78	30	43	0.38	0.56	0.78	0.56
R7	124	51	74	0.41	0.59	0.78	0.56
R8	132	73	105	0.55	0.80	0.78	0.56
R9	136	38	55	0.28	0.40	0.78	0.56
R10	160	68	98	0.43	0.61	0.78	0.56
R11	224	115	166	0.51	0.74	0.78	0.56
R12	118	67	97	0.57	0.82	0.78	0.56
Mean	**127.92**	**59.58**	**86**	**0.47**	**0.67**	**0.78**	**0.56**

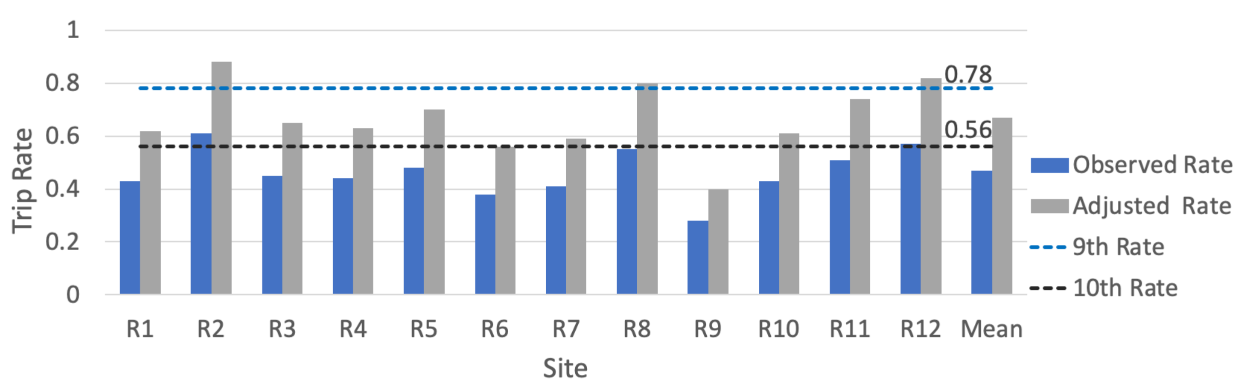


Figure 8. Comparisons of Trip Rates for the Land Use of Multi-Family Low-Rise (General Urban and Suburban Setting)

General Office in General Urban & Suburban Setting

For the general office in a general urban & suburban setting, we computed the adjusted trip count using the equation (5) and then divided it by gross floor area to obtain the adjusted trip rate. Observed, adjusted, and TG trip rates of the 9th and 10th editions are reported in Table 12. Comparisons of these rates are illustrated in Figure 9. The mean observed trip rate for all sites is 1.01. After applying the COVID adjustment factor 78.80%, the mean adjusted trip rate increases to 1.28. The TG 10th edition rate (1.15) is closer to either the observed rate or the adjusted rate in comparison with the TG 9th edition rate (1.49).

Table 12. Comparisons of Trip Rates for the Land Use of General Office (General Urban and Suburban Setting)

Site	Area (1000 Sq. Ft.)	Observed Count	Adjusted Count	Observed Rate	Adjusted Rate	9th Rate	10th Rate
O1	31.72	25	32	0.79	1.00	1.49	1.15
O2	31.68	43	55	1.36	1.72	1.49	1.15
O3	7.18	8	10	1.11	1.41	1.49	1.15
O4	59.93	16	20	0.27	0.34	1.49	1.15
O5	22.63	11	14	0.49	0.62	1.49	1.15
O6	27.00	35	44	1.30	1.65	1.49	1.15
O7	29.94	55	70	1.84	2.33	1.49	1.15
O8	31.25	63	80	2.02	2.56	1.49	1.15
O9	82.89	61	77	0.74	0.93	1.49	1.15
O10	10.64	21	27	1.97	2.50	1.49	1.15
Mean	**33.49**	**33.8**	**42.9**	**1.01**	**1.28**	**1.49**	**1.15**

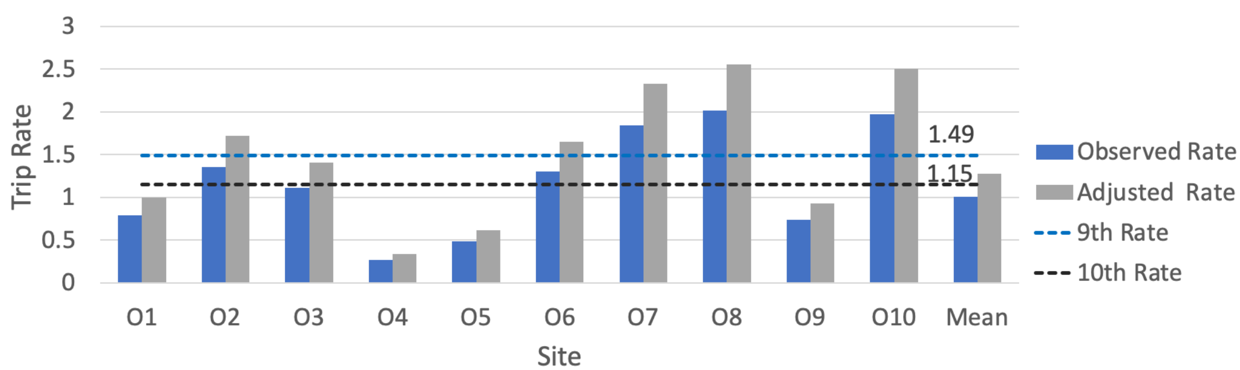


Figure 9. Comparisons of Trip Rates for the Land Use of General Office (General Urban and Suburban Setting)

General Office in Dense Multi-Use Urban Setting

For the general office in a dense multi-use urban setting, the adjusted trip count was computed using the equation (5) and then divided it by gross floor area to obtain the adjusted trip rate. Observed, adjusted, and TG trip rates for the 9th and 10th editions (for both general urban & suburban and dense multi-use urban) are reported in Table 13. The comparisons of these rates are also visualized in Figure 10. The mean observed trip rate for all sites is 0.12. The TG 10th edition rate for dense multi-use urban (0.87) is the closest to either the observed rate or the adjusted rate in comparison with the TG 9th edition rate (1.49) and the TG 10th edition rate for general urban & suburban (1.15).

Table 13. Comparisons of Trip Rates for the Land Use of General Office (Dense Multi-Use Urban Setting)

Site	Area (1000 Sq. Ft.)	Observed Count	Adjusted Count	Observed Rate	Adjusted Rate	9th Rate Suburban	10th Rate Suburban	10th Rate Urban
O11	276.50	40	121	0.14	0.44	1.49	1.15	0.87
O12	77.32	35	106	0.45	1.37	1.49	1.15	0.87
O13	54.14	6	18	0.11	0.33	1.49	1.15	0.87
O14	336.41	7	21	0.02	0.06	1.49	1.15	0.87
O15	52.29	8	24	0.15	0.46	1.49	1.15	0.87
Mean	**159.33**	**19.2**	**58**	**0.12**	**0.36**	**1.49**	**1.15**	**0.87**

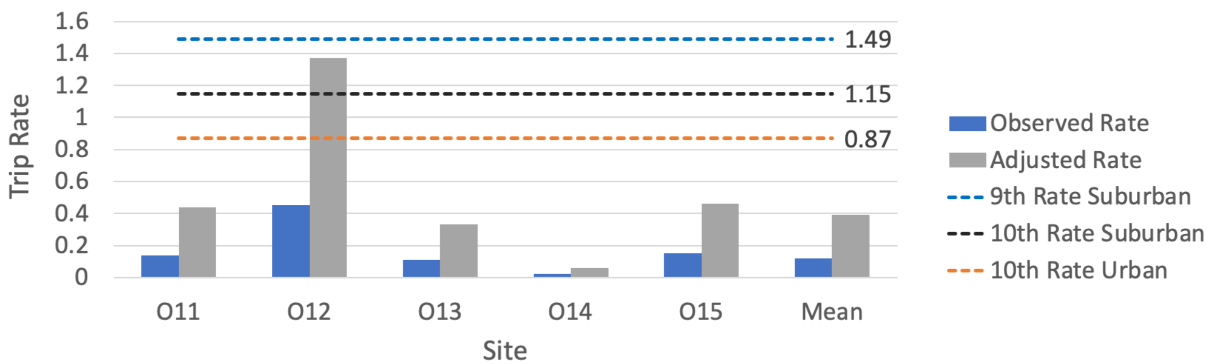


Figure 10. Comparisons of Trip Rates for the Land Use of General Office (Dense Multi-Use Urban Setting)

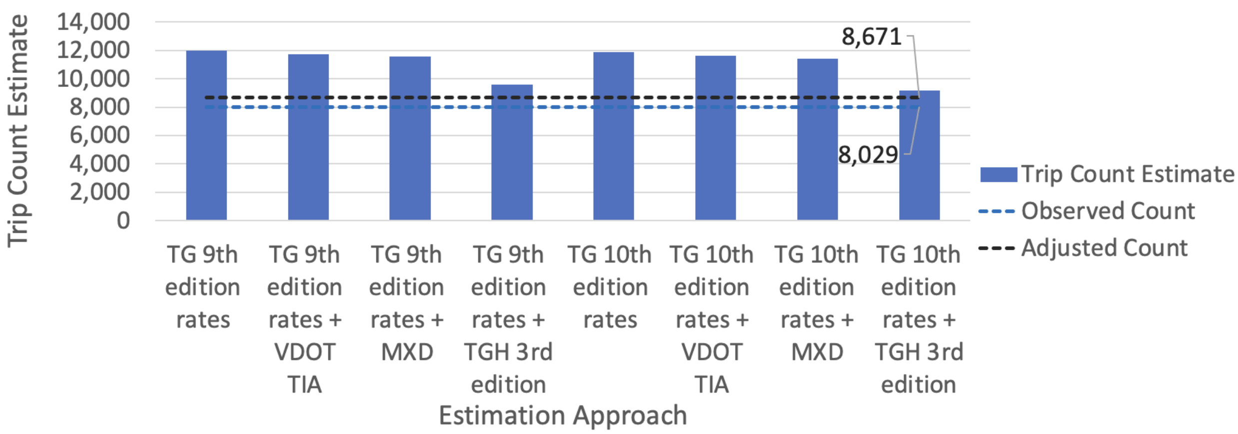
Mixed-Use Development

For mixed-use developments in the general urban & suburban setting, the total observed trip count is 8,029. After applying the COVID adjustment factor of 92.60%, the adjusted total trip count increases to 8,671. For each mixed-use development, all eight approaches were used to estimate the trip count for each mixed-use site (See Appendix D for more details). The total trip count estimate of all ten mixed-use sites and percentage errors with regard to observed and adjusted counts are reported in Table 14. The comparisons of different approaches are also illustrated in Figure 11. Results showed that the TG 10th edition rates and the TGH 3rd edition approach could generate the trip count estimate that was the closest to either the observed or adjusted counts. A paired t-test was applied to evaluate the difference of estimates of the TG 10th edition rates and the TGH 3rd edition approach, and the TG 9th edition rates and the TGH 3rd edition approach (the second-best approach) among 10 sites. The p-value of the paired t-test is 0.026. If a significance level of 0.05 is used, we are 95% confident that the trip count estimates of these two approaches are significantly different. The percentage errors with respect to observed and adjusted counts for this approach are as low as 14.00% and 5.56%. All approaches overestimated the trip counts. In general, when the TG 10th edition rates were used, lower percentage errors were generated.

Table 14. Comparisons of Trip Count Estimates with Observed and Adjusted Trip Counts for Mixed-Use Developments (General Urban and Suburban Setting)

Approach	Trip Count Estimate	% Error vs Observed Count (8,029)	% Error vs Adjusted Count (8,671)
TG [a] 9th edition rates	12,013	49.62%	38.55%
TG 9th edition rates + VDOT TIA [b]	11,722	46.00%	35.19%
TG 9th edition rates + MXD [c]	11,576	44.18%	33.51%
TG 9th edition rates + TGH [d] 3rd edition	9,575	19.26%	10.43%
TG 10th edition rates	11,899	48.20%	37.23%
TG 10th edition rates + VDOT TIA	11,611	44.61%	33.91%
TG 10th edition rates + MXD	11,427	42.32%	31.79%
TG 10th edition rates + TGH 3rd edition	**9,153**	**14.00%**	**5.56%**

[a] TG = *Trip Generation*
[b] TIA = *Traffic Impact Analysis Regulations*
[c] MXD = *Mixed-use Development Method* by EPA/SANDAG
[d] TGH = *Trip Generation Handbook*



[a] TG = *Trip Generation*
[b] TIA = *Traffic Impact Analysis Regulations*
[c] MXD = *Mixed-use Development Method* by EPA/SANDAG
[d] TGH = *Trip Generation Handbook*

Figure 11. Comparisons of Trip Count Estimates with Observed and Adjusted Trip Counts for Mixed-Use Developments (General Urban and Suburban Setting)

DISCUSSION

To investigate the applicability of the ITE TG 10th edition to Virginia and to make recommendations on how to incorporate the TG 10th edition into state guidelines, the research team conducted a literature review, a survey of state transportation agencies, field data collection, and data analysis. This study adds to the literature on trip generation by investigating the applicability of the TG 10th edition, given that very limited research has collected field data to validate the trip rates and estimation approaches provided in the TG 10th edition. We collected trip generation data from 37 selected sites in Virginia and examined trip rates from the TG 9th and 10th editions and various approaches to estimate internal capture for mixed-use development.

All trip data were collected after the outbreak of COVID-19, so trip counts were adjusted for the impacts of the COVID-19 pandemic using Streetlight data.

The validity of the findings of this study is subject to the sample size of the selected sites and the accuracy of Streetlight data used to account for the impacts of COVID. The selection of only 37 sites did not materially affect the inference that trip rates from the 10^{th} edition for the land uses studied tended to be closer to the observed adjusted rates than those from the 9^{th} edition simply because statistical testing was not used in this portion of the report. However, the restriction of 37 sites limited the scope of this research to only a few of the many land uses available in this reference, some of which are shown in Table 3. For instance, drive-in banks—a fairly common land use—are not covered. Rates vary substantially by land use type: Table 9 showed that 1,000 square feet of development generates 5.34 trips for mixed use development compared to 1.01 trips for a general office development. Thus, the ability to collect additional data beyond what was feasible in this study might yield a better understanding of how the land uses not addressed in this research are affected by the 9^{th} and 10^{th} edition rates. Within the scope of the land uses studied, a large increase in additional sites could allow one to perform limited hypothesis testing. However, a modest increase in the number of sites would not permit this additional analysis. For instance, consider Table 12: if normality is presumed and all sites (rather than trips) are weighted equally, one should be 95% confident that the true mean is between 0.84 and 2.17—a fairly wide tolerance interval of about 1.33. With 30 sites, if the remaining 20 sites had the same values as those reported in Table 12, this tolerance interval narrows to 0.57, which is wider than the difference between the weighted mean in Table 12 (1.28) and the 9^{th} or 10^{th} rates of 1.49 and 1.15. In fact, it appears that if the standard deviation did not change, about 200 sites would be needed to achieve a confidence interval associated with the mean trip rate (based on Table 12) that included the 10^{th} edition but not the 9^{th} edition.

CONCLUSIONS

- *More than 80% of the states that responded to the survey have accepted the trip rates of the TG 10^{th} edition and more than 60% of them have adopted the approaches presented in the TGH 3^{rd} edition to estimate the internal capture trips for mixed-use developments.* Survey results suggest that states tend to adopt the latest ITE trip rates and approaches. Given the vast diversity of local contexts, some states develop state-specific trip generation rates and trip estimation approaches as alternatives to ITE ones.

- *The COVID-19 pandemic significantly reduced trips.* The magnitude of COVID impacts varies greatly by land use and setting. Trips declined more in dense multi-use urban setting (e.g., 66.90% reduction for general office) compared with general urban & suburban setting. Trip reduction rates for multi-family and general office were much higher than those for mixed-use sites (mainly composed of retail and service land uses).

- *The TG 10^{th} edition generally results in more accurate trip estimates for Virginia than the 9^{th} edition with or without accounting for COVID impacts.* TG 10^{th} edition is more likely to underestimate trip rates than 9^{th} edition. The TG 9^{th} edition overestimates the trip rates for all single land uses investigated, while the TG 10^{th} edition produces both overestimates (for general office in dense multi-use urban) and underestimates (for multi-family and general office in general urban & suburban). Regarding the TG 10^{th} edition, selecting trip rates according to the setting leads to better estimates. For example, when considering general office in a multi-use urban setting, the TG 10^{th} edition rate for multi-use urban is the closest to both the observed rate and the rate adjusted for the impacts of COVID.

- *For mixed-use developments, using TG 10^{th} edition rates along with the internal capture approach presented in the TGH 3^{rd} edition provides the best trip estimates with or without applying the adjustment factor for COVID impacts.* Results show the necessity of applying trip reduction factors to capture internal trips. If no internal capture approach is used, the estimation error is as high as 38.55% for using the TG 9^{th} edition rates and 37.23% for using the 10^{th} edition rates. It is also found that using an appropriate internal capture approach matters more than using the latest trip rates. If one uses the internal capture approach in the TGH 3^{rd} edition, the errors decrease dramatically. This approach, used in conjunction with the 9^{th} edition rates yields an error of 10.43% and using the 10^{th} edition rates would reduce the error further to 5.56%.

RECOMMENDATIONS

1. The Office of Land Use should provide guidance to VDOT districts to accept traffic impact analysis reports using ITE's 10th Edition *Trip Generation* and the 3rd Edition of the *Trip Generation Manual*. This research suggests that appropriate rates based on settings specified in the 10th edition (e.g., center city core, dense multi-use urban, general urban/suburban, and rural) are more accurate than those with the 9th edition.

2. The Office of Land Use should provide guidance to VDOT districts to accept traffic impact analysis reports prepared using the methodology presented in the 3rd edition of the *Trip Generation Handbook* to estimate internal capture for mixed-use developments. This research suggests that for internal capture estimation, the 3rd edition is more accurate than other methods studied.

IMPLEMENTATION AND BENEFITS

Implementation

Following publication of this report, the Director of the Office of Land Use will incorporate these recommendations into VDOT's *Administrative Guidelines for the Traffic Impact Analysis Regulations* by January 1, 2022. The suggested revisions to the VDOT guidelines by the research team are presented in Appendix E.

Benefits

The benefits of implementing Recommendations 1 and 2 are that the accuracy of trip generation estimation in Virginia contexts will be improved, leading to sounder decision-making concerning the modification of existing facilities and the design of new facilities. Wilkerson (2021) identified four broad categories of situations where accurate site-specific trip generation rates are fundamental to planning practice: determination of whether a formal traffic impact analysis is required, estimation of the 95th percentile queue length to confirm that a proposed entrance will not adversely affect traffic operations, estimation of the length of turning lanes, and determination of whether signal warrants are met. Each of these practices can yield an excess cost if trip generation rates are not accurate. Such costs may be borne by landowners (e.g., monies spent constructing a signal where none is needed), VDOT (e.g., not building sufficient turning lanes prior to land development and then paying a larger cost to later build such lanes), or the public (e.g., additional delay or heightened crash risk because the trips associated with a proposed entrance were underestimated). Wilkerson (2021) articulates the relevance of site-specific trip generation estimates for compliance with design guidance, noting that VDOT land use engineers use trip generation estimates for these four types of decisions:

- Compliance with the Chapter 527 (24 VAC 30-155) Traffic Impact Analysis Regulation (TIA) for determining which zoning cases meet the threshold for a formal TIA report:
    - Any zoning case that generates more than 5,000 vehicle trips per day will require a formal TIA
    - Residential development that generates over 400 trips per day, such that when trips are distributed, total trips added to an existing state-maintained road exceed the current ADT of the roadway

- Compliance with the Access Management Regulations (24 VAC 30-73) for determining the Functional Area of an intersection (particularly a signalized intersection)
    - The Regulations do not permit the installation of a commercial entrance within the functional area of an intersection
    - Trip generation is critical for projecting future year peak hour traffic at intersections and using SYNCHRO, or other modeling software to determine the 95th percentile queue length
    - Utilizing the formula in VDOT *Road Design Manual* - Appendix F (Page F- 108) to determine upstream Functional Area of Intersection
    - A VDOT Access Management Exception (AM-E) is required for the installation of any commercial entrances within the functional area of the intersection

- Determination of Turn Lane Warrants for Commercial Entrances and New Subdivision Streets
    - The need to have accurate peak hour ingress/egress volumes to determine the need for right and/or left turn lanes for a commercial entrance
    - VDOT Turn Lane Warrants are located in Appendix F of the VDOT Road Design Manual (Pages F-67 - 77, and 89 - 90)

- Determination of whether signal warrants are met due to the trip generation of a proposed development (commercial or residential)

- Many zoning cases will include proffer language that the developer will install a traffic signal at a specific intersection, if determined to be warranted by VDOT (per MUTCD signal warrants and the VDOT policy regarding signal warrants: VDOT-IIM-TE-387 - Signal Justification Reports (SJR) for New and Reconstructed Signals).
- Generally speaking, commercial developments typically want signals to get customers into their sites, while residential developments may not want to incur the cost to install a signal with their project.
- Signal warrants are based on 8-hour and 4-hour volumes, so having accurate daily and peak hour trip generation data for a development is important, because slight variations in the hourly numbers may change the result of a warrant analysis.

While it is not feasible to calculate the full benefit of having more accurate trip generation rates, the design guidance provided by Wilkerson (2021) demonstrates how these rates can influence cost. As just one example, consider Table 12, where the research team believes the adjusted rate of 1.28 per 1,000 square feet is closest to ground truth for the general office category. The 10th edition of the *Trip Generation*, with a rate of 1.15 (a difference of 0.13), is closer to this ground truth than the 9th edition, which has a rate of 1.49 (a difference of 0.21). One way to evaluate this impact is to consider that the 9th edition shows a 16% overprediction (e.g., 0.21/1.28), and the 10th edition shows a 10% underprediction (e.g., 0.13/1.28). Then, one can pick at random one type of decision: the required length of a turning lane, based on Figure 12 excerpted from Appendix F of the *VDOT Road Design Manual* (VDOT, 2021), where blue and red annotations have been added to the figure. We consider the situation where opposing volumes may range from 0 to 1,000 vehicles per hour and where ground truth is 200 left turns. The blue shows a 10% underprediction (from the 10th edition of the *Trip Generation*) and the red shows a 16% overprediction.

For some situations, the error would not matter; for instance, with an opposing volume of fewer than 100 vehicles, a turn lane is not required. For other situations, both editions cause a deviation from the ideal answer: with an opposing volume of 300 vehicles, the required turn lane length should be 150 feet. The 10th edition would lead one to presume a 125-foot length is acceptable, and the 9th edition would lead one to presume a 175-foot length is acceptable. That said, Table 15 shows that there is an advantage to the 10th edition overall, with 200 cumulative feet of error, in contrast to the 9th edition, with 550 cumulative feet of error (based on the ten situations from 0 to 900 opposing vehicles). Turn lanes represent a substantial cost; one sample run with VDOT's Preliminary Cost Estimating System suggested a single turn lane could add about $88,000 to the total cost of a project, and the Minnesota Department of Transportation (2011) suggests that the cost of a left turn lane ranges from $100,000 to $300,000. Presumably, the length of the turning lane—and associated right of way—would materially affect such costs.

Warrants for Left Turn Storage Lanes on Four-Lane Highways

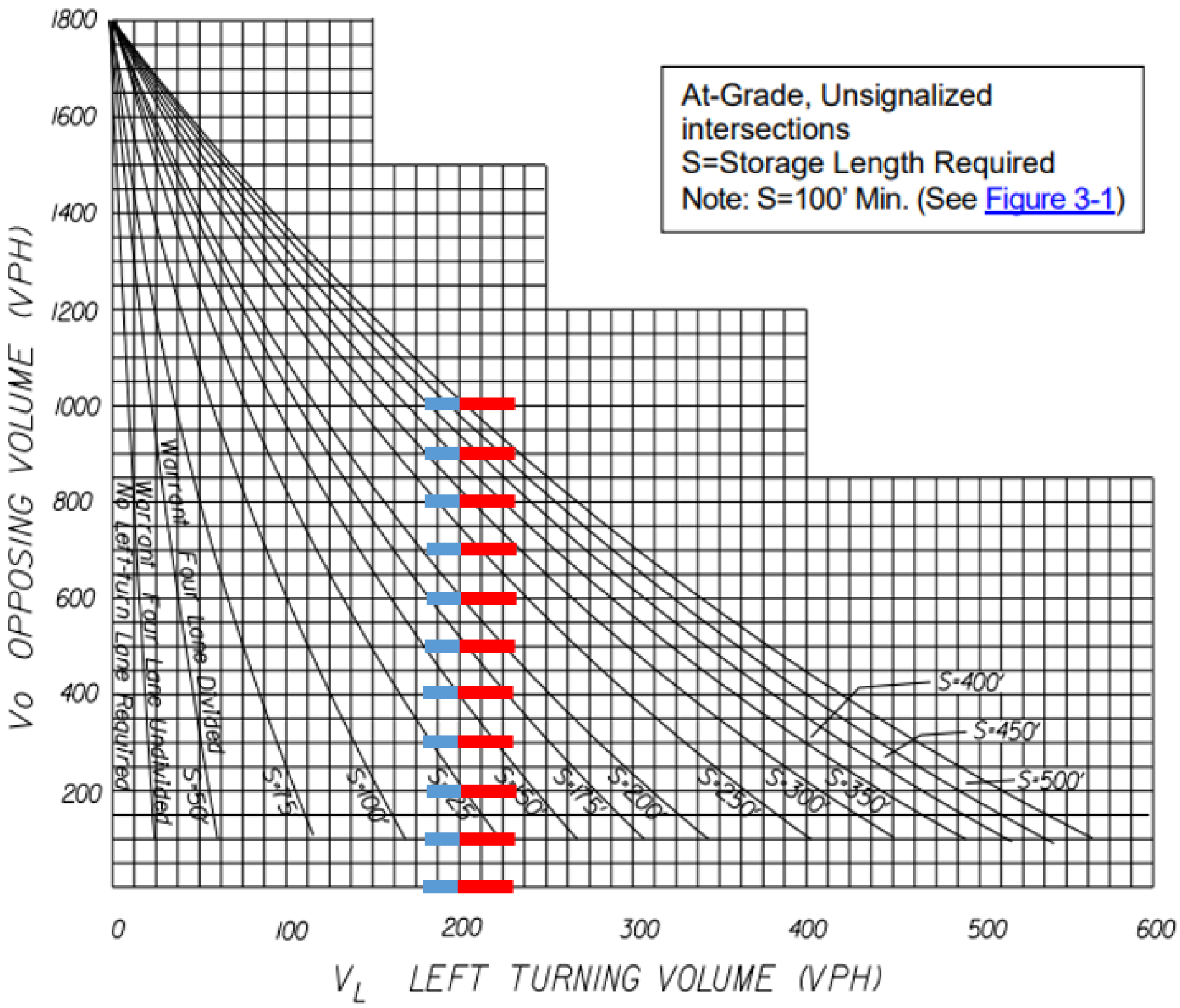


FIGURE 3-3 WARRANTS FOR LEFT TURN STORAGE LANES ON FOUR LANE HIGHWAYS

Figure 3-3 was derived from *Highway Research Report No. 211*.

Opposing volume and left turning volume in vehicles per hour (VPH) are used for left turn storage lane warrants on four-lane highways.

[a] Blue and red horizontal lines were added by the research team and show a 10% underprediction and a 16% overprediction of a left turning volume of 200 vehicles per hour.

Figure 12. Modified Figure 3-3 from Appendix F of the VDOT Road Design Manual (VDOT, 2021)

Table 15. Impact of Forecast Error on the Required Length of a Left Turning Lane

Opposing lane volume (vehicles per hour)	Impact on left turn length based on the	
	16% Overprediction (red line)	10% Underprediction (blue line)
0	None	None
100	25 ft (too long)	None
200	25 ft (too long)	None
300	25 ft (too long)	25 ft (too short)
400	25 ft (too long)	25 ft (too short)
500	75 ft (too long)	None
600	75 ft (too long)	50 ft (too short)
700	50 ft (too long)	None
800	100 ft (too long)	50 ft (too short)
900	150 ft (too long)	100 ft (too short)
Total	550 ft in error	200 ft in error

[a] Based on Figure 3-3 from VDOT (2021) with a ground truth of 200 vehicles per hour. For example, with 300 opposing vehicles per hour, a perfect estimate of 200 left turns shows that the turn lane should be 150 feet. With a 10% underprediction—that is, if one instead estimated 180 left turns—the blue line shows that one would calculate the turn lane should be just 125 feet, an underestimate of 25 feet.

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REFERENCES

Bochner, B. S., Hooper, K. G., Sperry, B. R., & Dunphy, R. T. *Enhancing Internal Trip Capture Estimation for Mixed-Use Developments* (0309155584). Transportation Research Board, Washington, DC, 2011.

Clifton, K. J., Currans, K. M., Cutter, A. C., & Schneider, R. Household travel surveys in context-based approach for adjusting ITE trip generation rates in urban contexts. *Transportation Research Record, 2307*(1), January 2012, pp.108-119.

Clifton, K. J., Currans, K. M., & Muhs, C. D. Adjusting ITE's Trip Generation Handbook for Urban Context. *Journal of Transport and Land Use, 8*(1), March 2015, pp. 5-29.

Currans, K. M. *Improving Vehicle Trip Generation Estimations for Urban Contexts: A Method Using Household Travel Surveys to Adjust ITE Trip Generation Rates*, Portland State University, 2013.

Currans, K. M., & Clifton, K. J. Using household travel surveys to adjust ITE trip generation rates. *Journal of Transport and Land Use, 8*(1), April 2015, pp. 85-119.

Daisa, J. M., Schmitt, M., Reinhofer, P., Hooper, K., Bochner, B., & Schwartz, L. (2013). *Trip Generation Rates for Transportation Impact Analyses of Infill Developments* (0309283701). Transportation Research Board, Washington, DC, 2013.

Ewing, R., Tian, G., Lyons, T., & Terzano, K. Trip and parking generation at transit-oriented developments: Five US case studies. *Landscape and Urban Planning, 160,* April 2017, pp. 69-78.

Greenberg, E., Walters, J., Lee, R., & Ang-Olson, J. *Smart Mobility 2010: A Call to Action for the New Decade*. California Department of Transportation Sacramento, February 2010.

Hagler Bailly Services Inc., & Criterion Planners/Engineers. *The Transportation and Environmental Impacts of Infill Versus Greenfield Development: A Comparative Case Study Analysis*. United States Environmental Protection Agency, 1999.

Handy, S., Shafizadeh, K. R., & Schneider, R. *California smart-growth trip generation rates study*. University of California Davis Urban Land Institute and Transportation Center, 2013.

ITE. *Trip Generation Handbook, Second Edition - an ITE Recommended Practice*. Institute of Transportation Engineers, Washington, DC, 2004.

ITE. *Trip Generation Manual, 9th Edition*. Institute of Transportation Engineers, Washington, DC, 2012.

ITE. *Trip Generation Handbook, Third Edition - an ITE Recommended Practice*. Institute of Transportation Engineers, Washington, DC, 2017a.

ITE. *Trip Generation Manual, 10th Edition*. Institute of Transportation Engineers, Washington, DC, 2017b.

Lee, R., Miller, J., Maiss, R., Campbell, M., Shafizadeh, K., Niemeier, D., Handy, S., & Parker, T. *Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies*. University of California Davis, Institute of Transportation Studies, 2011.

Minnesota Department of Transportation. *Turn Lanes. Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads*. St. Paul, 2011. https://www.dot.state.mn.us/stateaid/trafficsafety/safety/turn-lanes.pdf. Accessed June 8, 2021

Nelson\Nygaard Consulting Associates. *Crediting Low-Traffic Developments: Adjusting Site-Level Vehicle Trip Generation Using URBEMIS.* Nelson\Nygaard Consulting Associates, San Feancisco, CA, 2015.

NYC. *Chapter 16 in City Environmental Quality Review (CEQR)*. New York City, Mayor's Office of Environmental Coordination, 2020.

Palakurthy, R., Tung, L.-W., Cryer, L., & Bell, L. Trip Generation Rates at Park-and-Ride Facilities with Regional Bus and Light Rail Service: A Supplement to ITE Trip Generation Data. *Transportation Research Record, 2651*(1), January 2017, pp. 60-70.

Parr, S., Wolshon, B., Renne, J., Murray-Tuite, P., & Kim, K. Traffic impacts of the COVID-19 pandemic: Statewide analysis of social separation and activity restriction. *Natural hazards review, 21*(3), 04020025, August 2020.

Rahaim, J., Reiskin, E., & Chang, T. *Transportation Impact Analysis Guidelines*. San Francisco Planning, 2019.

United States Environmental Protection Agency. *Mixed-Use Trip Generation Model*. https://www.epa.gov/smartgrowth/mixed-use-trip-generation-model. Accessed March 13, 2020.

VDOT. *LandTrack: Transportation Impact of Land Development*. Virginia Department of Transportation, 2008. http://landtrx.vdot.virginia.gov. Accessed September 13, 2019

VDOT. *Road Design Manual*. Richmond , 2021. http://www.virginiadot.org/business/resources/LocDes/RDM/AppendF.pdf. Accessed June 7, 2021.

Wilkerson, A. *Email to J.S. Miller.* June 4, 2021.

Xie, K., & Dong, X. *Map of Sites*. https://www.google.com/maps/d/u/2/viewer?mid=1c1cJw2A8NbAJCmCG6td_-1TyXmt_w_xJ&ll=37.39326438221603%2C-77.24748735000001&z=8. Accessed November 3, 2020.

APPENDIX A. QUESTIONNAIRE FOR TRIP GENERATION ESTIMATION

State______________ Agency______________ Date______________

Introduction

The Institute of Transportation Engineers (ITE) released the 10^{th} edition of its Trip Generation in 2017. The 10^{th} edition significantly updates its database and provides new approaches for trip generation estimation. The Virginia Department of Transportation (VDOT) has asked researchers at Old Dominion University to investigate how to incorporate the 10^{th} edition into VDOT's regulations and guidelines. This survey aims to collect information from state agencies on the adoption of the 10^{th} edition and current practices in estimating trip generation.

This survey should take about **5-10 minutes** to complete. All questions in the survey are for research purposes only. If you have any questions regarding this survey, please contact Dr. Kun Xie at kxie@odu.edu. Thank you for your participation.

Survey Questions

Q1. Has your state updated or is your state updating its regulations (or guidelines) for trip generation estimation based on the 10^{th} edition of the Trip Generation?

- Yes (go to Q2)
- No (go to Q5)

Q2. (If answer Yes in Q1): Trip generation rates for some land use types (e.g., general office, drive-in bank, etc.) provided in 10^{th} edition are substantially lower than those of previous editions of the Trip Generation. Those lower rates may already reflect the effect of internal capture and modal split. Does your state recommend further applying trip reduction approaches in addition to those lower trip generation rates?

- Yes, please specify or provide the web link to your state's reduction recommendations ____________________
- No
- Don't know

Q3. (If answer Yes in Q1): The 10th edition provides a new Trip Generation web application—*ITETripGen*. This new application allows electronic access to the entire Trip Generation database with filtering capabilities including region (e.g., Pacific Coast, Southeast, etc.), age of data, and development size.

Does your state provide any guidance for using the database to customize trip generation rates?

- ○ Yes, please specify or provide the web link to the database guidance ____________________
- ○ No

Q4. (If answer Yes in Q1): The 10th edition has defined four settings for developments including center city core, dense multi-use urban, general urban/suburban, and rural for the first time. Has your agency adopted the criteria provided by the 10th edition to classify development settings?

- ○ Yes, criteria provided in the 10th edition are adopted
- ○ No, state-specific criteria for settings have been adopted. Please specify or provide the web link to the setting criteria____________________

Q5. Check all the versions of ITE Trip Generation that provide trip generation rates accepted by your state:

- ☐ ITE Trip Generation 7th or earlier editions
- ☐ ITE Trip Generation 8th edition
- ☐ ITE Trip Generation 9th edition
- ☐ ITE Trip Generation 10th edition
- ☐ If your state provides state-specific trip generation rates, please specify or provide the web link to your state's rates____________________

Q6. Check all the approaches that are acceptable in your state to estimate the **internal capture trips** within a mixed-use development:

- ☐ ITE Trip Generation Handbook 2nd edition
- ☐ ITE Trip Generation Handbook 3rd edition/NCHRP Report 684: Enhancing Internal Trip Capture Estimation for Mixed-Use Developments
- ☐ EPA/SANDAG MXD method
- ☐ If other approach(es) is/are allowed, please specify or provide the web link(s) to the approach(es)_________________________

Q7. Check all the approaches that are acceptable in your state to estimate **external walk/bike trips**:

- ☐ ITE Trip Generation Handbook 2nd edition
- ☐ ITE Trip Generation Handbook 3rd edition/NCHRP Report 684: Enhancing Internal Trip Capture Estimation for Mixed-Use Developments
- ☐ NCHRP Report 758: Trip Generation Rates for Transportation Impact Analyses of Infill Developments
- ☐ EPA/SANDAG MXD method
- ☐ If other approach(es) is/are allowed, please specify or provide the web link(s) to the approach(es)__________________________

Q8. Check all the approaches that are acceptable in your state to estimate **external transit trips**:

- ☐ ITE Trip Generation Handbook 2nd edition
- ☐ ITE Trip Generation Handbook 3rd edition/NCHRP Report 684: Enhancing Internal Trip Capture Estimation for Mixed-Use Developments
- ☐ NCHRP Report 758: Trip Generation Rates for Transportation Impact Analyses of Infill Developments
- ☐ EPA/SANDAG MXD method
- ☐ If other approach(es) is/are allowed, please specify or provide the web link(s) to the approach(es)__________________________

Q9. Check all the approaches that are acceptable in your state to estimate **pass-by/diverted trips**:

- ☐ ITE Trip Generation Handbook 2nd edition
- ☐ ITE Trip Generation Handbook 3rd edition
- ☐ If other approach(es) is/are allowed, please specify or provide the web link(s) to the approach(es)__________________________

Table A1. A Matrix Design for Q6-Q9

	Check all the approaches that are acceptable in your state for the estimation of:			
	Internal Capture Trips (Q6)	**External Walk/Bike Trips (Q7)**	**External Transit Trips (Q8)**	**Pass-by/Diverted Trips (Q9)**
ITE Trip Generation Handbook 2nd edition	☐	☐	☐	☐
ITE Trip Generation Handbook 3rd edition	☐	☐	☐	☐
NCHRP Report 684: Enhancing Internal Trip Capture Estimation for Mixed-Use Developments				
NCHRP Report 758: Trip Generation Rates for Transportation Impact Analyses of Infill Developments		☐	☐	
EPA/SANDAG MXD method	☐	☐	☐	
If any other approach is allowed, please specify or provide the web link to the approach	____________ ____________	____________ ____________	____________ ____________	____________ ____________

Q10. Has your state adopted any approach to adjust trip estimation based on **transportation demand management strategies** such as increasing parking fees and providing a public transit subsidy?

- ○ Yes, please specify or provide the web link to the approach____________________
- ○ No

Q11. Does your state recommend any **alternative approach** to estimate trip generation? Examples might include applying region-specific adjustment factors, incorporating local trip generation data, use of household travel survey data, or use of travel demand models.

- Yes, please specify or provide the web link to the alternative approach ____________________
- No

Thank you for taking the time to complete this survey. If you have any other references to share or suggestions, please send them to Dr. Kun Xie (kxie@odu.edu).

APPENDIX B. TRIP DATA COLLECTION FORM

Site/Address/City: ______________________ ITE LUC________ Approx. Development Units___________

Count Location: ______________ Counter: ____________ Date: __________ Hour Starting: ____:00 a.m. p.m. Area Type[a] ________

Minutes after hour	Direction	Personal Passenger Vehicle				Delivery/Service Truck		Walk	Transit	Bicycle
		Occupants				Occupants				
		1	2	3	4+	1	2+			
:00 to :15	Enter									
	Exit									
:15 to :30	Enter									
	Exit									
:30 to :45	Enter									
	Exit									
:45 to :00	Enter									
	Exit									

[a] Area Types: (0a) regional CBD, (0b) outlying CBD, (1) urban core, (2) activity center, (3) general urban, (4) suburban business district, (5) suburban strip commercial, (6) general suburban, (7) special district, (8) rural town business district, (9) rural, (C) adjacent to university campus, (Ta) rail transit station within one-quarter mile, (Ta) rail transit station within one-quarter mile, (To) rail station adjacent or connected.

Figure B1. Vehicle Trip and Person Trip Count Form

APPENDIX C. PLACE TYPE CLASSIFICATION CRITERIA IN CALIFONIA

Table C1. Criteria Summarized from California's Smart Mobility Framework for "Place Type" Classification (Greenberg et al., 2010)

	Urban Core and Urban Centers	Close-in Compact Communities	Suburban Communities	Rural and Agricultural Lands
Description	Central Cities or large downtowns with high jobs-housing ratios overall	Small and medium sized downtown located near Urban Core or Urban Centers	Low levels of integrations of housing with jobs, retails and services, large amount of surface parking	Widely - spaced towns separated by farms, vineyards, orchard, or grazing lands which may include tourist destinations
Community Design of Development	Strongest/strong transit-oriented development with high density and mixed land uses	Strong/Moderate development with scattered mixed-use centers and the skeleton of transportation system	Weak to moderate presence of location efficient community design factors like low land use efficiency and poor aesthetics	Moderate to high development of towns which may be focuses of tourist, very low development of scattered dwelling units
Regional Accessibility	Strongest/strong with high capacity of transit stations/corridors and service levels including the airport access	Available to connect neighborhoods to multiple destinations with an emphasis on serving commute trips	Variable with respect to regional accessibility; some are located within easy commute distance of urban centers, while others are not	Low level of accessibility to commercial centers and public facilities
Pedestrian facility	High levels of pedestrian supportive environments	Walkable neighborhoods with housing in close to shops, services and public facilities	Inadequate walkability	Inadequate walkability
Examples	Downtowns of Long Beach, San Francisco, Berkeley, Palo Alto	Downtowns of San Rafael, Alameda County, Midtown	Typical areas of Orange County and Inland Empire Counties	Hillmer, St. Helena, Ferndale, Mariposa

APPENDIX D. TRIP ESTIMATES FOR MIXED-USE SITES

Table D1. Trip Estimates Using Different Approaches for Site M1

Approach	Vehicle Trips
Observed count	1,314
Adjusted count	1,419
TG 9th edition rates	1,500
TG 9th edition rates + VDOT TIA	1,458
TG 9th edition rates + MXD	1,440
TG 9th edition rates + TGH	1,150
TG 10th edition rates	1,482
TG 10th edition rates + VDOT TIA	1,440
TG 10th edition rates + MXD	1,423
TG 10th edition rates + TGH 3rd edition	1,086

Table D2. Trip Estimates Using Different Approaches for Site M2

Approach	Vehicle Trips
Observed count	708
Adjusted count	765
TG 9th edition rates	1,378
TG 9th edition rates + VDOT TIA	1,347
TG 9th edition rates + MXD	1,322
TG 9th edition rates + TGH	9,44
TG 10th edition rates	1,359
TG 10th edition rates + VDOT TIA	1,328
TG 10th edition rates + MXD	1,305
TG 10th edition rates + TGH 3rd edition	931

Table D3. Trip Estimates Using Different Approaches for Site M3

Approach	Vehicle Trips
Observed count	1,127
Adjusted count	1,217
TG 9th edition rates	1,603
TG 9th edition rates + VDOT TIA	1,563
TG 9th edition rates + MXD	1,576
TG 9th edition rates + TGH	1,300
TG 10th edition rates	1,541
TG 10th edition rates + VDOT TIA	1,503
TG 10th edition rates + MXD	1,479
TG 10th edition rates + TGH 3rd edition	1,231

Table D4. Trip Estimates Using Different Approaches for Site M4

Approach	Vehicle Trips
Observed count	1,103
Adjusted count	1,191
TG 9th edition rates	1,231
TG 9th edition rates + VDOT TIA	1,201
TG 9th edition rates + MXD	1,182
TG 9th edition rates + TGH	882
TG 10th edition rates	1,178
TG 10th edition rates + VDOT TIA	1,149
TG 10th edition rates + MXD	1,131
TG 10th edition rates + TGH 3rd edition	842

Table D5. Trip Estimates Using Different Approaches for Site M5

Approach	Vehicle Trips
Observed count	1,236
Adjusted count	1,335
TG 9th edition rates	1,795
TG 9th edition rates + VDOT TIA	1,781
TG 9th edition rates + MXD	1,705
TG 9th edition rates + TGH	1,478
TG 10th edition rates	1,812
TG 10th edition rates + VDOT TIA	1,796
TG 10th edition rates + MXD	1,721
TG 10th edition rates + TGH 3rd edition	1,442

Table D6. Trip Estimates Using Different Approaches for Site M6

Approach	Vehicle Trips
Observed count	548
Adjusted count	592
TG 9th edition rates	1,566
TG 9th edition rates + VDOT TIA	1,511
TG 9th edition rates + MXD	1,519
TG 9th edition rates + TGH	1,550
TG 10th edition rates	1,563
TG 10th edition rates + VDOT TIA	1,514
TG 10th edition rates + MXD	1,516
TG 10th edition rates + TGH 3rd edition	1,357

Table D7. Trip Estimates Using Different Approaches for Site M7

Approach	Vehicle Trips
Observed count	500
Adjusted count	540
TG 9th edition rates	492
TG 9th edition rates + VDOT TIA	475
TG 9th edition rates + MXD	467
TG 9th edition rates + TGH	399
TG 10th edition rates	508
TG 10th edition rates + VDOT TIA	491
TG 10th edition rates + MXD	483
TG 10th edition rates + TGH 3rd edition	405

Table D8. Trip Estimates Using Different Approaches for Site M8

Approach	Vehicle Trips
Observed count	216
Adjusted count	233
TG 9th edition rates	346
TG 9th edition rates + VDOT TIA	342
TG 9th edition rates + MXD	339
TG 9th edition rates + TGH	276
TG 10th edition rates	373
TG 10th edition rates + VDOT TIA	368
TG 10th edition rates + MXD	362
TG 10th edition rates + TGH 3rd edition	282

Table D9. Trip Estimates Using Different Approaches for Site M9

Approach	Vehicle Trips
Observed count	382
Adjusted count	413
TG 9th edition rates	745
TG 9th edition rates + VDOT TIA	730
TG 9th edition rates + MXD	723
TG 9th edition rates + TGH	492
TG 10th edition rates	755
TG 10th edition rates + VDOT TIA	738
TG 10th edition rates + MXD	732
TG 10th edition rates + TGH 3rd edition	499

Table D10. Trip Estimates Using Different Approaches for Site M10

Approach	Vehicle Trips
Observed count	895
Adjusted count	967
TG 9th edition rates	1,357
TG 9th edition rates + VDOT TIA	1,314
TG 9th edition rates + MXD	1,303
TG 9th edition rates + TGH	1,104
TG 10th edition rates	1,328
TG 10th edition rates + VDOT TIA	1,284
TG 10th edition rates + MXD	1,275
TG 10th edition rates + TGH 3rd edition	1,078

APPENDIX E. SUGGESTED REVISIONS TO THE ADMINISTRATIVE GUIDELINES FOR THE TRAFFIC IMPACT ANALYSIS REGULATIONS

Page 51: Current statement

2. TRIP GENERATION.

Trip generation estimates for a proposed development shall be prepared using the Institute of Transportation Engineers (ITE) **Trip Generation** publication unless the VDOT reviewer agrees to the use of alternate trip generation rates based upon alternate published guides or local trip generation studies. Rezoning proposals shall assume the highest vehicle trip generating use allowable under the proposed zoning classification.

In determining which trip generation process (equation or rate) may be used, the preparer shall follow the guidance in the **Trip Generation Handbook** – **except rates may be utilized if the criteria for the use of regression equations are not met**. Regression equations to calculate trips as a result of development shall be utilized, provided the following is true:

a. Independent variable falls within range of data; and

b. Either the data plot has at least 20 points; or

c. R2 is greater than 0.75, equation falls within data cluster in plot and standard deviation greater than 110% of weighted average rate.

51

Administrative Guidelines December 2018

If the above criteria are not met, then the preparer can use average trip rates, **though if the following do not apply a rate based upon the study of similar local sites should be considered**:

d. At least three data points exist;

e. Standard deviation less than 110% of weighted average rate; **and**

f. Weighted average rate falls within data cluster in plot.

Proposed modification

For "(ITE) Trip Generation", specify "the appropriate edition of" (Trip Generation, 10th Edition, for urban studies after agreed to in a scoping meeting, for example) and to update the URL. For "Trip Generation Handbook", specify "the appropriate edition of", (i.e., Trip Generation, 3rd Edition for items discussed in scoping meetings) and update the URL. Change "110%" to "55%" according to the TGH 3rd edition. If we assume that the trip rate follows a normal distribution, a one-sided 95% confidence interval of trip rate is [mean rate + 1.64×standard deviation, ∞). When the standard deviation is less than 55% of the mean rate, we can ensure that the lower bound of the 95% confidence interval is larger than 0, i.e., the mean rate is significantly larger than 0. However, this cannot be guaranteed if 110% is used.

Page 52: Current statement

3. INTERNAL CAPTURE AND PASS-BY TRIPS.

Internal capture rates consider site trips "captured" within a mixed use development, recognizing that trips from one land use can access another land use within a site development without having to access the adjacent street system. **For office with retail use – use the smaller of 5% office or retail trips generated.**

Pass-by trip reductions consider site trips drawn from the existing traffic stream on an adjacent street, recognizing that trips drawn to a site would otherwise already traverse the adjacent street regardless of the existence of the site. The reduction applies only to volumes on adjacent streets, not to ingress or egress volumes at entrances serving the proposed site. Unless otherwise approved by VDOT, **the pass-by rates utilized shall be those reported in Trip Generation Handbook**.

52

Administrative Guidelines December 2018

~~Various internal capture rates are listed and can be used in combination to provide greater flexibility to more accurately determine internal trips that do not impact adjacent streets.~~

~~For VDOT TIA studies associated with small area plans, pass-by trip reductions and internal capture rates may be based on the "Mixed Use Trip Generation Model V 4.0" trip generation methodology as described on page 43 of this chapter.~~

Proposed modification

Replace the highlighted statement with:
"Various internal capture rates are listed in the Regulations, 24VAC30-155-60. D. "Methodology and Standard Assumptions" (see page 62) and can be used in combination to provide greater flexibility to more accurately determine internal trips that do not impact adjacent streets. For VDOT TIA studies associated with small area plans, internal capture can also be estimated based on the methodology presented in ITE Trip Generation Handbook, 3rd Edition and the "Mixed Use Trip Generation Model V 4.0" (see page 43)."

Delete the statements crossed out with red lines.