

# **Small Data: Local Trip Generation Data and Developing a Better Model for the City of Austin, Texas**

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**Abstract**

Trip generation estimates for specific land uses are traditionally gathered from data included in the most current version of a handbook entitled *Trip Generation Manual*, produced by the Institute of Transportation Engineers (ITE). Data collected to develop these rates have typically been collected at suburban, single-use, freestanding sites. These defining characteristics limit their applicability to development projects in urban settings.

From a collection of planning studies and impact analyses done in the last two years within the City of Austin, BIG RED DOG Engineering examined existing data to show that vehicle trip generation estimates to and from new development have been overestimated during the peak hours by more than 50 percent.

To remedy this overestimation, BIG RED DOG Engineering developed a vehicle trip generation model specific to the City that accounts for specific characteristics of the development, availability of non-auto modes, and the demographic profile of the surrounding area. Aside from the traffic count data, the BIG RED DOG team used readily available information as variables for the model, both for calibration and validation as well as for use in developing new forecasts.

The results of this analysis have implications for engineers and planners that continue to design the City for vehicles, thus creating a self-fulfilling prophecy of vehicle congestion. As the City moves toward a more multimodal vision while wrestling with their responsibility to those in vehicles, the use of the national rates create an undue burden on the engineers and planners championing that multimodal vision.

## ***Introduction***

As part of development applications throughout the country, developers are often required to provide a transportation impact analysis (TIA), which requires the applicant to assess impacts of the proposed development on the surrounding transportation network. Every jurisdiction has its own requirements, but many focus on vehicle capacity at intersections and on roadway segments. If a TIA indicates that a project will cause facilities to not meet their requirements, jurisdictions can require applicants to add capacity through widened roads and intersections, new traffic signals, and other improvements.

A major part of this analysis is the vehicle trip generation estimate that is developed for the project, typically based only on the proposed land use and its intensity. Trip generation estimates for specific land uses are traditionally gathered from data included in the most current version of a handbook entitled *Trip Generation Manual*, produced by the Institute of Transportation Engineers (ITE).

New models have been developed in the last decade to better account for mixed-use and urban infill development projects, accounting for additional variables that influence vehicle trip generation:

- Diversity of uses within the development
- Connectivity/walkability
- Adjacent land uses
- Distance to non-auto modes
- Size of development
- Demographic profile of the surrounding area
- Transportation Demand Management (TDM) tools

Data collected to develop the ITE rates have typically been collected at suburban, single-use, freestanding sites and reflect sites across the nation, as well as dates extending back to the 1960s. With changing trends in travel behavior, including a decrease in auto trips per person and declining vehicle ownership rates, many of these data points are no longer applicable to the type of development under consideration today. These defining characteristics limit their applicability to development projects in more unique environments, such as urban settings and/or projects with a mix of uses.

## ***Background / Previous Studies***

As urban infill and mixed-use development projects have become more popular, standard trip generation rates have not provided for the subtlety of the variables mentioned above that affect vehicle trip generation. Overestimating vehicle trip generation can lead to excessively conservative traffic analysis and additional capacity for vehicles that is neither warranted nor consistent with a jurisdiction's vision for their mobility network. Not only does it increase the cost of the development (which gets passed on to its tenants), it can also color the community's opinion of a potential development and increase opposition.

Many transportation planners and traffic engineers will use the standard ITE rates without questioning their appropriateness. While this method is quick to complete and objective in its assessment, it is also often incorrect. ITE's *Trip Generation Handbook*, which provides guidance as to how to best use the data included in *Trip Generation Manual* (as well as to incorporate methodologies for mixed-use and urban infill developments), states that local data should be used to supplement the national data provided, should it be available. Estimates generated through the data included in *Trip Generation Manual* also only reflect one variable: the density of the land use selected.

Particularly for urban infill and mixed-use development projects, previous studies have shown that standard ITE rates significantly overestimate both daily and peak hour vehicle trip generation. Some studies have shown that actual vehicle trip generation for urban infill developments is overestimated by up to 70 percent. Other studies have indicated that mixed-use developments located in suburban settings can have a daily vehicle trip generation rate up to 30 percent lower than what would be estimated using standard rates; that number rises to 50 percent during the peak periods.

Comparisons to ITE's *Trip Generation Manual* (9<sup>th</sup> Edition) for certain development projects within the City of Austin were the original impetus for this review. The standard rates in the manual combine all data from a particular land use into a single category, and much of the data were decades old.

Late in 2017, ITE released the 10<sup>th</sup> Edition of *Trip Generation Manual*. This edition updated the data set to remove data from before 1980; it also included data collected at a range of geographic settings, including Central Business Districts, midtown areas, and residential developments near transit stations. For certain land use categories, rates specific to geographic settings (e.g. Center City Core, Dense Multi-Use Urban) are provided in addition to the overall rate for several land use categories. Data can also be sorted by the year the data was collected to develop trip generation rates through a web application.

For mixed-use developments, ITE's *Trip Generation Handbook* defers to the methodology established in *NCHRP Report 684: Enhancing Internal Trip Capture for Mixed-Use Developments*. The variables mentioned in the introduction have typically been used to more appropriately estimate vehicle trip generation for mixed-use development, though they apply to the surrounding areas of single-use urban infill sites as well.

For urban infill sites, the *Handbook* simply states the data do not reflect vehicle trip generation at those locations; it also acknowledges that development in areas that are almost fully built out often does not result in the number of vehicle trips that would be generated in suburban or outlying locations.

Other models for vehicle trip generation have been created, though they typically reflect national data at mixed-use sites. One such methodology was developed from a national study sponsored by the US

Environmental Protection Agency (EPA). Travel survey data were gathered from 239 mixed-use developments in six major metropolitan regions and correlated with the characteristics of the sites and their surroundings. Characteristics listed earlier were related statistically to trip behavior observed at the study development sites, which produced equations allowing better predictions for external vehicle trip reduction as a function of the mixed-use development characteristics. Validation at 27 developments reduced overestimation of vehicle trips from two to twelve percent.

These equations have been used for urban, suburban, and exurban mixed-use projects. Some development projects in dense, urban areas have shown reductions of 30 to 50 percent. Mixed-use development projects in suburban areas more often showed reductions between ten and twenty percent. Single-use projects without transit connections, or mixed-use projects without complementary land uses, typically showed very low reductions.

### ***Data Collection***

In lieu of using the national models to estimate vehicle trip generation, BIG RED DOG Engineering staff compiled vehicle trip generation counts from a series of transportation planning studies and traffic impact analyses done in the last two years within the City of Austin. A total of 31 sites were included in the analysis, representing all ten City Council districts and ten different land use categories. Sixteen of the sites were collected for TIAs since 2016; an additional fifteen sites were collected in early 2018 to complement that data set by filling in gaps in geography and land uses. Data from four additional sites were deemed incomplete or inappropriate for the purposes of this analysis.

Nineteen of the projects had a residential component, while thirteen had a commercial component. Three projects had a mix of uses, though two were retail plazas with supporting uses. A number of variables were collected in addition to the counts for model development; these are detailed later in this paper.

### ***Comparison to ITE Trip Generation (9<sup>th</sup> and 10<sup>th</sup> Editions)***

The results indicate that by using the ITE data alone, vehicle trip generation estimates are too high by 52 percent during the AM peak hour and 50 percent during the PM peak hour for the 31 locations. The average error per prediction was 47 percent during the AM peak hour and 54 percent during the PM peak hour. Four of the 31 locations had actual trip counts that were higher than predicted in the AM peak hour, and only one had a trip count that was higher than predicted in the PM peak hour.

During the AM peak hour, 22 of the 31 locations had actual trip counts that were less than 80 percent of what would have been predicted by the national data; fourteen were less than 60 percent of the predicted values. For the PM peak hour, 24 of the 31 counts were less than 80 percent of predicted values, and twelve were less than 60 percent. **Figure 1** and **Figure 2** show predicted and actual vehicle trip generation for

each of the 31 projects for the AM and PM peak hours, respectively. **Figure 3** shows the ratios of predicted to actual vehicle trip generation for the AM and PM peak hours for each of the 31 projects.

With the updated data in the 10<sup>th</sup> Edition, the results indicate that using the ITE data alone would overestimate vehicle traffic traveling to and from the developments by 22 percent during the AM peak hour and 30 percent during the PM peak hour. The average error per site was seventeen percent during the AM peak hour and 31 percent during the PM peak hour. Eleven of the 31 locations had actual trip counts that were higher than predicted in the AM peak hour, and seven had a trip count that was higher than predicted in the PM peak hour.

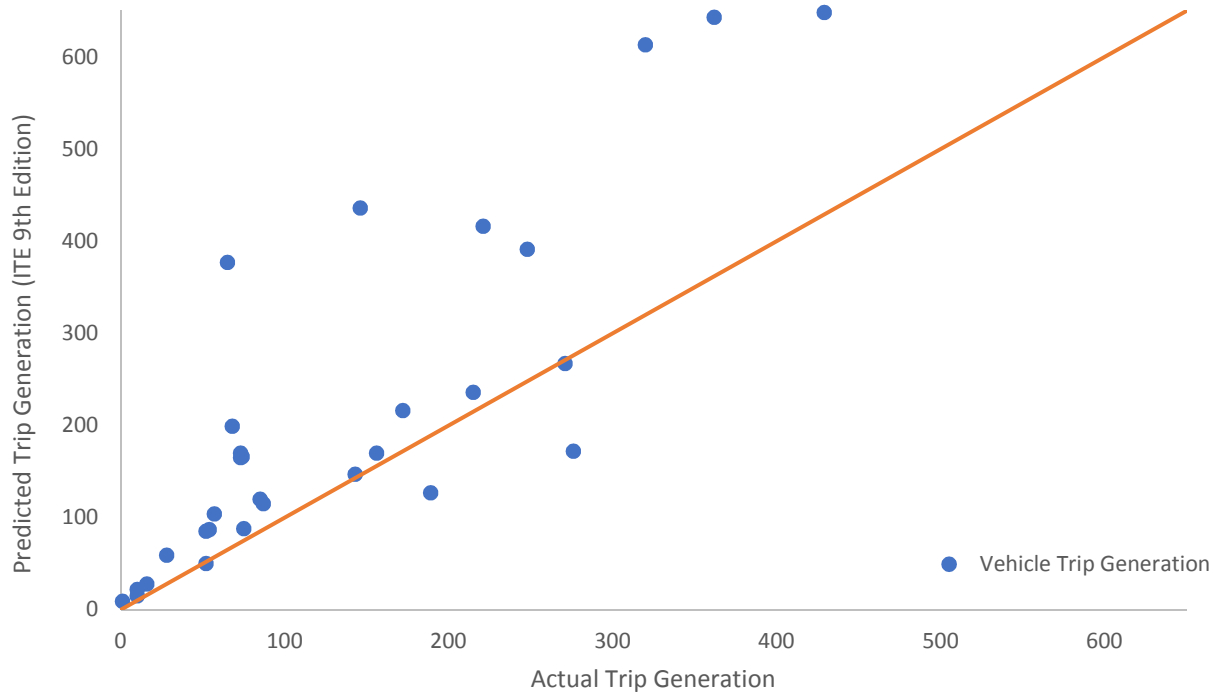
During the AM peak hour, 14 of the 31 locations had actual trip counts that were less than 80 percent of what would have been predicted by the national data; six were less than 60 percent of the predicted values. Seven of the 31 predictions were within ten percent of the actual value. For the PM peak hour, 17 of the 31 counts were less than 80 percent of predicted values, and ten were less than 60 percent. **Figure 4** and **Figure 5** on the following page shows predicted and actual vehicle trip generation for each of the 31 projects for the AM and PM peak hours, respectively. **Figure 6** shows the ratios of predicted to actual vehicle trip generation for the AM and PM peak hours for each of the 31 projects. Statistics comparing these estimates for the 9<sup>th</sup> and 10<sup>th</sup> Editions of *Trip Generation Manual* are shown below in **Table 1**.

For residential projects, the national data underestimated traffic by 1.4 percent during the AM and overestimated traffic by 20 percent during the PM peak hour. For commercial projects, the standard rates overestimated traffic by 44 and 34 percent during the AM and PM peak hours, respectively.

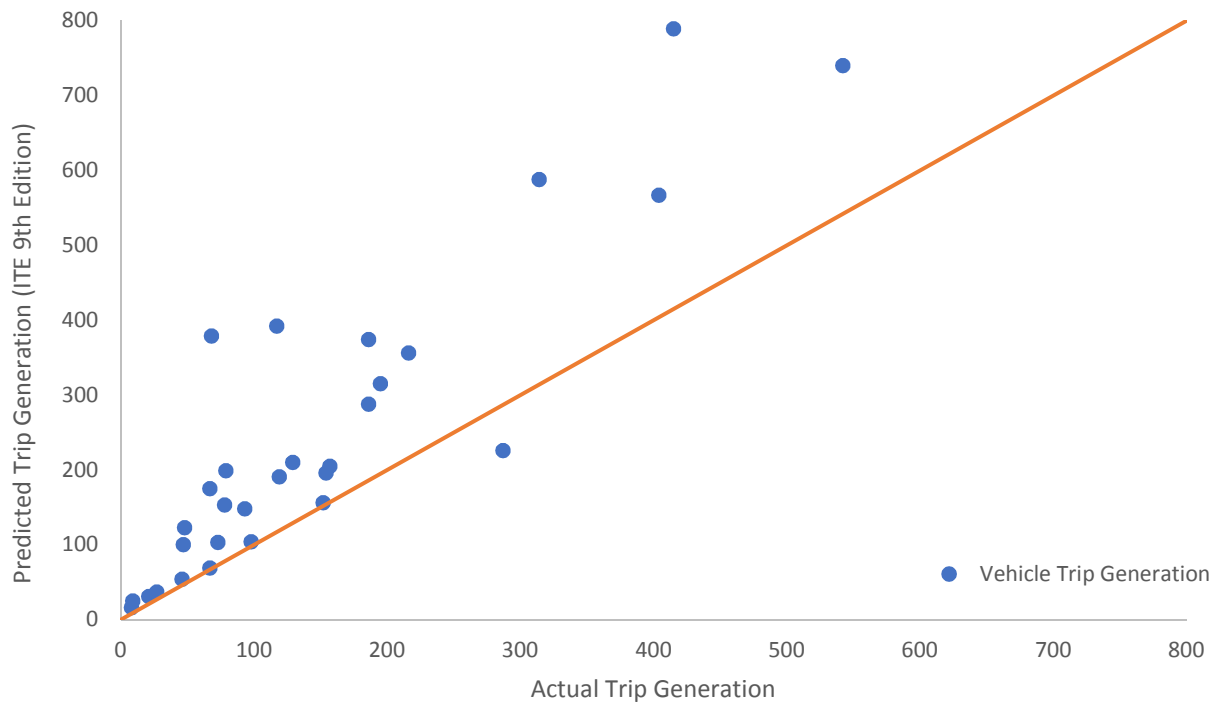
For the mixed-use projects, the overestimation was 41 and 50 percent during the AM and PM peak hours, respectively. Even accounting for internalization estimates for these projects, overestimation of vehicle trip generation was 23 and 36 percent during the AM and PM peak hours, respectively.

As previously mentioned, the 10<sup>th</sup> Edition also provides vehicle trip generation rates with specific geographic settings for certain land uses categories. For land uses that had more detailed rates available for those geographic settings (Center City Core or Dense Multi-Use Urban instead of General Urban/Suburban), the results indicate that using the ITE rates underestimates vehicle traffic traveling to and from new development by 11 percent during both the AM and PM peak hours. These rates were only applicable to four of the 31 sites included in the data set.

**Figure 1 - Predicted vs. Actual Trip Generation (ITE 9th Edition) - AM Peak Hour**



**Figure 2 - Predicted vs. Actual Trip Generation (ITE 9th Edition) - PM Peak Hour**



**Figure 3 - Predicted vs. Actual Trip Generation (ITE 9th Edition) - PM Peak Hour**



**Figure 4 - Predicted vs. Actual Trip Generation (ITE 10th Edition) - AM Peak Hour**

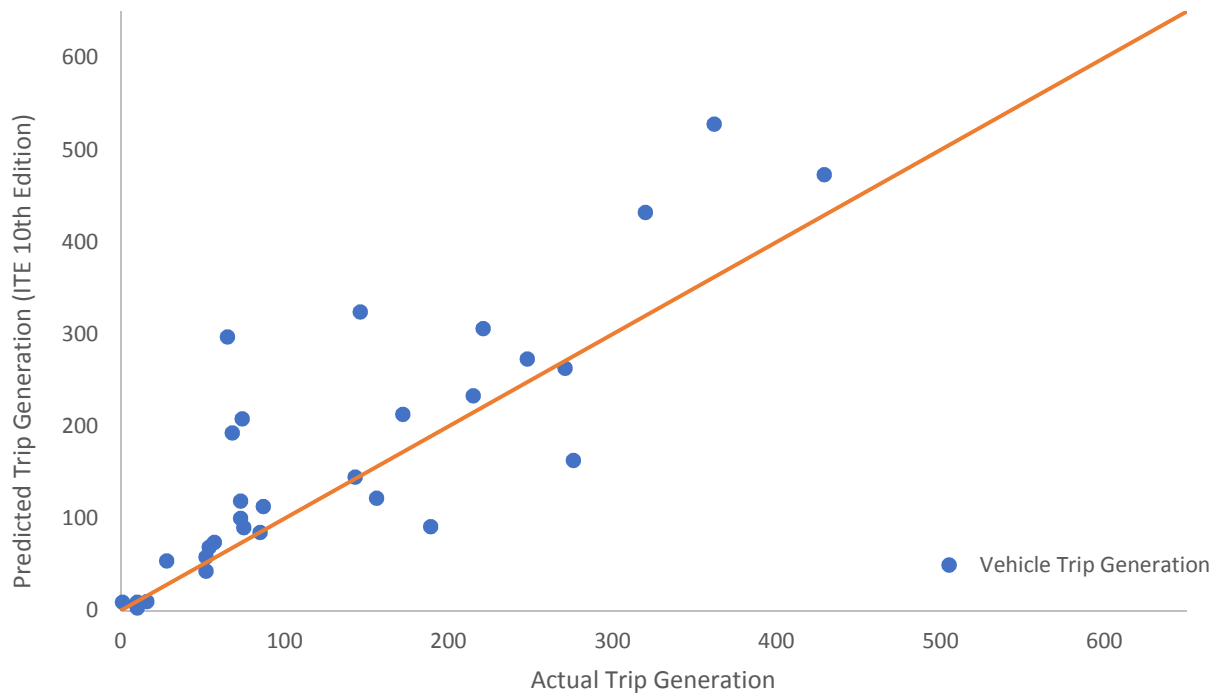




Figure 5 - Predicted vs. Actual Trip Generation (ITE 10th Edition) - PM Peak Hour

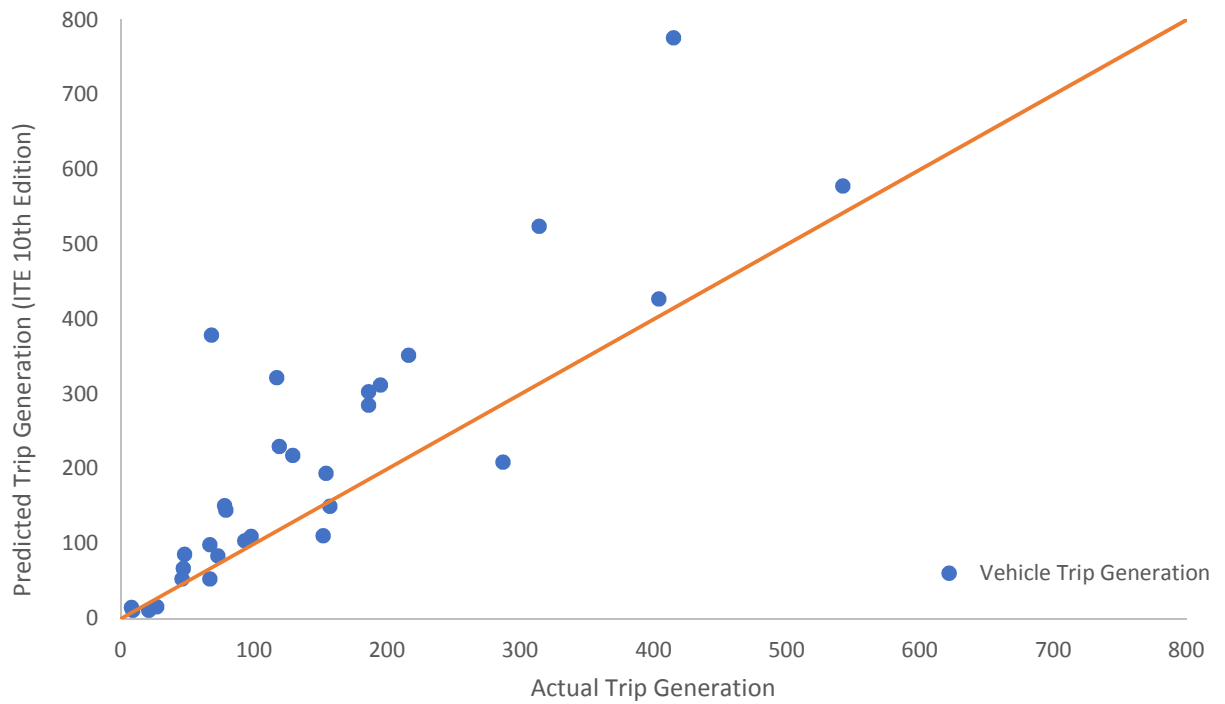


Figure 6 - Predicted vs. Actual Trip Generation (ITE 10th Edition) - PM Peak Hour



**Table 1 – Statistical Comparison of Actual Totals vs. Estimates Predicted by ITE's *Trip Generation Manual* (9<sup>th</sup>, 10<sup>th</sup> Editions)**

ITE Edition	Statistic	AM Peak Hour	PM Peak Hour
9 <sup>th</sup> Edition	ITE Generated Estimates vs. Actual Vehicle Trip Generation Totals <sup>1</sup>	152%	150%
	Average Overestimation Per Site <sup>2</sup>	47%	54%
	Sites with Higher Actual Vehicle Trip Generation Than Estimate	4 / 31	1 / 31
	Sites with Actual Trip Generation Estimate Less Than 80% of ITE Generated Estimate	22 / 31	24 / 31
	Sites with Actual Trip Generation Estimate Less Than 60% of ITE Generated Estimate	14 / 31	12 / 31
10 <sup>th</sup> Edition	ITE Generated Estimates vs. Actual Vehicle Trip Generation Totals <sup>1</sup>	122%	130%
	Average Overestimation Per Site <sup>2</sup>	17%	31%
	Sites with Higher Actual Vehicle Trip Generation Than Estimate	11 / 31	7 / 31
	Sites with Actual Trip Generation Estimate Less Than 80% of ITE Generated Estimate	14 / 31	17 / 31
	Sites with Actual Trip Generation Estimate Less Than 60% of ITE Generated Estimate	6 / 31	10 / 31

Notes:

1. Observed trip generation total for all 31 sites divided by predicted trip generation for same sites
2. The inverse of the sum of observed trip generation totals divided by predicted trip generation totals minus 1

### ***Model Development***

BIG RED DOG Engineering started this research effort with a goal to determine if vehicle trip generation was systemically overestimated within the City; with the referenced evidence that that was indeed occurring, the team set out to develop a vehicle trip generation model specific to the City that accounts for specific characteristics of the development, availability of non-auto modes, and the demographic profile of the surrounding area. Aside from the traffic count data, the team used readily available information as variables for the model, both for calibration and validation as well as for use in developing new forecasts.

Typically during the scoping process for a TIA for the City of Austin, the applicant and the City will agree on a vehicle trip reduction percentage, which includes internalization due to a mix of uses, as well as potential utilization of alternative modes. This reduction is occasionally based on an objective analysis method, though more typically it is based on the gut feel of City staff and engineers based on the diversity of the land uses and the location of the project. The goal of developing this model was to put objective analysis behind those reductions.

In addition to the counts themselves, a number of additional variables were recorded for potential use in a vehicle trip generation model:

- Land use categories and respective intensities
- Zip code and City Council district
- Most-frequent transit service within ¼-mile radius of project
- Intersection density within ¼-mile radius
- Provision of parking and fees associated

- Walk Score, Bike Score, and Transit Score from walkscore.com
- MobilityScore from TransitScreen
- Size of project in acres
- Household size and average family size per zip code
- Percentage of households without vehicles per zip code
- Average vehicle ownership per household per zip code
- Drive alone commute percentage per zip code

Generally, these variables were intended to be representative of the larger categories mentioned earlier in this paper while also being easily accessible. These variables either mirror or are a reflection of variables used in other vehicle trip generation models.

Based on the data from Walk Score and TransitScreen, projects ranged from having “Excellent Transit” and being a “Walker’s Paradise” to having “Minimal Transit” and being “Very Car-Dependent.” Within the City of Austin limits, it was difficult to find developments that were rated as having the best possible transit service and pedestrian accommodations. TransitScreen’s MobilityScore is included as a measure of the availability of transportation options and overall access from a particular address. The score is intended to measure ease of mobility, including the availability of carsharing and bike sharing services as well as ride-hailing services.

The final five variables were all collected from United States Census and American Community Survey data. Data for the sites included in the study are shown in **Table 2**. The selected sites are representative of the City of Austin, which has smaller households, fewer households without a vehicle, fewer vehicles per household, and a lower drive alone commute percentage than the national rates indicate.

**Table 2 – Comparison of National, City of Austin, and Study Site Census and American Community Survey Data**

Potential Variable	National Rate	City of Austin Rate	Average Study Site Rate	Rate Range
Household Size	2.58	2.37	2.45	1.44 – 3.67
Average Family Size	3.14	3.16	3.15	2.23 – 4.05
Households without Vehicles	9.0%	6.4%	6.6%	0.4% - 14.9%
Vehicles per Household	1.79	1.66	1.68	1.26 – 2.19
Drive Alone Commute Percentage	76.4%	73.7%	72.9%	60.9% – 81.8%

### ***Model Calibration***

The baseline vehicle trip generation estimates used in the City of Austin model are developed from the ITE standard rates and equations. The model then attempts to determine a ratio to adjust for the characteristics of vehicle trip generation within the City of Austin. The model does not distinguish between trips that might

stay internal to the project or will be made by walking, bicycling, or taking transit; its goal is to simply provide a more accurate estimate of vehicle trip generation.

These ratios would be used to multiply the vehicle trip generation estimates derived from the 10<sup>th</sup> Edition of the *Trip Generation Manual*. Separate ratios were developed for the AM and PM peak hours; while the data showed similar patterns, they were often on different scales.

Several variables are similar and correlate heavily to one another. As a result, the following variables were eliminated:

- Zip code and City Council district
- Most-frequent transit service within ¼-mile radius of project
- Bike Score, Transit Score, and MobilityScore
- Average family size per zip code
- Percentage of households without vehicles per zip code

Walk Score had high correlations with Bike Score, Transit Score, and MobilityScore and had the greatest correlation with vehicle trip generation estimate accuracy. Transit frequency also had a high correlation with the Transit Score and held little explanatory value. Household size and average family size proved to be redundant variables. Percentages of households without vehicles was a weaker explanatory variable than average vehicle ownership and drive alone commute percentage. Those two variables also had a high coefficient of correlation. Average vehicle ownership had additional weight in explaining the overestimate of vehicle trips; as result, drive alone commute percentage was removed from the data set.

As a result, the following variables were further examined for use in developing the vehicle trip generation ratios:

- Land use categories and respective intensities
- Intersection density within ¼-mile radius
- Provision of parking and fees associated
- Walk Score
- Size of project in acres
- Household size per zip code
- Average vehicle ownership per household per zip code

Only four of the sites included in the data set charged for parking provided on-site; observations also indicated that parking (another potential driver for vehicle trip generation) was also widely available across these sites. Because of the lack of diversity, provision of parking and its associated fees were removed from the data set.

Intersection density is an important variable in the estimation of vehicle trip generation for mixed-use developments. It is typically used to reflect the design of a project, including connectivity and walkability. Walk Score did a much better job of reflecting the true reduction of the vehicle trip generation than intersection density. Because so few projects included are truly mixed-use, it is likely that the data set decreased the weight of this variable; with additional data, particularly for larger mixed-use developments, it is likely that intersection density (particularly internal to the project) would be a greater indicator for true vehicle trip generation. Similarly, the size of the development did not vary enough within this data set to find a statistically significant correlation with vehicle trip generation. Both variables were removed from the data set.

As a result of strong correlation statistics between the tested variables and the actual vehicle trip generation totals (as well as the overestimate), the following variables were used in the final calibration of the model to develop the AM and PM peak hour ratios:

- Land use categories and respective intensities
- Walk Score
- Household size per zip code
- Average vehicle ownership per household per zip code

With estimates generated by the equation produced by the calibration efforts above, the calibration statistics shown in **Table 3** were much better as compared to those same statistics using predictions from the one-variable ITE data.

### ***Model Validation***

Five additional sites were selected to validate the model. Actual vehicle trip generation data were collected at these locations but were not included in previous results or the model calibration. Using the model created with the data at the 31 sites, the average overestimation of vehicle trips decreases from seventeen percent in the AM peak hour and 31 percent in the PM peak hour using only the ITE data to nine percent and five percent, respectively. All validation statistics improved as well using the BIG RED DOG Engineering model, as shown in Table 3.

**Table 3 – Calibration / Validation Statistics of Using ITE (10<sup>th</sup> Edition) and BRD Trip Generation Models**

	Validation Statistic	AM Peak Hour		PM Peak Hour	
		ITE Method	BRD Model	ITE Method	BRD Model
Calibration	Average Model Error %	14%	13%	24%	9%
	Average Absolute Model Error %	34%	16%	33%	7%
	Root Mean Square Error %	49%	21%	57%	13%
	R-Squared	0.89	0.97	0.80	0.95
Validation	Average Model Error %	21%	12%	29%	14%
	Average Absolute Model Error %	32%	15%	39%	11%
	Root Mean Square Error %	59%	24%	61%	14%
	R-Squared	0.86	0.94	0.74	0.94

***Potential Issues with Model / Data / Results***

While we believe that use of this model does a better job of predicting peak hour vehicle trip generation than solely using data from *Trip Generation Manual*, we also acknowledge a number of areas in which the model could be improved.

While 31 data points felt significant enough to establish a clear pattern with a diverse set of land uses and geographies, additional data would help to further calibrate (and validate) the model. Counts for each site occurred on one day only, adding to the variability of the observed data.

The included land uses represent a small subset of the available choices in ITE's *Trip Generation Manual*; additional data to support the patterns found with the predominantly residential and office locations would lend more credence to the model for use with other land uses.

Because this was an internally-funded research project, some locations were chosen because they would be easier to count vehicle trips; for the purposes of this effort, developments with fewer access points were obvious candidates for the supplemental data collection to reduce costs. While limited connectivity could be an indicator of additional vehicle dependency, more connected locations could be added to the data set to further support the results found at the 31 selected locations.

Lastly, simplified versions of many variables were used for this study. As mentioned in the "Model Calibration" section, the data set may have eliminated some variables that would otherwise influence vehicle trip generation. The model developed for this effort simply looked at different correlative effects on vehicle trip generation that seemed consistent with the principles used in more advanced vehicle trip generation models. While this model improves on the data provided by ITE's *Trip Generation Manual*, additional advances are almost certainly possible with a larger data set for calibration.

### ***Follow-Up Analysis Possibilities***

In addition to supplementary calibration and validation, more detailed information could be gleaned from this type of analysis with additional data. Person-trip estimates, which have begun to become available in the 10<sup>th</sup> Edition of *Trip Generation Manual*, could in the same manner be locally calibrated and validated. Person-trip estimates could add significant context to the evaluation of the development as well. Person-trip data collection is also much more labor intensive due to the need for intercept surveys to complete counts for each of the different modes.

As an example, how does the evaluation of a project change if each vehicle carries three to four people? What if many of the vehicles at an intersection are transit vehicles, carrying 50 passengers per vehicle? Perhaps the vehicle trip generation estimated from ITE data is fairly accurate, but the mode split for the project could be evenly split among non-private automobile modes.

With additional travel options available, mode choice is no longer limited to private automobiles, walking, bicycling, and/or taking transit. Transportation network companies (TNCs), shared resources (both car and bicycle), and dockless operators (bicycles, electric bicycles, and electric scooters), are providing more options particularly for shorter trips.

This model could also be combined with additional data to develop estimates for vehicle-miles traveled (VMT) for any given development project. Projects could be evaluated by total VMT, by VMT per capita, or by VMT per trip. Two developments may generate similar numbers of vehicle trips; should they be treated similarly if one has an average trip length of two miles and another has an average trip length of ten miles? Those are judgments for individual jurisdictions to make, but the data is available for those evaluations to be made.

As more jurisdictions look toward TDM methods to manage vehicle traffic (rather than attempting to add supply to vehicle capacity), understanding the baseline level of vehicle trip generation is important if TDM plans and programs are to be judged for performance, rather than for implementation. As an example, if the City of Austin required each of the sites to reduce vehicle trips to and from their sites during both peak periods by 15 percent tomorrow, 13 of the 31 sites would be compliant without having to change anything if trip generation estimates were compared to ITE rates.

Among the City's foremost issues right now is housing affordability; the overestimation of vehicle traffic has consequences for rents and home ownerships prices as well. With the City undergoing an update to its land development code and associated standards, this has wide-ranging implications for the future of land development and transportation planning.

## **Conclusion**

As the City moves toward a more multimodal vision while wrestling with their responsibility to those in vehicles, the use of the national data create an undue burden on City staff championing that multimodal vision. Estimates derived from these data have caused engineers and planners to continue to build the City for vehicles, thus creating a self-fulfilling prophecy of vehicle congestion. While ITE's 10<sup>th</sup> Edition of the *Trip Generation Manual* lowers this error, the national data still do not reflect actual vehicle trip generation measured throughout the City of Austin.

Using a combination of variables in addition to the land use and its intensity, BIG RED DOG Engineering has developed a model to lower average error from 17-31 percent to 5-9 percent. The data for the additional variables are readily available and consistent with the types of variables examined in previous studies. Additional data would help to further calibrate the model and provide more information regarding the trip generating characteristics of a potential development, but a very clear pattern has been observed with the data collected.

Lastly, the total cost for the data included in this study through a third-party vendor was just under \$10,000; fewer than 100 hours of staff time were needed to process the data, build the database for both the counts, ITE estimates, and the potential variables, calibrate and validate the model, and document the results within this paper. Only the traffic counts require significant cost and time to gather; while this model is a simplified version of some that have come before it, a version of this could be replicated for most jurisdictions within the United States.

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