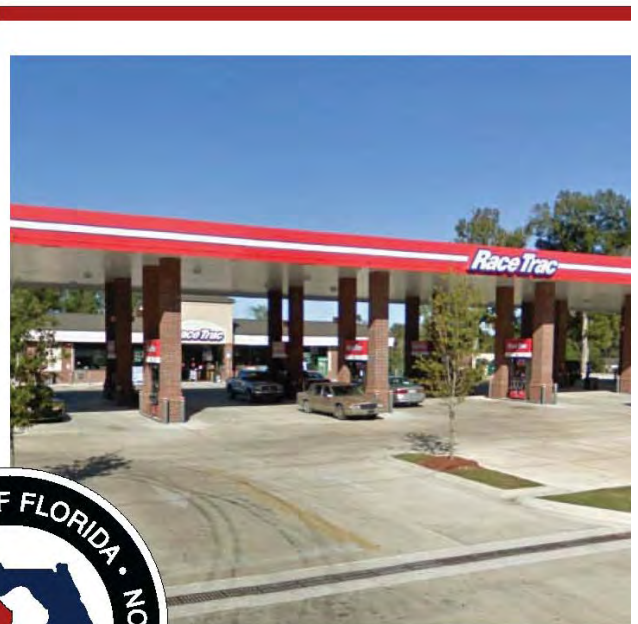


# Trip Generation

## Characteristics of Large Gas Stations/Convenience Stores and Student Apartments



Florida Department of Transportation  
Systems Planning Office/Systems Management  
605 Suwannee Street #19  
Tallahassee, Florida 32399  
[www.dot.state.fl.us](http://www.dot.state.fl.us)  
Questions/Comments: gary.sokolow@dot.state.fl.us

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## **Executive Summary**

Staff at the Florida Department of Transportation (FDOT) is responsible for determining access requirements and impacts of developments. Therefore, FDOT set out to identify the latest trip generation information on two of the new land uses: Convenience Markets with Gas Pumps and Student Apartments.

### **Convenience Markets with Gas Pumps**

Previous studies on Convenience Markets with Gas Pumps implied that newer Florida developments might have trip generation characteristics different than those already included in ITE reports. Potential differences in rates from ITE reports, and the possibility of good multi-variable regression equations formed the background for our research efforts.

Once the sites were selected for study, background data was gathered. This included square footage information for Convenience Markets with Gas Pumps. Traffic data collection efforts included 48-hour driveway and adjacent street counts for 12 Convenience Market with Gas Pumps sites on consecutive weekdays between Tuesday and Thursday. Pass-by counts were also conducted at the same time.

Overall, the multi-variable equations represented the highest level of predictability for Convenience Market with Gas Pumps in the FDOT 2012 study. Results were compared with the closest ITE Land Uses 853 Convenience Market with Gas and ITE Land Use 945 Service Station with Convenience Market. With a low level of correlation between fueling positions and base square footage, it appears the combined influence of each variable may be a better indicator of trip generation. These modern gas stations aim to gain more customers by providing larger stores with more amenities, as well as more fueling positions to eliminate waiting or the need to move their vehicles when going into the store. The complex nature of these newer sites demands a different model than used in the past. Specifically, the following equations perform well for estimating trips in Florida. Pass-by rates were relatively consistent and matched ITE guidance for Florida sites at around 78%.

## The Trip Generation Rates from Our Florida 2012 Study

Description	Trip Rate Formula Note: As with most retail the practical directional distribution is 50%/50%
<b>Weekday/Daily Trips</b>	
<b>Weekday Trip Ends</b> using 1,000 sq ft of gross floor area of the convenience store ( <b>kft<sup>2</sup></b> )	Weekday Trips = 1,141.59 * kft <sup>2</sup>
<b>Weekday Trip Ends</b> using Fueling Positions ( <b>FP</b> )	Weekday Trips = 233.70 *FP
<b>Weekday Trip Ends</b> using multi Variable Equation	Weekday Trips = 256.7*FP-144.5*kft2
<b>PM Peak Hour Trips</b>	
PM Peak Hour of Adjacent Street Traffic Trip Ends One Hour between 4 and 6 p.m. using 1,000 sq ft of gross floor area of the convenience store ( <b>kft<sup>2</sup></b> )	PM Peak Trips = 85.66 * kft <sup>2</sup>
PM Peak Hour of Adjacent Street Traffic Trip Ends using Fueling Positions ( <b>FP</b> )	PM Peak Trips = 17.09*FP
<b>Trip Ends</b> using multi Variable Equation	PM Peak Trips = 12.3*FP+15.5*kft2

In these equations:

**FP:** fueling positions

**kft<sup>2</sup>:** 1,000 square feet gross floor area of the convenience market

Comparison of Trip Generation Rates Convenience Market with Gas Pumps 9th Edition ITE Trip Generation Manual

What we found is shown in the following trip rates and compared them to the existing (9<sup>th</sup> Edition ITE Trip Generation report)

Comparison of Trip Generation Rates Convenience Market with Gas Pumps 9<sup>th</sup> Edition ITE Trip Generation Manual

	Daily	PM Peak		
	Weekday Daily Rate	Percent of 2012 FDOT Study Daily Rate	PM Peak of Adjacent Street	Percent of 2012 FDOT Study PM Peak Rate
Trip Generation Rates using the Independent Variable 1,000 ft <sup>2</sup> Convenience Market gross floor area				
2012 FDOT Statewide Study	1,141.59	NA	85.66	NA
ITE 853 Convenience Market with Gas Pumps	845.60	74%	50.92	70%
Trip Generation Rates using the Independent Variable Fueling Positions				
2012 FDOT Statewide Study	233.70	NA	17.09	NA
ITE 853 Convenience Market with Gas Pumps	542.60	232%	19.07	112%

Generator peaks generally correspond to adjacent street peaks for the studied Convenience Market with Gas Pumps sites. However, there is also a moderate amount of trip-making between the AM and PM peaks that analysts should note for future traffic impacts. Pass-by rates were relatively consistent and matched ITE guidance for Florida sites at around 78%.

## Student Apartments

As there is no ITE land use category specifically for Student Apartments, analysts can expect Student Apartment rates to be higher than traditional apartment rates in ITE guidance by both dwelling units and occupied dwelling units. The primary concern for the apartments was selecting sites that offered leases by bedroom. Another major trend found in previous literature and suggested in this study was the impact of walking, cycling, and improved transit service options on trip generation rates. Both findings should be considered in estimating new Student Apartment trip generation, and more research is needed to determine the most appropriate variables and multimodal impacts. This research calculated average trip generation rates for several independent variables; therefore it is difficult to make strong conclusions without further research or analysis. The PM peak of the generator was found to be similar to the PM peak of the adjacent traffic, which would indicate this is the critical analysis period to assess traffic impacts. Student Apartments received 48-hour driveway counts only for 18 sites.

As a result of this study, traffic impacts on these land uses are better understood and therefore can be more accurately predicted in future developments.



# Convenience Markets with Gas Pumps

## Literature Review

In the fall of 2011, FDOT began to consider the changing trip generation impacts of Convenience Market with Gas Pumps type land uses. Analysts noted a shift in the industry toward larger convenience market size and more fueling positions, and wanted to ensure the best trip projection for new locations. In addition to more than 10 vehicle fueling positions and convenience stores of up to 5,000 ft<sup>2</sup>, these stores offer fresh made sandwiches, coffee, and other higher quality food options. Previous studies on these types of uses included: *Traffic Operational Impacts of Contemporary Multi-Pump Island Fueling Centers* (ITE Journal June 2011) and the related full report also titled *Traffic Operational Impacts of Contemporary Multi-Pump Island Fueling Centers* (January 2008), *Trip Generation Characteristics for Convenience Stores* (ITE Journal August 2001), and *Trip Generation of Convenience Stores with Gas Pumps* (Transportation Research Center UF February 1992). See Figure 1 and **Figure 2** for examples of this new type of land use.

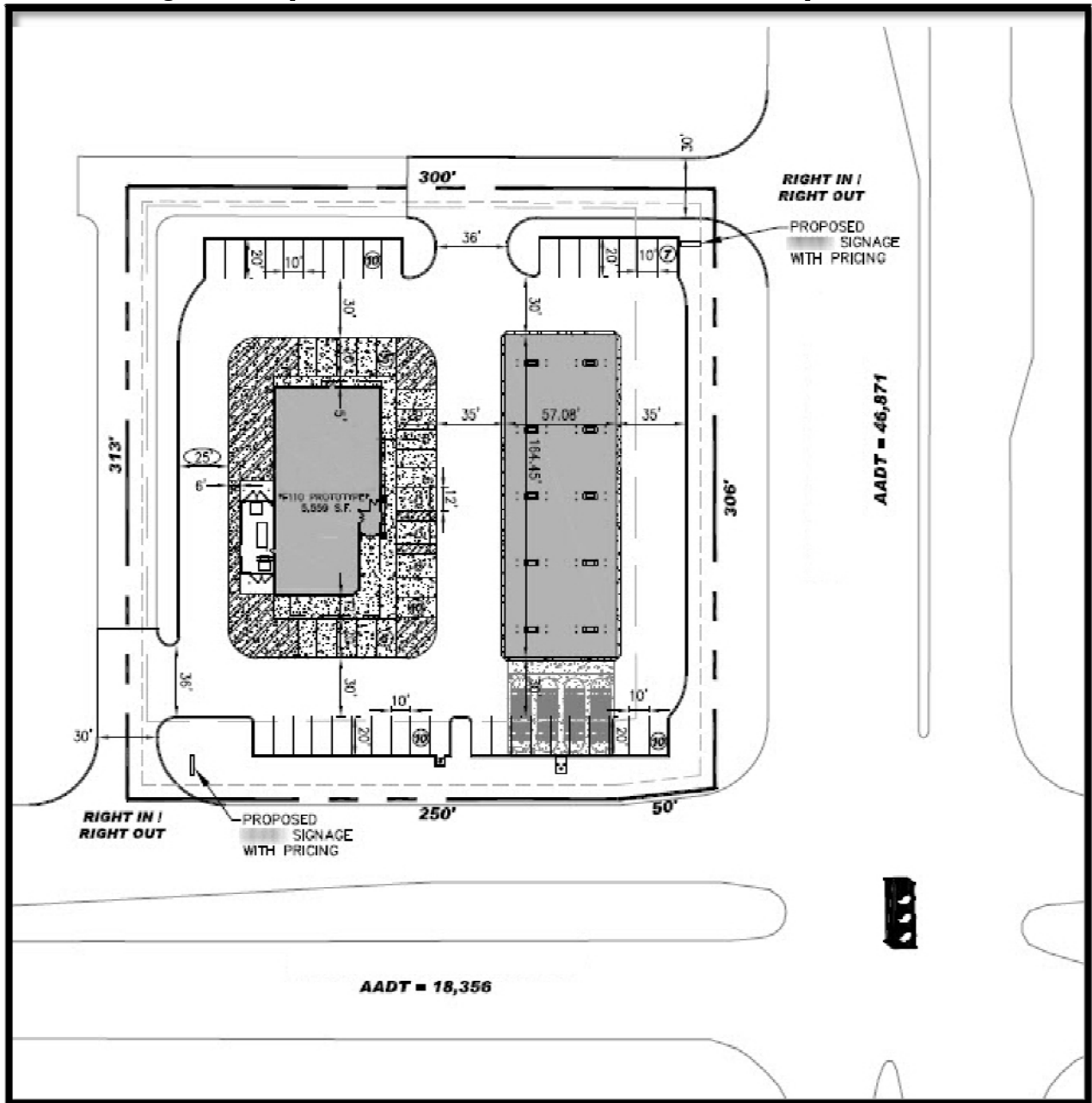
**Figure 1: Changing Nature of the Convenience Market with Gas Pumps Land Use**



The 1992 Trip Generation of Convenience Stores with Gas Pumps study was also prepared for FDOT, and was the first which considered the possibility of using multi-variable equations. All of the current equations in the ITE Trip Generation reports have only one independent variable, such as number of fueling positions *or* square footage. Their regression analysis suggested an equation using both gross floor area and gas pumps to find the number of trips during the PM peak. Their sites were slightly smaller, with convenience stores ranging from 700 – 3,600 sf<sup>2</sup>. However, the sites in their study did include up to 12 gas pumps (24 vehicle fueling positions), which is similar to the current study. Food offerings and other additional services were not considered in the research. Their model had an adjusted R<sup>2</sup> value of 0.904. This indicates a very high level of predictability.

$$\text{Site Trips during PM peak of the adjacent street} = 0.0382 * GFA + 16 * Pumps$$

**Figure 2: Proposed New Convenience Market with Gas Pumps Land Use**



In 2001, the ITE Journal published an article titled Trip Generation Characteristics for Convenience Stores that suggested the consideration of a new land use code due to different trip generation characteristics of modern stores. The authors began by noting the historical changes in the size of convenience stores and numbers of fueling positions. They claimed contemporary stores to be two or three times larger than traditional stores, as well as averaging about twice as many fueling positions. Their trip generation rates for ITE LU 853 Convenience Market with Gas Pumps were higher during the AM peak hour, significantly lower in the PM peak hour, and had higher pass-by rates than seen in *Trip Generation 6<sup>th</sup> Edition*. Their sites were located in the northeast, but otherwise had characteristics

similar to the 2012 FDOT study with an average of 15 fueling positions and 5,070 gross floor area.

The 2011 [ITE Journal article](#) and [2008 report Traffic Operational Impacts of Contemporary Multi-Pump Island Fueling Centers](#) agreed that new gas stations had different characteristics than traditional sites. However, instead of recommending new rates, they chose to focus on multi-variable regression analysis. They suggested that because modern facilities have so many more potential services to offer, traditional analyses can no longer estimate traffic impacts with only one variable. The ability to pay at the pump, availability of more fueling stations, car wash facilities, larger convenience markets, and fast food restaurants are some examples of relatively new services. They studied 30 sites with a variety of characteristics, including four they called “**hybrid**” which most closely resemble those FDOT chose to study in 2012. Due to a small sample size, their hybrid specific equation had a very low R<sup>2</sup> value. The researchers recommended equations that incorporate average daily traffic (ADT), characteristics (hybrid, yes or no), and presence of a drive through. The R<sup>2</sup> values for the AM and PM peak equations were 0.591 and 0.558 respectively. Their sites were all located in North Carolina.

$$\begin{aligned} \mathbf{AM\ Trips} &= (0.625 * \mathbf{ADT}) + (128 * \mathbf{Hybrid}) + (136 * \mathbf{Drive\ Through}) + 116 \\ \mathbf{PM\ Trips} &= (0.654 * \mathbf{ADT}) + (130 * \mathbf{Hybrid}) + (119 * \mathbf{Drive\ Through}) + 153 \end{aligned}$$

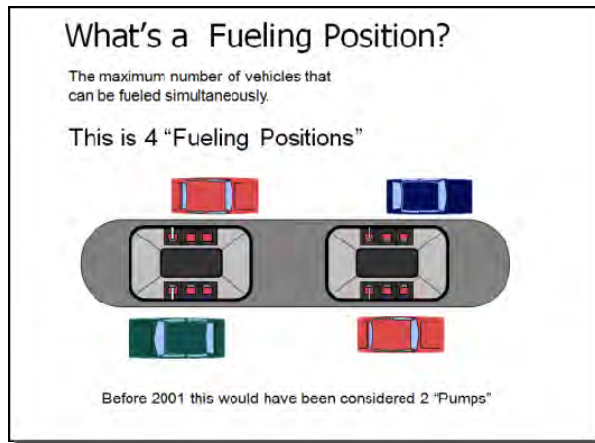
Note on definitions for independent variable terms:

Over the years studies of this type have created trip generation rates using a number of different variables. Specifically, the main variable in the 1992 study was gas pumps, and vehicle fueling positions were used in later referenced studies. Rates have been adjusted for proper comparison. Please below for definitions.

**Gross Floor Area-** The gross floor area of a building is the sum of the area at each floor level, including cellars, basements, mezzanines, penthouses, corridors, lobbies, stores and offices, that are included within the principal outside faces of exterior walls, not including architectural setbacks or projections (ITE Trip Generation Handbook, 2001).

**Gas Pump-** The sum of the vehicles that can simultaneously access gasoline, divided by two (Trip Generation of Convenience Stores with Gas Pumps, 1992). This variable was dropped by the ITE and redefined to Vehicle Fueling Position for more clarity.

**Vehicle Fueling Position-** The maximum number of vehicles that can be fueled simultaneously at a service station. For example, if a service station has two fuel dispensing pumps with three hoses and **grades of gasoline on each side of the pump, where only one vehicle can be fueled at a time on each side, the number of vehicle fueling positions would be four** (ITE Trip Generation Handbook, 2001).



Hybrid- Characteristics somewhere between a non-fast food and fast food site (Traffic Operational Impacts of Contemporary Multi-Pump Island Fueling Centers, 2011).

*Figure 3: Defining Sites- No Small Urban Stations*



*Figure 4: Defining Sites- No Truck Facilities*



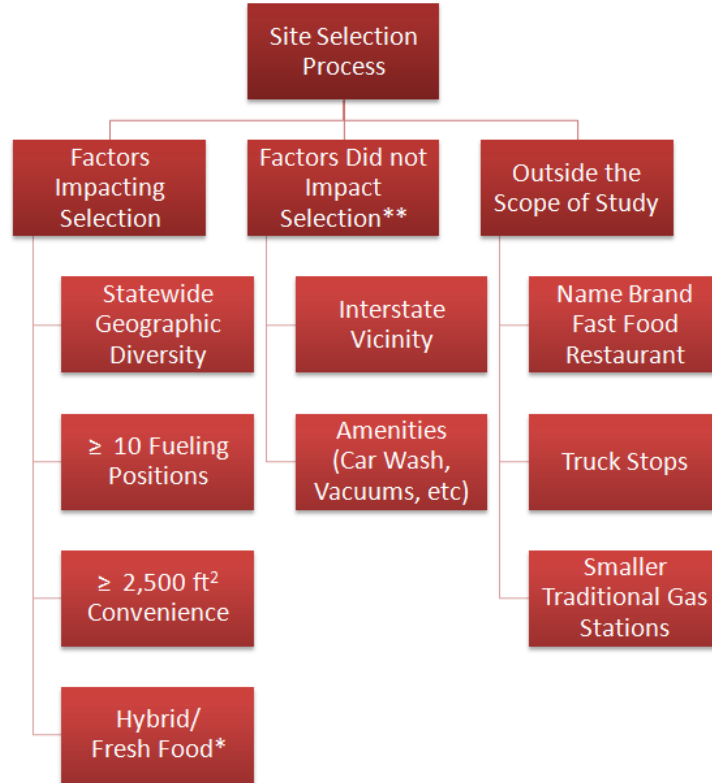
*Figure 5: Defining Sites- No Branded Food or Shopping*



## Methodology

The first step was selecting specific sites for study. This was an important process, as the hybrid type of gas station is not easily defined. Figure 3, Figure 4, and Figure 5 show stations which are not considered hybrids, and Figure 6 gives an overview of the process and characteristics that affected site selection.

**Figure 6: Convenience Market with Gas Pumps Site Selection**



\*Qualitative judgment of food options: more than prepackaged sandwiches, but less than a branded fast food restaurant.

\*\*These factors did not affect selection, but have been noted for further study

District FDOT staff provided recommendations where appropriate, as well as our partners with different gas brands in the state. When faced with a choice between two sites in the same region, we tried to mix brands. We wanted to reduce extraneous impacts on the counts, so any site with a competitor on the same block or across the street was abandoned. Most importantly, sites were chosen based on the lack of cut-through or other shared traffic confusion.

Once the sites were selected for study, background data was gathered for use in creating trip generation rates. ITE land uses 853 Convenience Market with Gas Pumps and 945 Service Station with Convenience Market are most similar, and use square footage and fueling positions. These sites were studied using aerial photography/street views and available property appraisal information.

Traffic data collection efforts included 48-hour driveway and adjacent street counts for 12 sites on consecutive weekdays between Tuesday and Thursday. Most were completed using traffic counting tubes, and some required video counting due to driveway configuration. As pass-by rates can become a key factor in calculating traffic impacts of gas station type uses, this data was gathered at the same time, using a combination of customer surveys and observation. Observation was done using technicians following vehicle movements, both to determine trip purpose and direction of travel. Individual customer surveys were performed from 4-6 PM, and non-survey observations from 4-7 PM. See Figures 7 and 8. See Figure 9 for a sample pass-by survey form.

**Figure 7: Observation Technicians on Site with Clipboards and Walkie Talkies**



**Figure 8: Example Aerial Image to Assist in Pass-By Observation**



*Figure 9: Sample Pass-By Survey*

**Pass-By Trip Interview**

Name and Number of Site \_\_\_\_\_  
Location of Surveyor \_\_\_\_\_  
Date of Survey \_\_\_\_\_  
Name of Surveyor \_\_\_\_\_

**Survey Instrument**

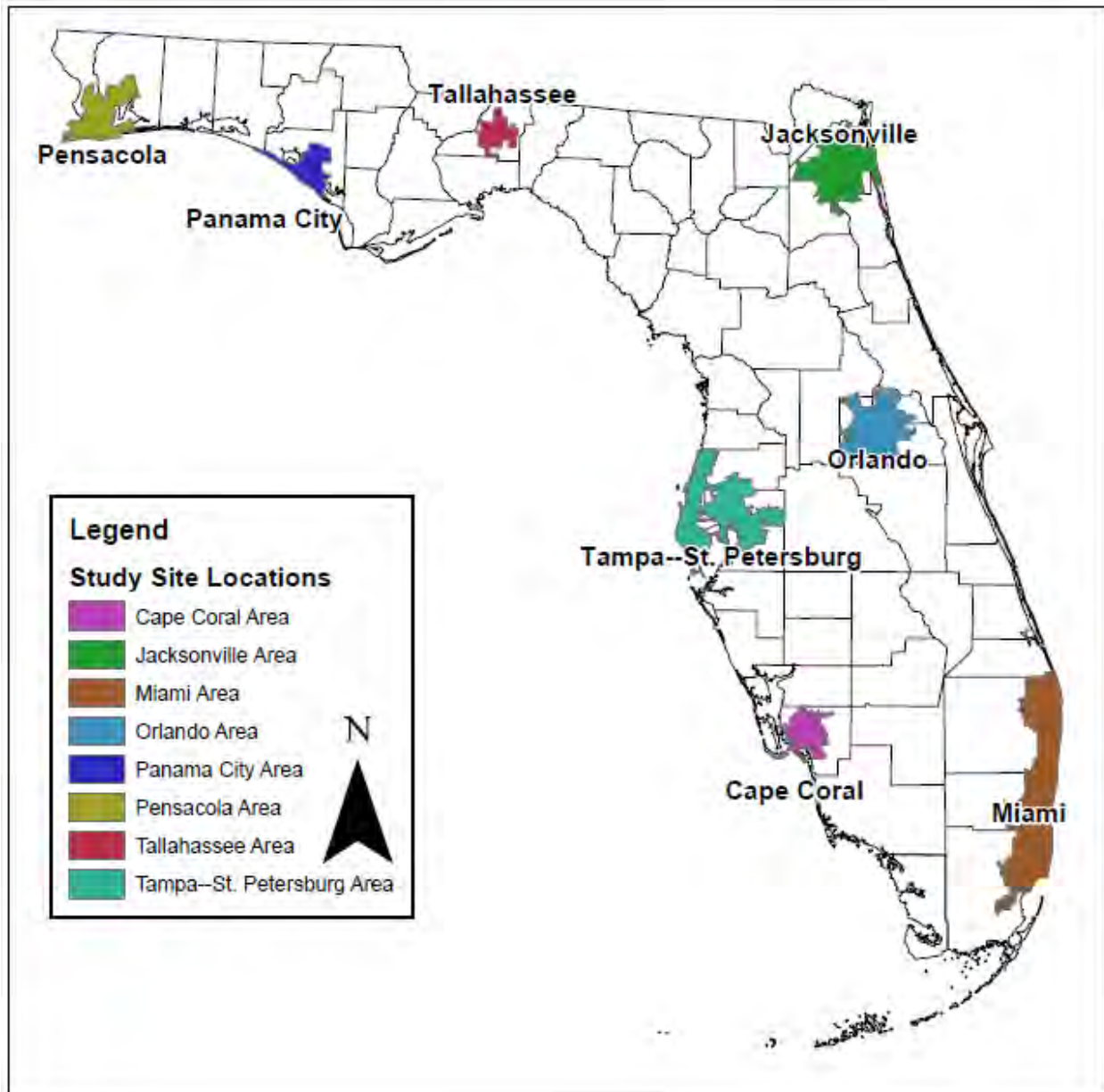
Time of Day	Q1: Where did your trip begin immediately prior to arriving at this site?	Q2: Will you go directly back to your origin from here?
	H. Home W. Work R. other Retail O. Other	Y. Yes N. No

## Geographic Distribution

Sites were selected statewide for this study. Because larger gas stations are seen more frequently in urban and suburban areas, all sites were located in metro areas. Figure 10 shows the geographic distribution of sites selected for this study.



Figure 10: Map of Study Sites



## Analysis and Findings

After compiling and quality checking the field data, the research team decided on two primary approaches to analyze the data. First, we determined typical ITE format average trip generation rates and regression equations based on a single variable. ITE uses trips per 1,000 ft<sup>2</sup> of convenience store for land use 853 Convenience Market with Gas Pumps, and trips per number of fueling positions for land use 945 Service Station with Convenience Market. Together these represented the most appropriate variables for our study sites. Secondly, we developed a series of multi-variable regression equations to investigate further possibilities.

Figure 11 shows average rate findings for Convenience Market with Gas Pumps, as well as values from ITE and our literature review for comparison. Square footage results show daily and PM peak rates higher than previous studies. This suggests that the larger stores and greater associated amenities are pulling in significantly more traffic than traditional stations. Trip generation rates per vehicle fueling position were also higher than most previous studies both daily and during the PM peak.

Figure 11 shows that when using convenience market size as the independent variable, the 2012 FDOT study has consistently higher trip generation rates. When comparing past studies using fueling positions the differences are not as consistent.

**Figure 11: Comparison of Convenience Market with Gas Pumps Trip Generation Rates**

	Weekday Daily	Percent of 2012 FDOT Study Daily Rate	PM Peak of Adjacent Street	Percent of 2012 FDOT Study PM Peak Rate	
1,000 ft <sup>2</sup> Convenience	2012 FDOT Statewide Study	1,141.59	100%	85.66	100%
	ITE 853 Convenience Market with gas Pumps	845.6	74%	59.69	70%
	2011 ITE Journal			60.50	71%
	2001 ITE Journal			48.03	56%
	1992 UF Study			56.40	66%
Fueling Positions	2012 FDOT Statewide Study	233.70	100%	17.09	100%
	ITE 945 Convenience Market with gas Pumps	162.78	70%	13.38	78%
	2011 ITE Journal			23.23	136%
	2001 ITE Journal			16.58	97%
	1992 UF Study			9.45	55%

**Figure 12: Scatter Chart for 1000 Sq. Feet Gross Floor Area  
During the PM Peak of Adjacent Street**

**Convenience with Gas**

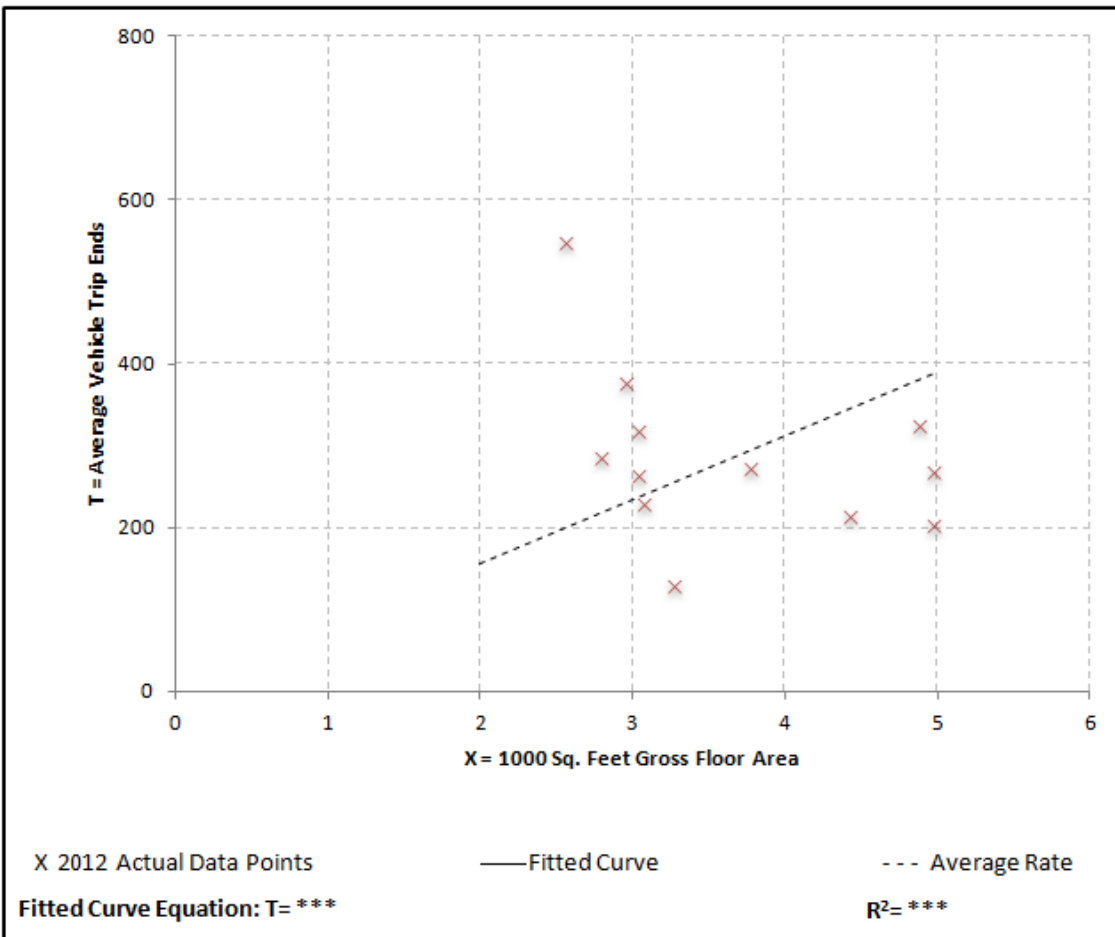
**Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area**  
**On a: Weekday, Peak Hour of Adjacent Street Traffic, One Hour Between 4 and 6 p.m.**

Number of Studies: 12  
 Average 1000 Sq. Feet GFA: 3.5

**Trip Generation per 1000 Sq. Feet Gross Floor Area**

Average Rate	Range of Rates	Standard Deviation
85.66	39.12- 213.17	48.49

**Data Plot and Equation**



**Figure 13: Scatter Chart for Fueling Positions  
During the PM Peak of Adjacent Street**

**Convenience with Gas**

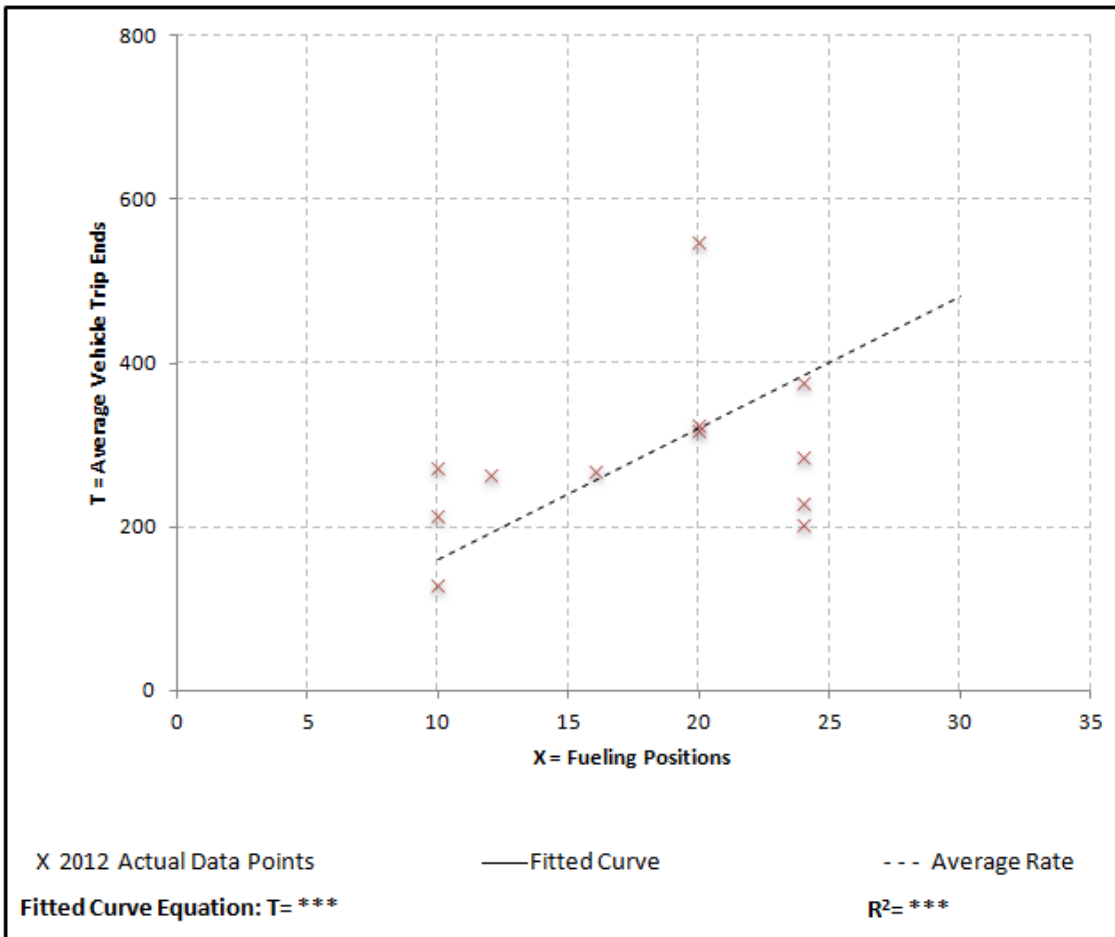
**Average Vehicle Trip Ends vs: Fueling Positions**  
**On a: Weekday, Peak Hour of Adjacent Street Traffic, One Hour Between 4 and 6 p.m.**

Number of Studies: 12  
 Average Fueling Positions: 18

**Trip Generation per Fueling Position**

Average Rate	Range of Rates	Standard Deviation
17.09	8.48- 27.35	6.25

**Data Plot and Equation**

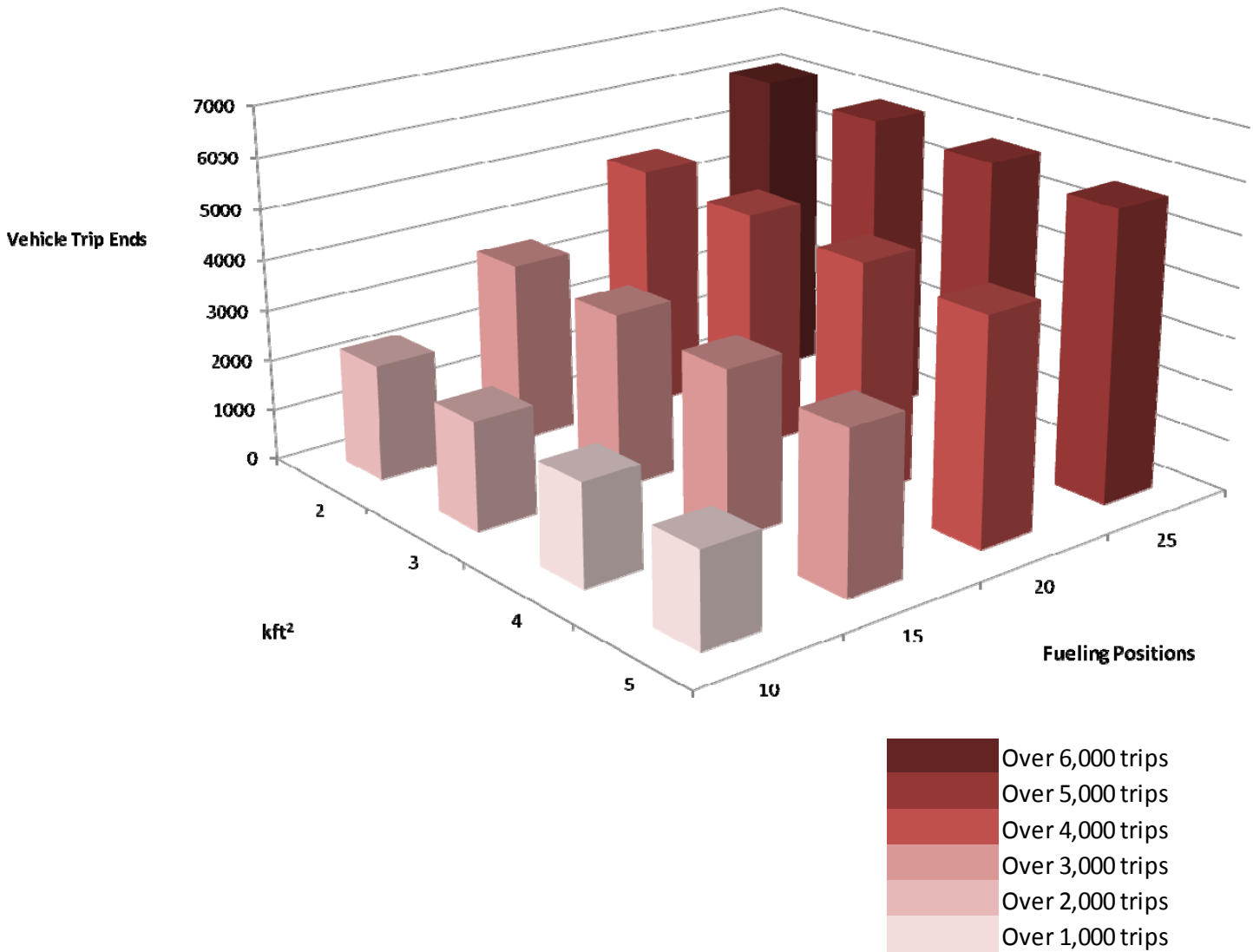


**Figure 14: Sample Values Matrix of Recommended Equation For Daily Trips**

		Fueling Positions			
		10	15	20	25
Convenience	2	2,280	3,560	4,850	6,130
	3	2,130	3,420	4,700	5,980
	4	1,990	3,270	4,560	5,840
	5	1,840	3,130	4,410	5,700

$$\text{Trips (rounded)} = 256.7 * \text{FP} - 144.5 * \text{kft}^2$$

**Figure 15: Visualization of Recommended Equation For Daily Trips**

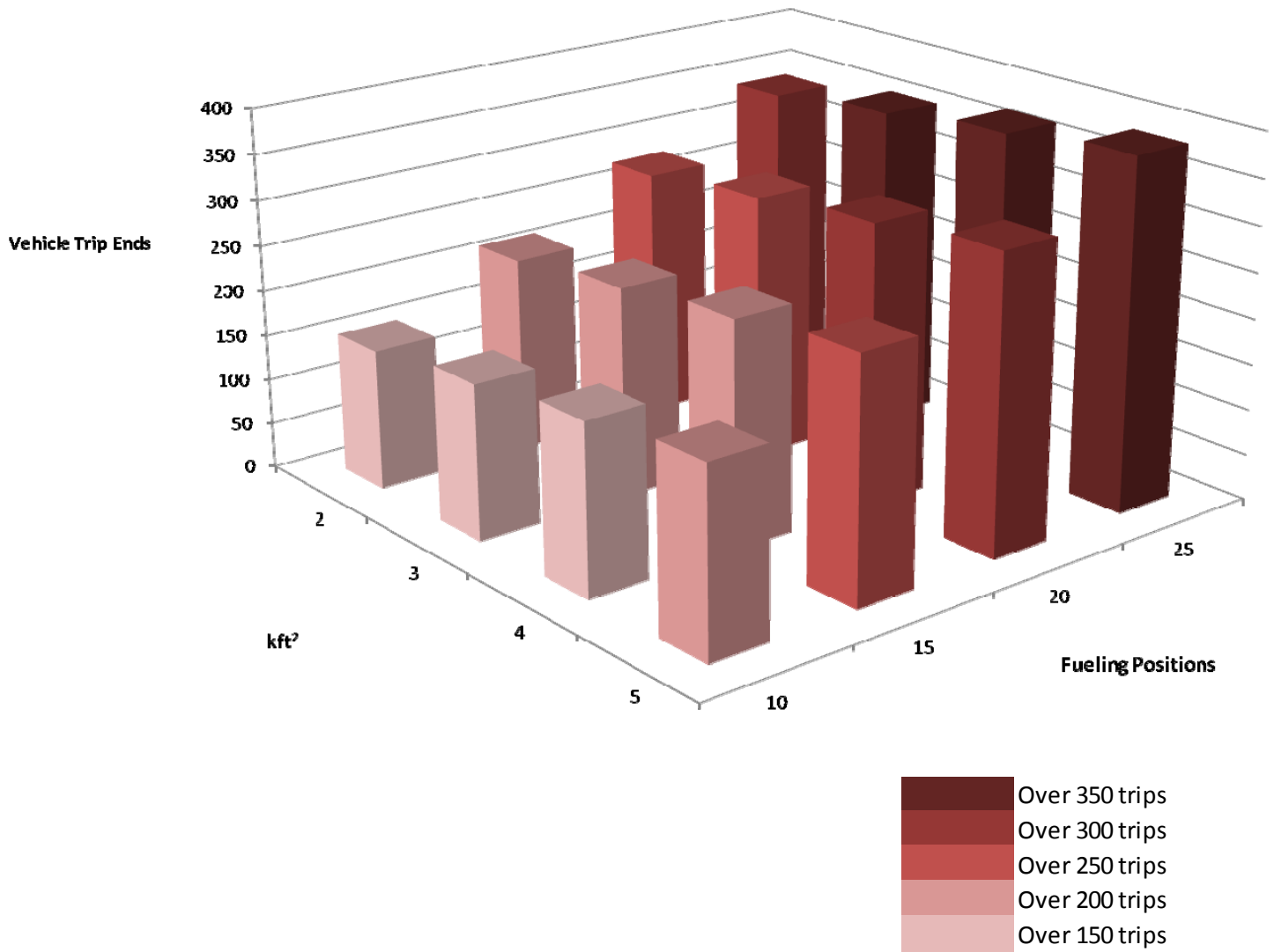


**Figure 16: Sample Values Matrix of Recommended Equation For PM Peak Hour Trips**

		Fueling Positions			
		10	15	20	25
1,000 ft <sup>2</sup> Convenience	2	150	220	280	340
	3	170	230	290	350
	4	190	250	310	370
	5	200	260	320	390

Trips (rounded) =  $12.3 * FP + 15.5 * kft^2$

**Figure 17: Visualization of Recommended Equation For PM Peak Hour Trips**



In order to explore more possibilities with the data, we also examined the relationship between daily trips and PM peak hour trip rates. The  $R^2$  value was higher than any of the other regression equations. Consequently analysts may want to consider using Equations H or h to verify the daily and PM peak generation rates or when only one is known. Though these relationships are important, because we can use these relationships when we only have daily or hourly traffic; these are, by definition not truly independent variables. Daily and hourly tripmaking are highly dependent on each other, and so they are not independent variables.

Please see the Appendix for all scatter charts depicting the relationships between counts and each independent variable. These also include average rates and appropriate regression equations.

**Figure 18: Percentage of Daily Trips per Hour for Convenience Market with Gas Pumps**

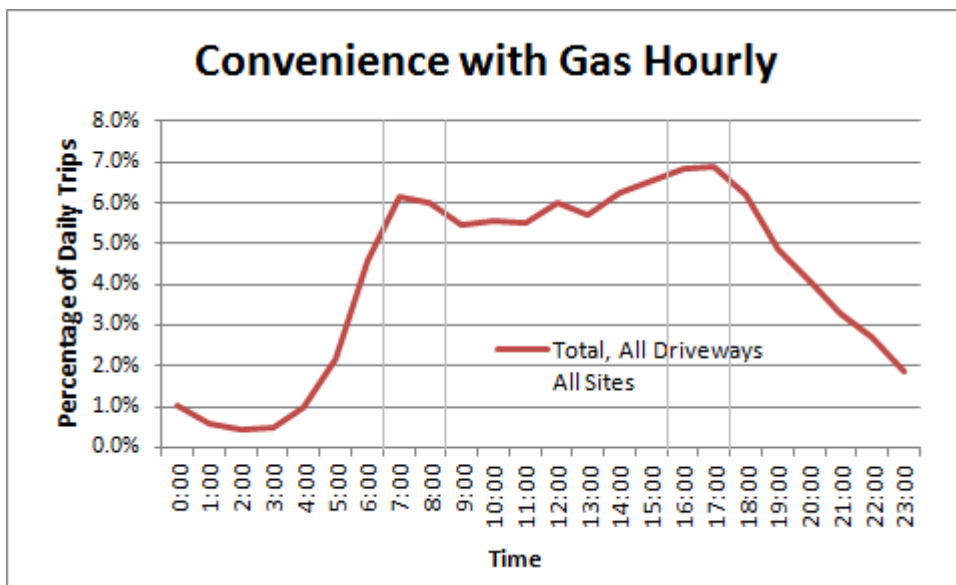


Figure 18 above shows the hourly breakdown of traffic counts. From this we gain some insight on the generator peaks in relation to the peaks of the adjacent street traffic. While the AM and PM peaks do coincide with the peaks of the adjacent street, there are other trends to note. Instead of the drastic peaks one might assume due to people getting gas on the way to or from work, the traffic does not drop off drastically between the AM and PM peaks. There is also a small noon peak.

## Pass-By Trips

Figure 19 shows pass-by rates for all Convenience Market with Gas Pump sites in the 2012 FDOT Statewide Study. The first four sites were performed by observation of all vehicles and customers over a three hour period, which is why there are more total interviews than those with surveys conducted between 4:00 and 6:00 PM. Sites from Jacksonville to Homestead were completed by surveying selected customers, as described in the methodology section. Pass-by information was collected for each site over two consecutive days, and totaled to provide a two-day average pass-by rate.

The range of pass-by trip rates was 65-84 percent with an average of 78 percent. This is significantly higher than the average of 66 percent found in the ITE Handbook for the Convenience Market with Gas Pumps land use. However, the average of only Florida sites from 2001 ITE Trip Generation Handbook is 76 percent, and our results were quite similar. The consistency of this data suggests that future developments could reasonably assume about a 77 percent pass-by rate for sites of this type. See Figure 20 for details.

**Figure 19: Pass-By Rates for Convenience Market with Gas Pumps**

Site Location (FL)	1,000 ft <sup>2</sup>	Total Number of Interviews*	Percent Pass-By Trips
Pensacola	4	699	84%
Pensacola	3	709	65%
Panama City Beach	4	448	71%
Tallahassee	5	694	82%
Jacksonville	3	133	83%
Apopka	3	231	77%
Clearwater	3	216	74%
Tampa	3	166	75%
Cape Coral	5	133	83%
Fort Myers	5	182	79%
Fort Lauderdale	3	236	81%
Homestead	3	216	79%
Average	4	339	78%

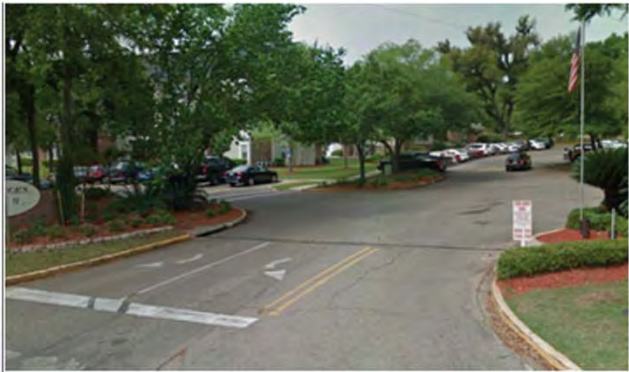
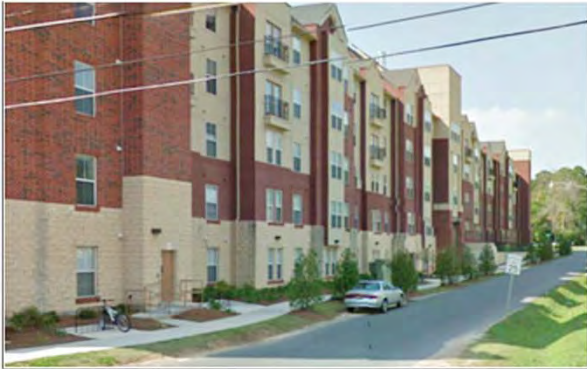
\*Combination of customer surveys and observation

**Figure 20: Comparison of Pass-By Rates**

		Number of Sites	Percent Pass-By Trips
ITE LU 853	2012 FDOT Statewide Study	12	78%
	2001 ITE Handbook	15	66%
	2001 ITE Handbook (FL only)	6	76%



# STUDENT APARTMENTS



## Background/Introduction

The purpose of this project was to determine the best Florida-specific trip generation factors for emerging land uses where current trip making information was insufficient. In consultation with FDOT District Site Impact Coordinators it was determined that current Florida trip making data for Student Apartments was needed more than other uses. These uses had little available data or rough estimates, and the latest development trends suggested these types of sites would be seeing substantial growth. Staff at the Florida Department of Transportation (FDOT) is responsible for determining access requirements and impacts of these developments. Therefore, FDOT set out to identify the latest trip generation information on these burgeoning land uses.

## Literature Review

In addition to gas stations, we researched what we are calling student apartments. Recent years have brought about changes in housing choices, with more specialization to focus specifically on college student needs. Leasing by the bedroom allows students the financial benefits of shared housing, without the risk of trusting strangers to help pay the bills. Figure 21 and Figure 22 are examples of this new type of apartment. Buildings are often clustered around a variety of college-oriented amenities such as computer labs and pools. Floor plans are often set up with 2-4 individual bedroom and bathroom pairs with a shared living and kitchen area.

Past literature has suggested that counts by bedroom have higher trip generation rates than current ITE guidance. The unique characteristics of student housing also may warrant further study. These characteristics include: higher number of individual drivers per apartment due to independent lives and varying school schedules, and proximity to campus that may encourage more targeted pedestrian, bike, and transit use than other apartment types. Relevant literature we found on the subject consist of

Draft Trip Generation Study – Private Student Housing Apartments (Spack Consulting Draft Report April 2012),  
Trip Generation Rates for Off-Campus Student Apartments (City of Auburn 2010),  
Traffic Impact Analysis for Welsh Hill Commons (Lenhart Traffic Consulting, Inc, 2008) and  
Traffic Impact Analysis for Baltimore Ave (Lenhart Traffic Consulting, Inc, 2008)

The Traffic Impact Analysis study performed for Welsh Hill Commons development in Maryland was part of an expansion effort. Traffic counts were completed on the existing three buildings in order to help predict the impacts of adding another two buildings. We used this study strictly for comparison of rates. Likewise, the Traffic Impact Analysis done for the Baltimore Avenue development was also an expansion project. However the characteristics varied considerably, as this site was located directly across a pedestrian bridge from the University of Maryland, and also had excellent transit connections. Therefore the trip generation rates were very different. We used this study for comparison purposes.

**Figure 21: Changing Nature of Apartment Living**

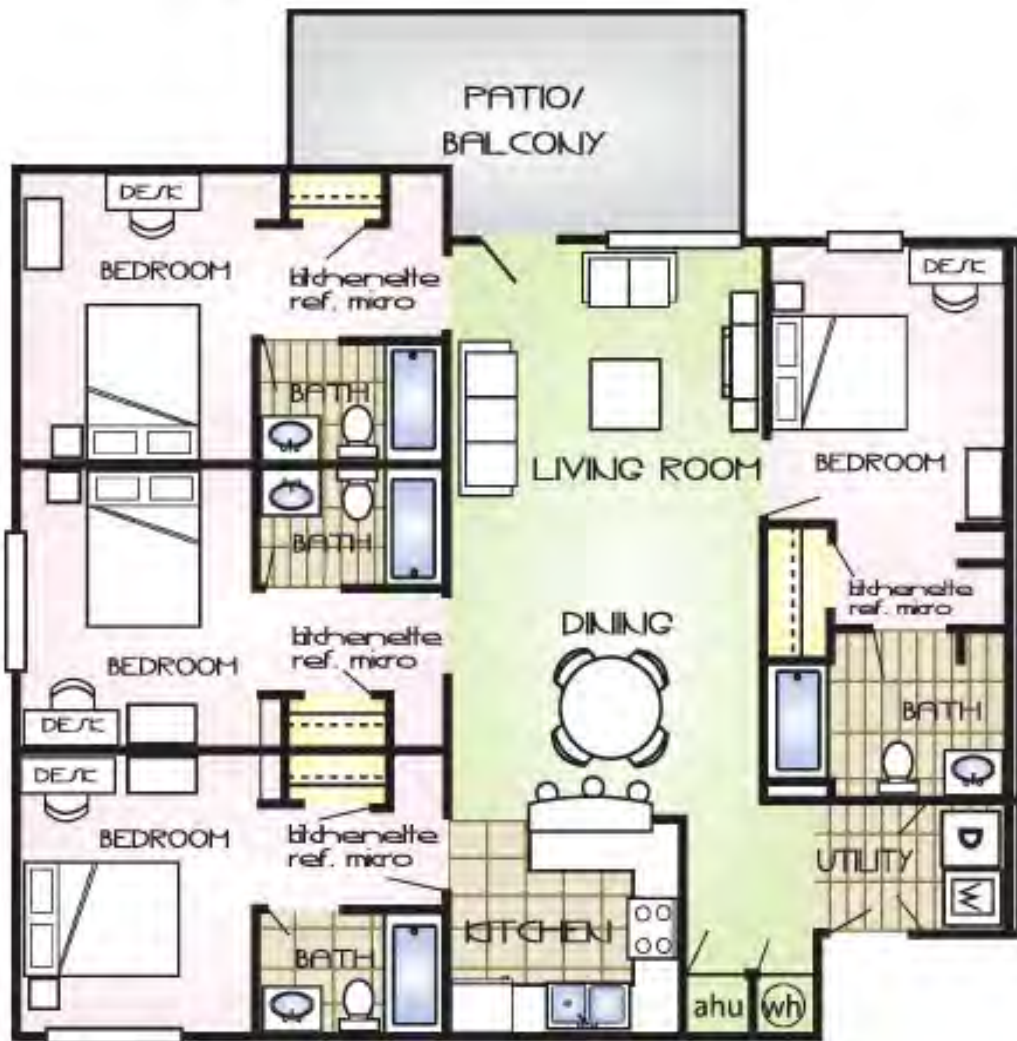


The City of Auburn, Alabama specifically addresses trip generation rates for off-campus student apartments in the Traffic Impact Studies section of their Public Works Design and Construction Manual. The manual sets minimum requirements for designing and constructing streets, alleys, sidewalks, bicycle facilities, drainage facilities, erosion and sediment control and traffic management facilities. This manual recommends conducting a local trip generation study for unique land uses not addressed in the latest version of *Trip Generation*. However, a professor at Auburn University conducted several studies to determine trip generation rates for off-campus student apartments in the city, and therefore these rates are included and accepted in lieu of individual studies. Their results were quite similar to ITE rates per person for locations near transit, and naturally higher lacking transit.

The 2012 technical memorandum by Spack Consulting summarizes their study analyzing six student apartment uses near the University of Minnesota. Preliminary findings by dwelling unit found much lower levels of traffic than ITE guidance; the student housing apartments generated about a third of the trips of a generic apartment building. The authors used dwelling units, parking stalls provided, and bedrooms for independent variables. The equations for dwelling units and parking stalls had high accuracy, with  $R^2$  values over 0.75. Their results for trip generation by number of bedrooms were less statistically valid, with lower  $R^2$  values.

The variation in these studies confirmed FDOT's decision to do more research on student apartment uses. The higher number of independent adults on different schedules could encourage more driving, however off-campus student housing is often near enough to campus to provide a variety of good alternative transportation options. We anticipated trip generation could be higher than ITE guidance, but may hinge on a number of factors. This research also aimed to determine which variables are more accurate predictors of student apartment trip generation. Further study of the data collected may also yield more insight into multimodal and location factor adjustments to the average rates determined by this study.

**Figure 22: Example Student Apartment Floor Plan**



## Methodology

Student Apartments required much data collection before the determination of suitability could be made. Sites were chosen based on the lack of cut-through or other shared traffic concerns. After creating a list of potential sites that fit the location requirements, we contacted each potential site to determine if it fit the rest of the criteria. If the site did offer leases by the bedroom, the next step was gathering information on the student-oriented amenities.

Data was easily found on the number of apartments, the percentage of occupied units, and the number of renters, but finding the number of parking spaces and number of total bedrooms was more difficult. There is less concrete information on these last two variables, therefore they were mostly estimates. Traffic data collection efforts included 48-hour, 2-way driveway counts for 18 sites.

Figure 23 and Figure 24 show common apartment types which are not considered student apartments.

Figure 25 gives an overview of the process and characteristics involved in the site selection process.

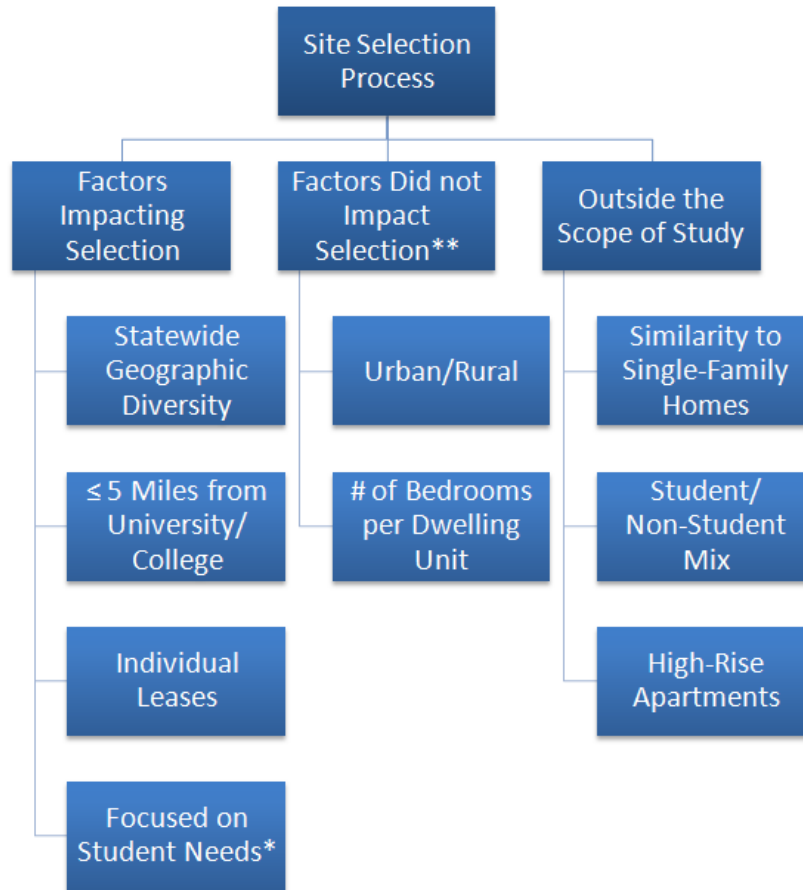
***Figure 23: Defining Sites- No Urban Apartments with Many Non-Student Tenants***



***Figure 24: Defining Sites- No Similarity to Single Family Homes***



**Figure 25: Student Apartment Site Selection**



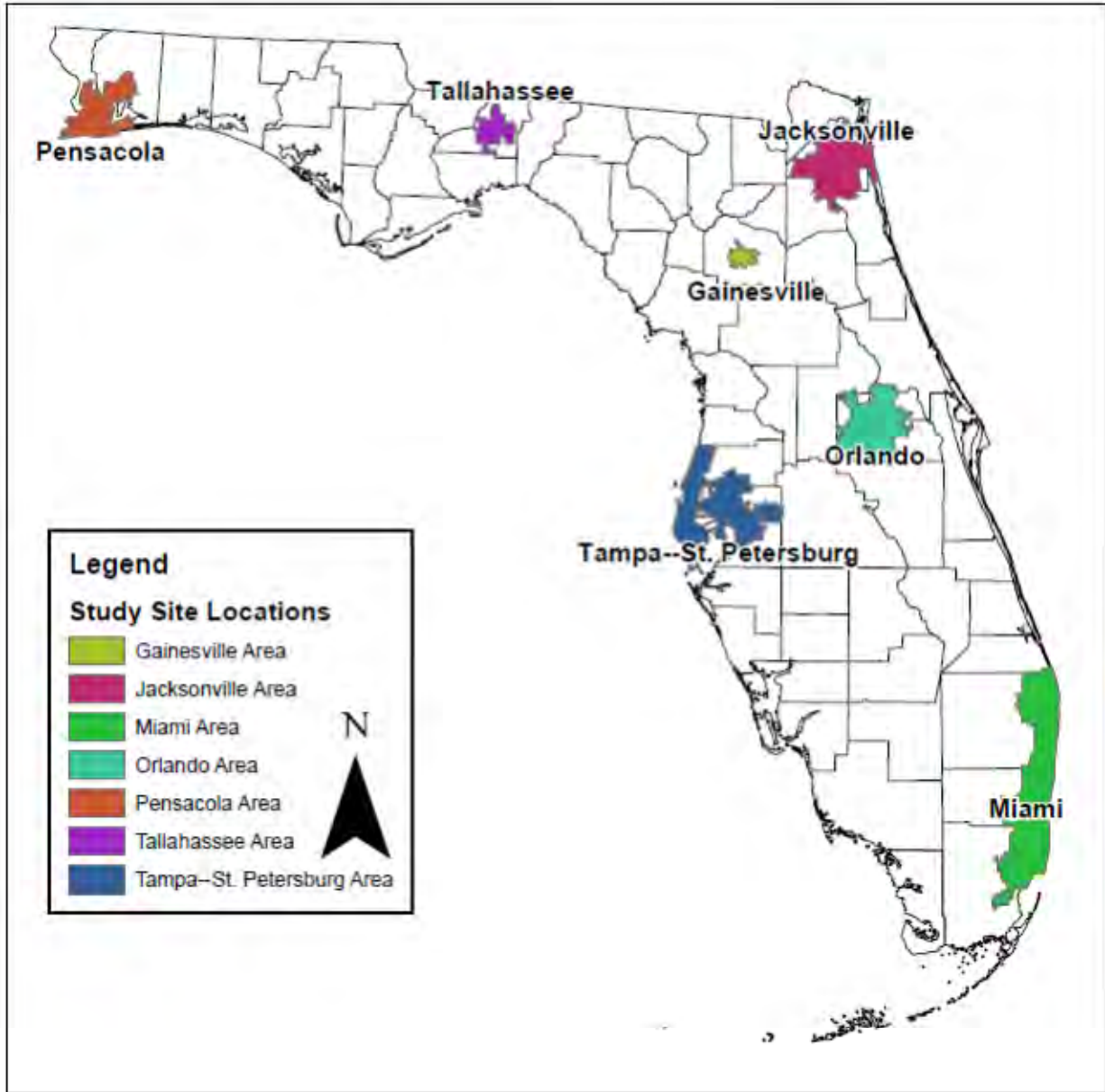
\*Qualitative judgment of amenities, such as computer labs or roommate matching programs.

\*\*These factors did not affect selection, but have been noted for further study

## Geographic Distribution

A good mix of sites statewide was achieved for Student Apartment land uses. Most of the universities and colleges with a large enough student population to warrant specialized off-campus housing were also in urban areas. Figure 26 shows the geographic dispersion of sites selected for study.

Figure 26: Map of Study Sites



## Analysis and Findings

The research team calculated average trip generation rates and regression equations for multiple independent variables. ITE uses a combination of dwelling units, occupied dwelling units, persons, and vehicles. These variables are associated with ITE land uses 220 Apartment, 221 Low-Rise Apartment, or 223 Mid-Rise Apartment. In addition we chose to collect information on the number of bedrooms where possible, as other studies have used this as a predictor of trip generation.



Figure 27 shows average rate findings for Student Apartments, as well as values from ITE and the literature review for comparison. The 2012 FDOT study daily rates by dwelling unit are twice as much as ITE guidance for Land Use 220 Apartment. 2012 FDOT PM peak rates are also much higher than previous studies for ITE LU 220 Apartments and ITE LU 223 Mid-Rise Apartments. The range in the PM peak rates by dwelling unit suggests other factors may play a part. Comparisons between the 2012 FDOT study and previous studies by occupied dwelling unit follow a similar pattern.

2012 FDOT daily and PM peak rates are around twice as much as previous studies. This appears logical, as Student Apartments may have more bedrooms and more drivers than typical apartments with one family per unit. Our trip generation rates per person is very close to the per person rate found in the ITE 8<sup>th</sup> Edition Trip Generation for land use 220 Apartments.

The variation in the rates for the number of bedrooms suggest the variable may require more data points before any assumptions can be drawn. Also evident is the significant impact pedestrian and transit facilities can have on trip generation rates. The comparison of rates from both the 2008 Baltimore Avenue and 2007 Auburn studies show that trip generation can be much less than average when there are true multimodal travel options available. Daily rates by vehicle for the 2012 FDOT study were similar to ITE LU 220 Apartment, but PM peak rates were lower. This may be because student travel patterns are more spread out throughout the day due to differing class schedules and other activities or to the relative uncertainty associated with these values.

**Figure 27: Comparison of Student Apartment Trip Generation Rates**

	Weekday Daily	Percent of 2012 FDOT Study Daily Rate	PM Peak of Adjacent Street	Percent of 2012 FDOT Study PM Peak Rate	
Dwelling Units (Dus)	2012 FDOT Statewide Study	12.57	100%	1.00	100%
	ITE LU 220 Apartment	6.65	53%	0.62	62%
	ITE LU 223 Mid-Rise Apartment			0.39	39%
	2008 TIA Welsh Hill Commons			0.83	83%
	2008 TIA 8204 Baltimore Avenue (near transit and ped. Facilities)			0.35	35%
Occupied Dwelling Units	2012 FDOT Statewide Study	13.06	100%	1.04	100%
	ITE LU 221 Low-Rise Apartment	6.59	50%	0.58	56%
Persons (Renters)	2012 FDOT Statewide Study*	4.11	100%	0.32	100%
	ITE LU 221 Low-Rise Apartment	3.31	80%	0.40	123%
	2007 Auburn Study (near transit)			0.40	123%
	2007 Auburn Study (no transit)			0.49	151%
Bedrooms	2012 FDOT Statewide Study**	3.98	100%	0.31	100%
	2008 TIA Welsh Hill Commons			0.52	166%
	2008 TIA 8204 Baltimore Avenue (near transit and ped. Facilities)			0.12	38%
Vehicles	2012 FDOT Statewide Study***	4.47	100%	0.35	100%
	ITE LU 220 Apartment	5.10	114%	0.60	172%

\* Based on values from 17 of 18 sites

\*\* Based on best estimates from 16 of 18 sites

\*\*\* Based on best estimates from 15 of 18 sites

Figure 29 shows the equation with the highest R<sup>2</sup> of 0.8086. Please see the Appendix for all scatter charts depicting the relationships between counts and each independent variable, including average rates and appropriate regression equations.

**Figure 28: Scatter Chart for Persons During the PM Peak of Adjacent Street**

## Student Apartments

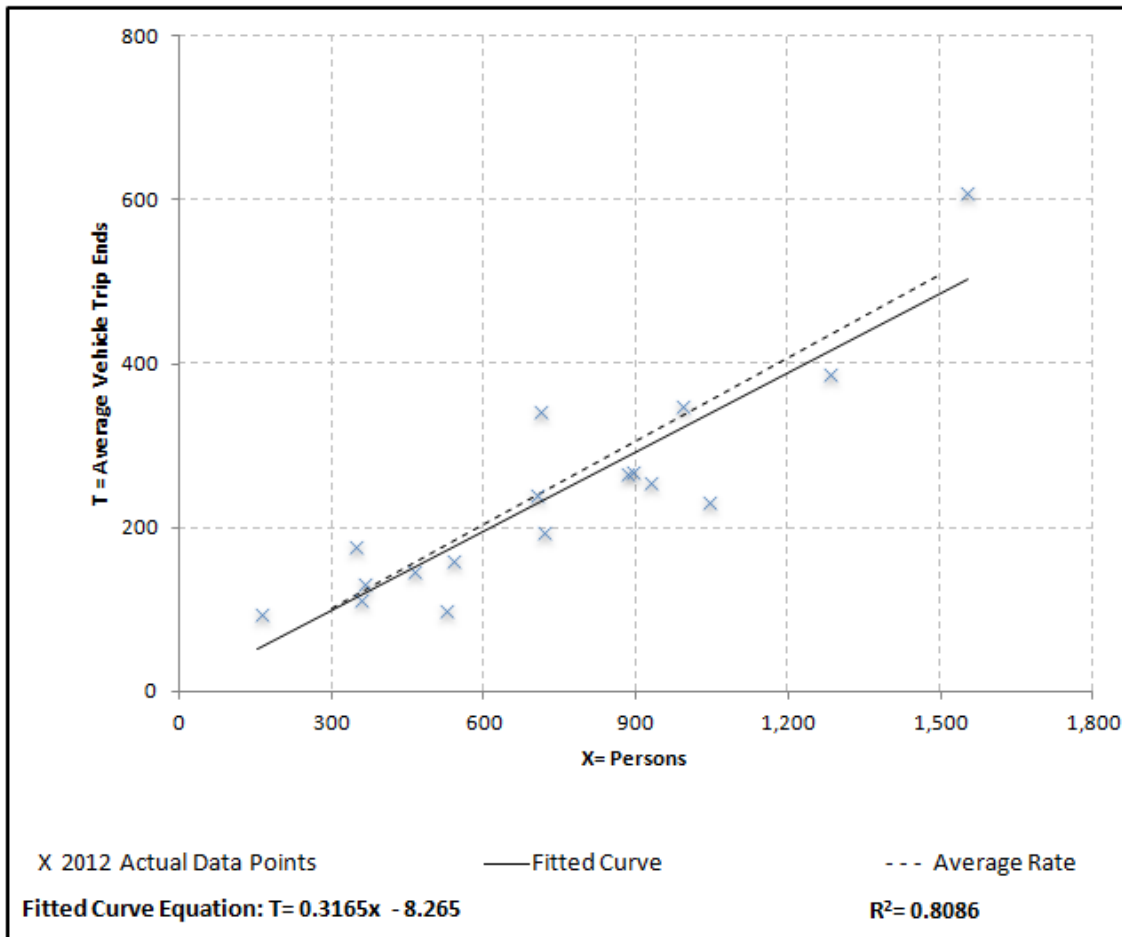
**Average Vehicle Trip Ends vs: Persons**  
**On a: Weekday, Peak Hour of Adjacent Street Traffic, One Hour Between 4 and 6 p.m.**

Number of Studies: 17  
 Average Persons: 718

**Trip Generation per Person**

Average Rate	Range of Rates	Standard Deviation
0.32	0.18 - 0.57	0.10

**Data Plot and Equation**



**Figure 29: Percentage of Daily Trips per Hour for Student Apartments**

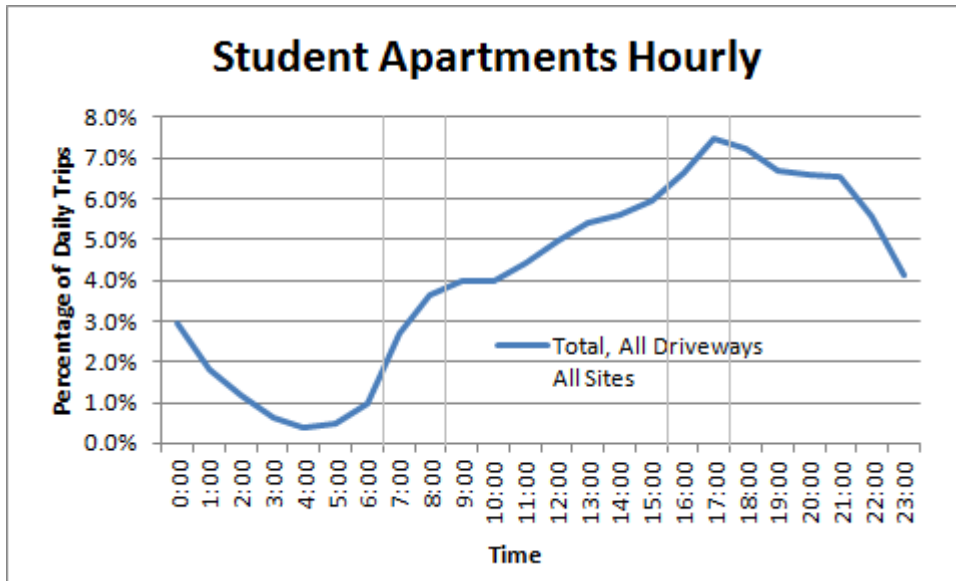


Figure 29 above shows the hourly breakdown of traffic counts for the 2012 FDOT study Student Apartment sites. From this we gain some insight on the generator peaks in relation to the peaks of the adjacent street traffic. The PM peak of the generator is the same as the adjacent street, however there are far more trips taken midday and late evening than during the AM peak of the generator. This appears logical, as varying student schedules and often a propensity toward attending more afternoon classes would create the slow climb of traffic during the day. As most do not yet have families, the high traffic until about 9:00 PM is also expected. With students typically having an active late night social life it is reasonable to expect more traffic during the 12:00-2:00 AM timeframe than many other land uses. Therefore future developments can reasonably expect traffic impacts during adjacent street PM peak hours, and perhaps early afternoon and late evening.

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## Appendices

In addition to average trip generation rate analyses, the 2012 FDOT study looked at a number of regression equations for the Convenience with Gas land use. Previous studies and ITE guidance had indicated that both the number of fueling positions and the base square footage of the convenience area significantly influenced the amount of site traffic. In order to explore additional trip generation options, the research team tested regression equations with both variables as well as each individually. As the correlation between the variables was found to be -0.15, it appears the variables are not measuring the same impacts. The team also tested the relationship between daily trips and PM peak hour trips, and compared all 2012 FDOT study equations with existing ITE guidance. illustrates the different equations we explored.

Equations A-H (daily trips) and a-h (peak hour trips) represent the different trip generation rates and regression equations tested for trip generation estimation accuracy. Equations A and B use our field collected average trip generation rate and ITE's average rate based on square footage. Although the  $R^2$  value is not shown for the ITE rate, this study's equation  $R^2$  value was not high enough to justify using it over the ITE square footage equation. Equations C and D are similar but use the number of pumps. The method using field collected data has an  $R^2$  value of only 0.40; however the ITE rate is based on older site surveys and many sites in the northeast region. Therefore analysts may want to consider our rate to replace the ITE rate per number of fueling positions.

As noted above, both base square footage and number of fueling positions were found to be significant predictors of trip generation. Equations E, F, and G are multivariate regression equations that combine both of these variables. Equations E and G have low  $R^2$  values, but Equation F had a very high level of accuracy with a  $R^2$  value of 0.92. Analysts may want to consider using this equation. There may be a concern with a negative coefficient preceding base square footage. It may not appear logical that in equations E and F the trip generation rate would go up as the base square footage decreases. However, our field collected data confirms that controlling for vehicle fueling positions, the ones with the largest convenience markets have lower daily trip generation rates. This phenomenon was also observed in a previous study (Traffic Operational Impacts of Contemporary Multi-Pump Island Fueling Centers, by Cunningham et al., January 2008). It is also possible that many of these sites serve more of a gas function than a convenience store function based on where they are located. Another possible cause is that most of them are the same brand with similar merchandise and fuel pricing characteristics. See Figure 15 for a visualization of Equation F including impacts of the negative coefficient.

Equations a-h are similar to Equations A -H except that the dependent variable is the number of PM peak hour trips rather than daily trips. Overall the results for the PM peak hour equations are consistent with corresponding equations for daily trips. For example, the results are similar between Equations a and b and Equations A and B. ITE rates do not show an equation for base square footage, and the  $R^2$  value of this study's equation is too low to justify its use. Equations c and d compare equations for

number of fueling positions. Similarly, the results are not accurate enough for analysts for further consideration. The multivariate equations in Equations e and g do not have high accuracy with  $R^2$  values of 0.23 and 0.24, but Equation f shows great potential. With an  $R^2$  value of 0.88, we feel it is accurate enough to be considered. Equation f does not have any negative coefficient concerns.

Scatter diagrams for Convenience With Gas land use equations A-D and a-d as illustrated in **Error! Reference source not found.** are included below. These are followed by the scatter diagram for pass-by studies and Student Apartment land uses.

Equation	Source	Equation form	Regression Equation	R <sup>2</sup>	Comments	Conclusions
A	FDOT	Daily trips= average rate*kft <sup>2</sup>	1141.6*kft <sup>2</sup>	0.24	Not accurate enough to warrant	Not recommended
B	ITE	Daily trips= average rate*kft <sup>2</sup>	845.6*kft <sup>2</sup>	-	Not very accurate	Keep unchanged
C	FDOT	Daily trips= average rate*fp	233.4*fp	0.43	Not very accurate, but more recent	<b>Recommended to replace ITE rate</b>
D	ITE	Daily trips= average rate*fp	162.8*fp	-	Not very accurate	Outdated
E	FDOT	Daily rates= a*fp+b*kft <sup>2</sup> +c	178.0*fp-772.8*kft <sup>2</sup> +3814.5	0.58	Negative coefficient for bsf and R2<0.75	Not recommended
F	FDOT	Daily rates= a*fp+b*kft <sup>2</sup>	256.7*fp-144.5*kft <sup>2</sup>	0.92	Negative coefficient for bsf but R2>0.75	<b>Recommended*</b>
G	FDOT	Daily rates= c*(a^fp)*(b^kft <sup>2</sup> )	2652.4*(1.05^fp)*(0.86^kft <sup>2</sup> )	0.54	Fractional coefficient for bsf and R2<0.75	Not recommended
H	FDOT	Daily rates= a*PM trips	14.3*PM trips	0.93	Good accuracy R2>0.75	<b>Recommended</b>
a	FDOT	PM Peak trips= a average rate*kft <sup>2</sup>	85.7*kft <sup>2</sup>	0.15	Not accurate enough to warrant	Not recommended
b	ITE	PM Peak trips= average rate*kft <sup>2</sup>	59.7*kft <sup>2</sup>	-	Not very accurate	Keep unchanged
c	FDOT	PM Peak trips= a average rate*fp	17.1*fp	0.13	Not accurate enough to warrant	Not recommended
d	ITE	PM Peak trips= average rate*fp	13.4*fp	-	Not very accurate	Keep unchanged
e	FDOT	PM Peak rates= a*fp+b*kft <sup>2</sup> +c	5.56*fp-38.24*kft <sup>2</sup> +326.20	0.24	Negative coefficient for bsf and R2<0.75	Not recommended
f	FDOT	PM Peak rates= a*fp+b*kft <sup>2</sup>	12.3*fp+15.5*kft <sup>2</sup>	0.88	Good accuracy R2>0.75	<b>Recommended</b>
g	FDOT	PM Peak rates= c*(a^fp)*(b^kft <sup>2</sup> )	255.1*(1.02^fp)*(0.91^kft <sup>2</sup> )	0.23	Fractional coefficient for bsf and R2<0.75	Not recommended
h	FDOT	PM Peak rates= daily trips/a	Daily trips/14.3	0.93	Good accuracy R2>0.75	<b>Recommended</b>

fp = fueling positions

kft<sup>2</sup> = 1,000 square feet gross floor area

a = coefficient for fp

b = coefficient for kft<sup>2</sup>

c = constant

\*Use is recommended even with a negative coefficient

Note: See appendices for scatter charts associated with these Equations



# FDOT 2012 Study- Gas Equation A

## Convenience with Gas

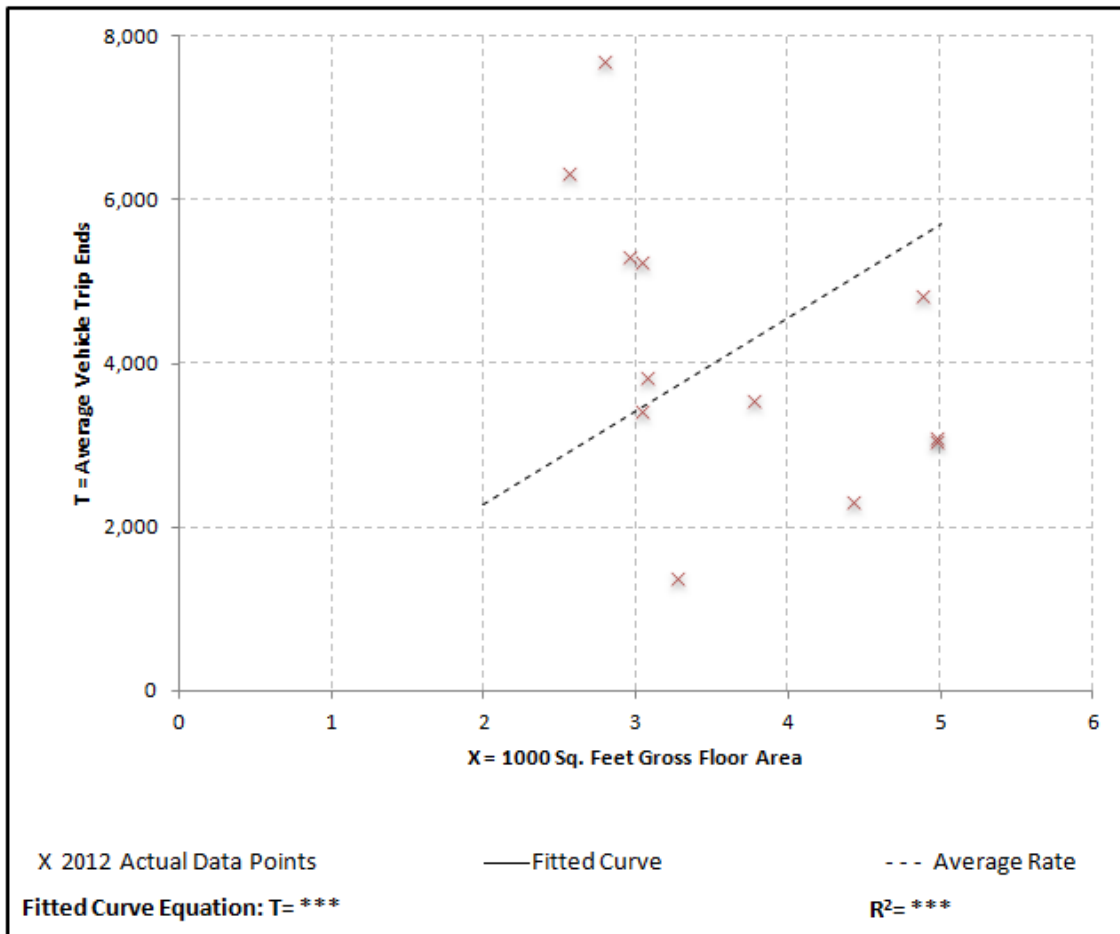
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area  
 On a: Weekday

Number of Studies: 12  
 Average 1000 Sq. Feet GFA: 3.5

### Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
1141.59	419.93- 2747.50	765.24

### Data Plot and Equation



# FDOT 2012 Study- Gas Equation a

## Convenience with Gas

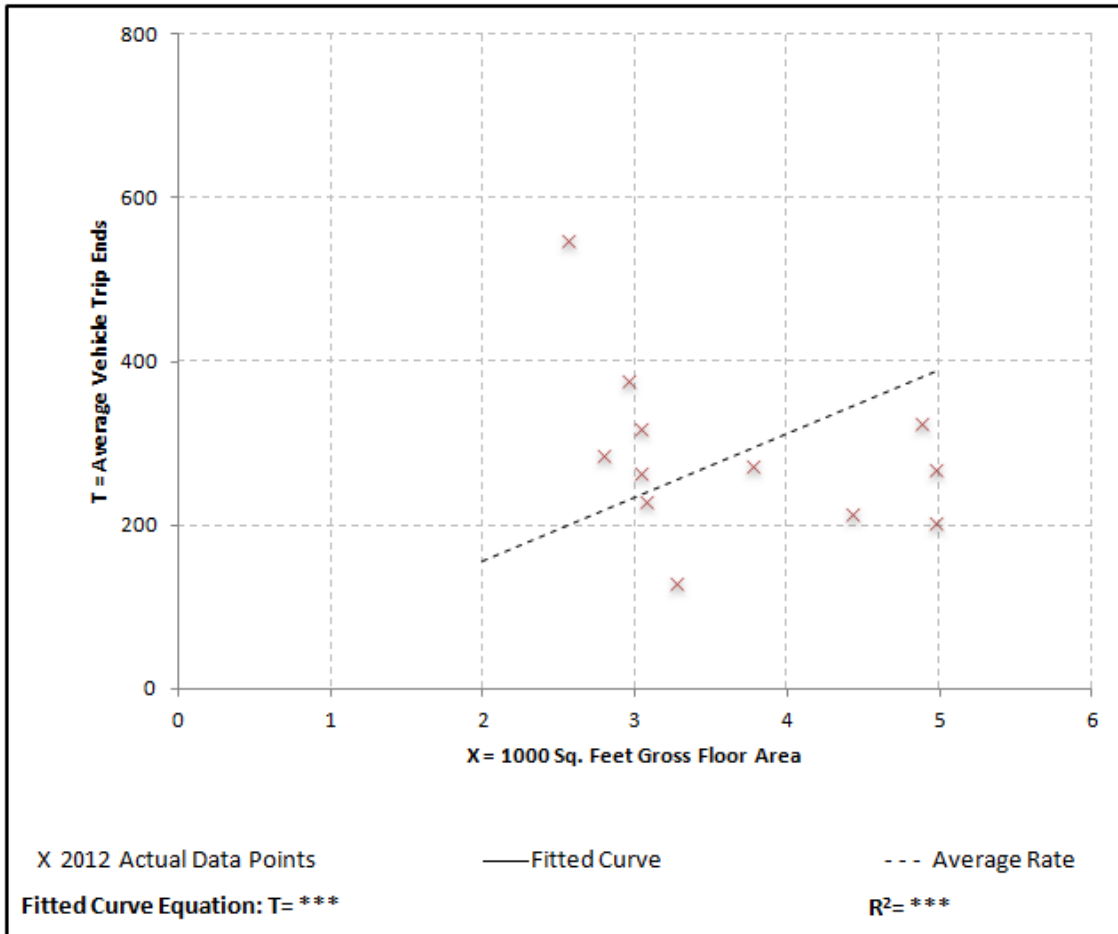
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area  
 On a: Weekday,  
 Peak Hour of Adjacent Street Traffic,  
 One Hour Between 4 and 6 p.m.

Number of Studies: 12  
 Average 1000 Sq. Feet GFA: 3.5

### Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
85.66	39.12- 213.17	48.49

### Data Plot and Equation



# ITE- Gas Equation B

## Convenience Market with Gasoline Pumps (853)

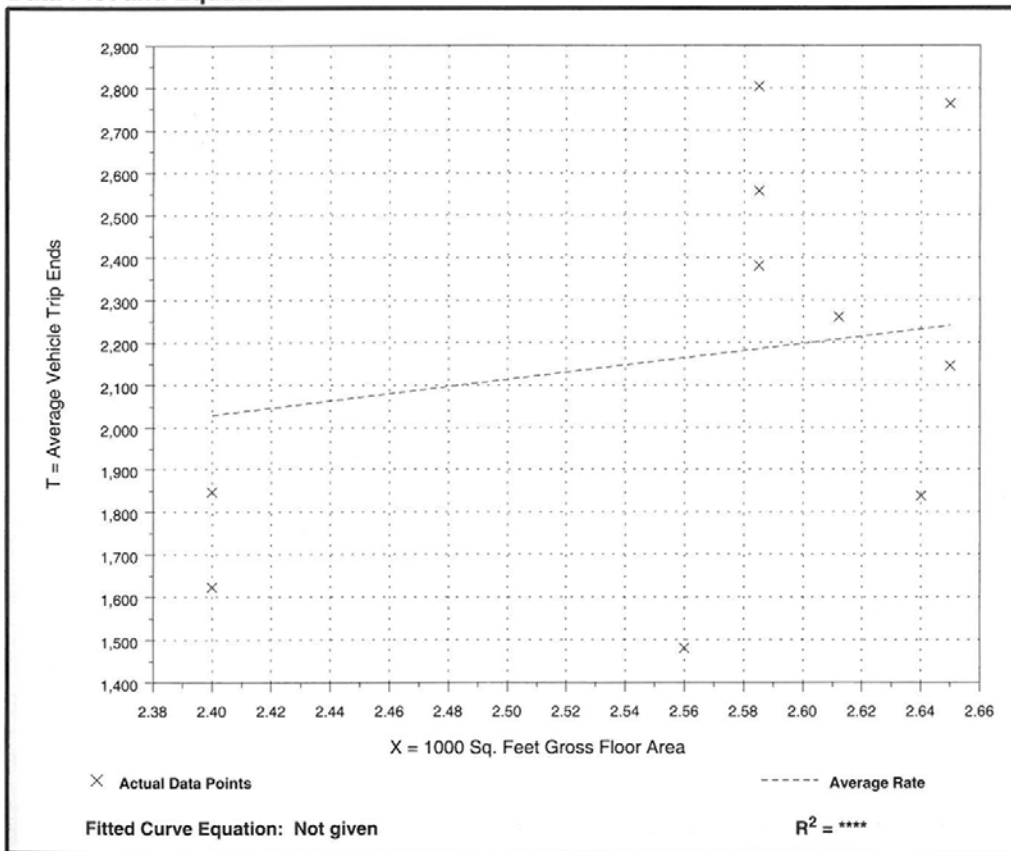
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area  
On a: Weekday

Number of Studies: 10  
Average 1000 Sq. Feet GFA: 3  
Directional Distribution: 50% entering, 50% exiting

### Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
845.60	578.52 - 1084.72	163.67

### Data Plot and Equation



# ITE- Gas Equation b

## Convenience Market with Gasoline Pumps (853)

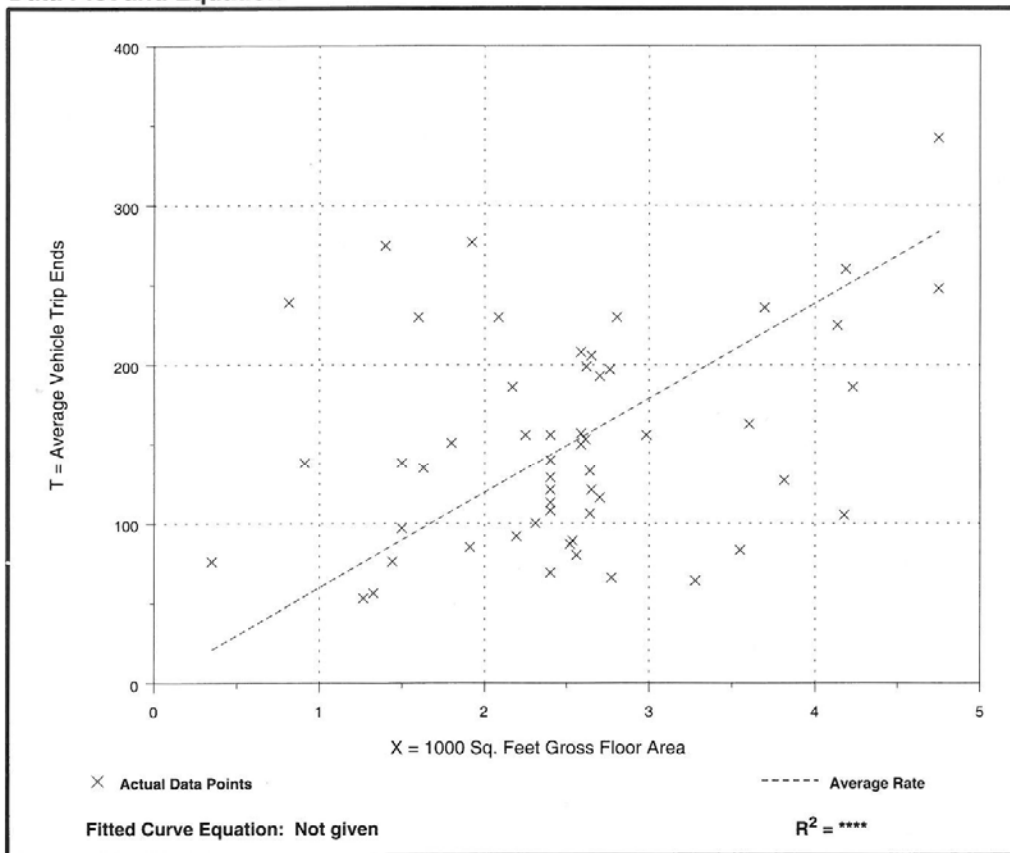
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area  
 On a: Weekday,  
 Peak Hour of Adjacent Street Traffic,  
 One Hour Between 4 and 6 p.m.

Number of Studies: 55  
 Average 1000 Sq. Feet GFA: 3  
 Directional Distribution: 50% entering, 50% exiting

### Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
59.69	19.54 - 292.89	35.05

### Data Plot and Equation



# FDOT 2012 Study- Gas Equation C

## Convenience with Gas

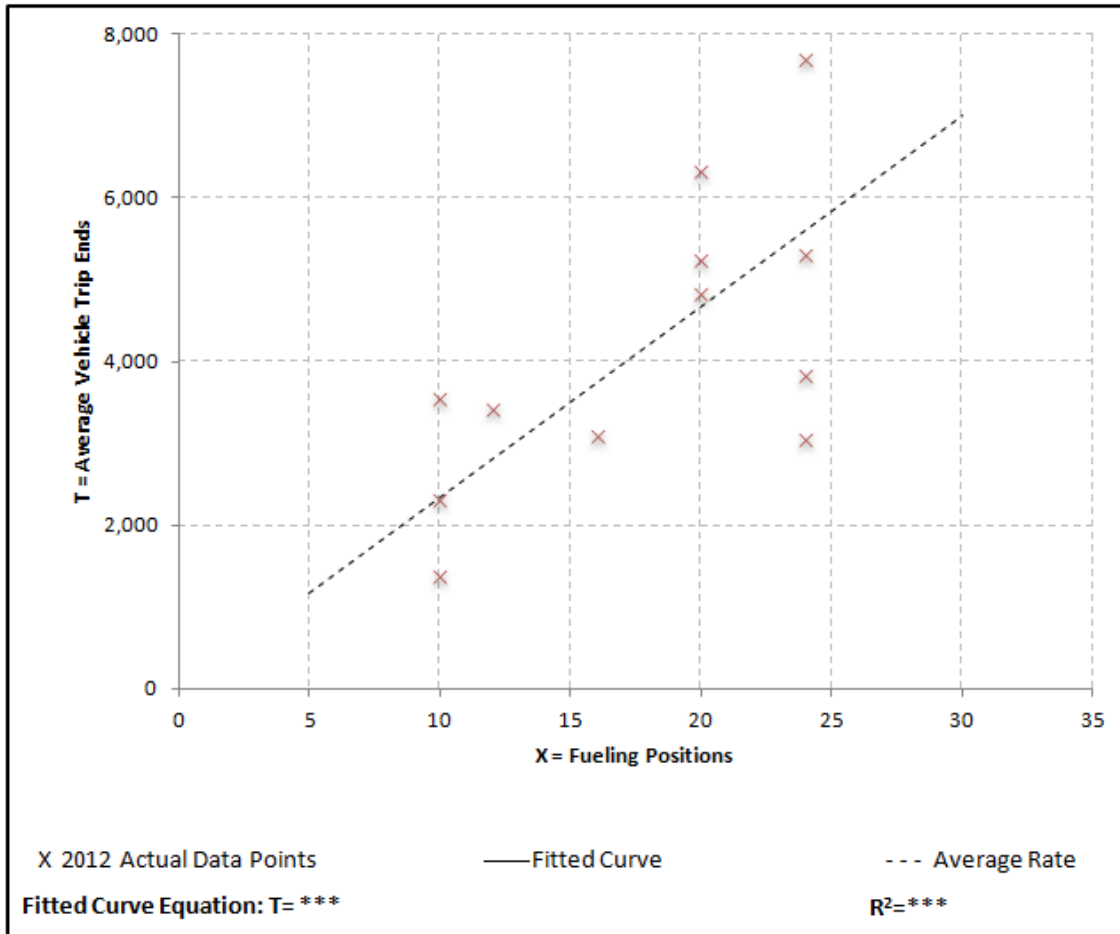
Average Vehicle Trip Ends vs: Fueling Positions  
 On a: Weekday

Number of Studies: 12  
 Average Fueling Positions: 18

### Trip Generation per Fueling Position

Average Rate	Range of Rates	Standard Deviation
233.70	126.75- 355.55	74.24

### Data Plot and Equation



# FDOT 2012 Study- Gas Equation c

## Convenience with Gas

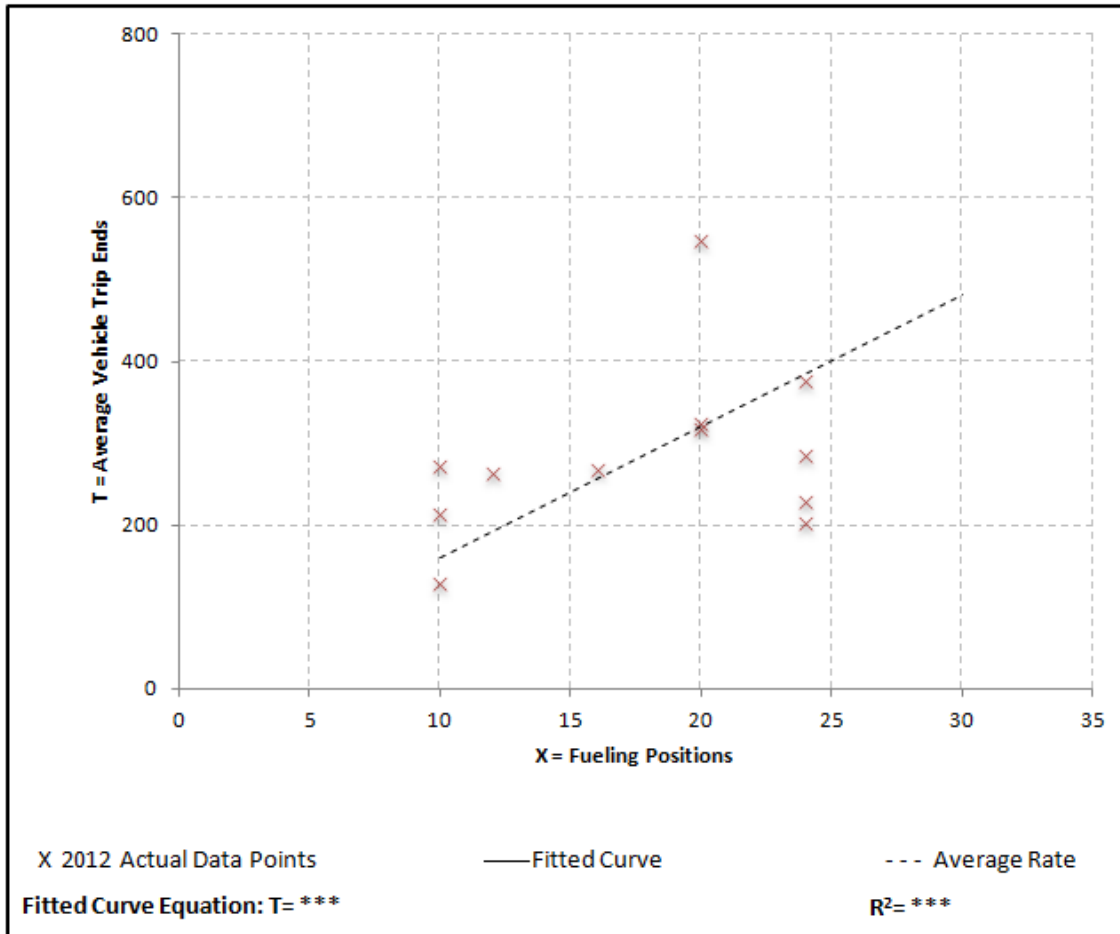
Average Vehicle Trip Ends vs: Fueling Positions  
 On a: Weekday,  
 Peak Hour of Adjacent Street Traffic,  
 One Hour Between 4 and 6 p.m.

Number of Studies: 12  
 Average Fueling Positions: 18

### Trip Generation per Fueling Position

Average Rate	Range of Rates	Standard Deviation
17.09	8.48- 27.35	6.25

### Data Plot and Equation



# ITE- Gas Equation D

## Gasoline/Service Station with Convenience Market (945)

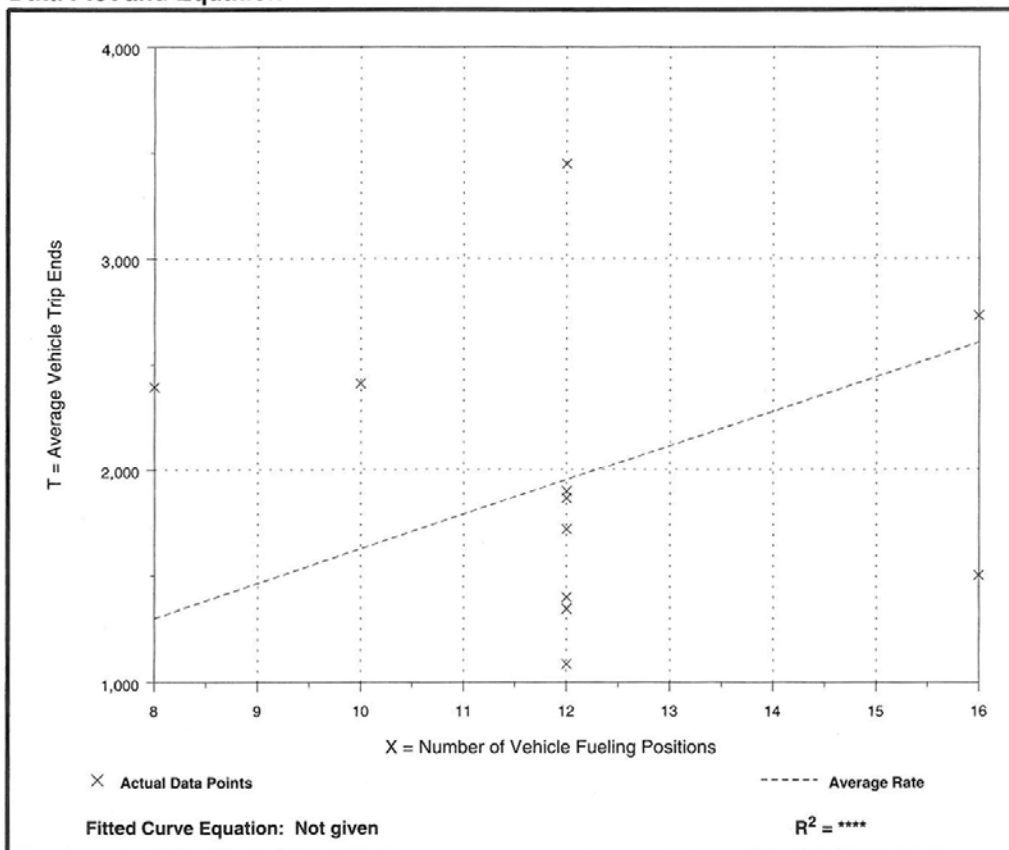
Average Vehicle Trip Ends vs: Vehicle Fueling Positions  
On a: Weekday

Number of Studies: 11  
Average Vehicle Fueling Positions: 12  
Directional Distribution: 50% entering, 50% exiting

### Trip Generation per Vehicle Fueling Position

Average Rate	Range of Rates	Standard Deviation
162.78	90.67 - 299.50	68.16

### Data Plot and Equation



# ITE- Gas Equation d

## Gasoline/Service Station with Convenience Market (945)

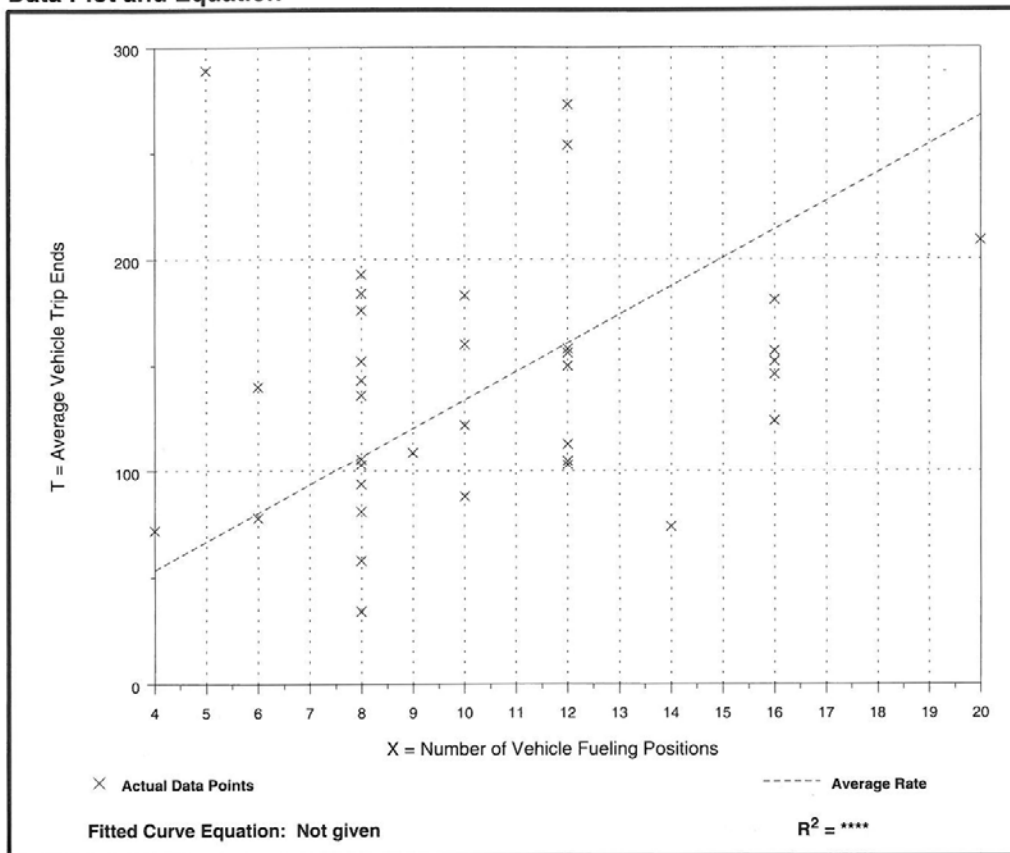
Average Vehicle Trip Ends vs: **Vehicle Fueling Positions**  
 On a: **Weekday,**  
**Peak Hour of Adjacent Street Traffic,**  
**One Hour Between 4 and 6 p.m.**

Number of Studies: 38  
 Average Vehicle Fueling Positions: 10  
 Directional Distribution: 50% entering, 50% exiting

### Trip Generation per Vehicle Fueling Position

Average Rate	Range of Rates	Standard Deviation
13.38	4.25 - 57.80	7.91

### Data Plot and Equation





# FDOT 2012 Study- Gas Pass-Bys

## Convenience with Gas

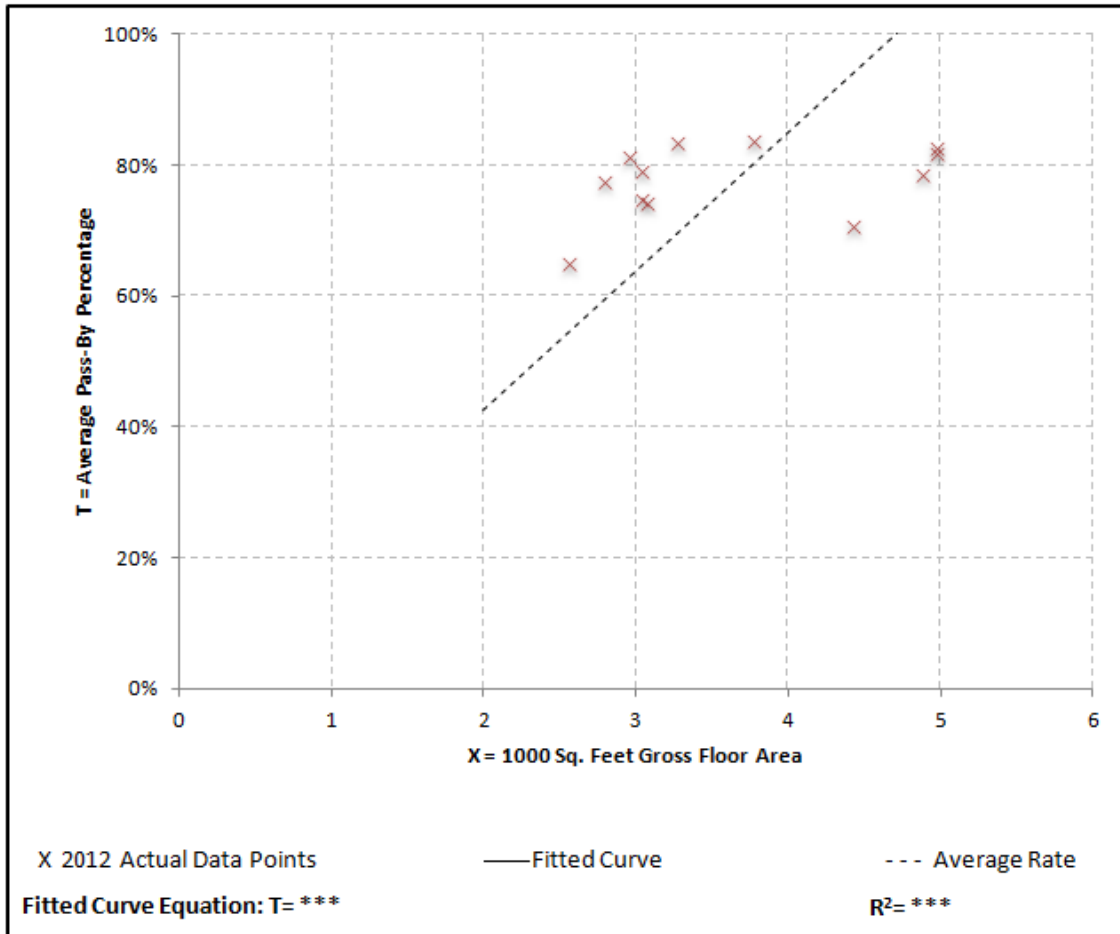
Average Pass-By Percentage vs: 1000 Sq. Feet Gross Floor Area  
 On a: Weekday,  
 Peak Hour of Adjacent Street Traffic,  
 One Hour Between 4 and 6 p.m.

Number of Studies: 12  
 Average 1000 Sq. Feet GFA: 3.5

### Percentage Pass-By per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
0.22	0.16 - 0.28	0.05

### Data Plot and Equation



Student Apartments

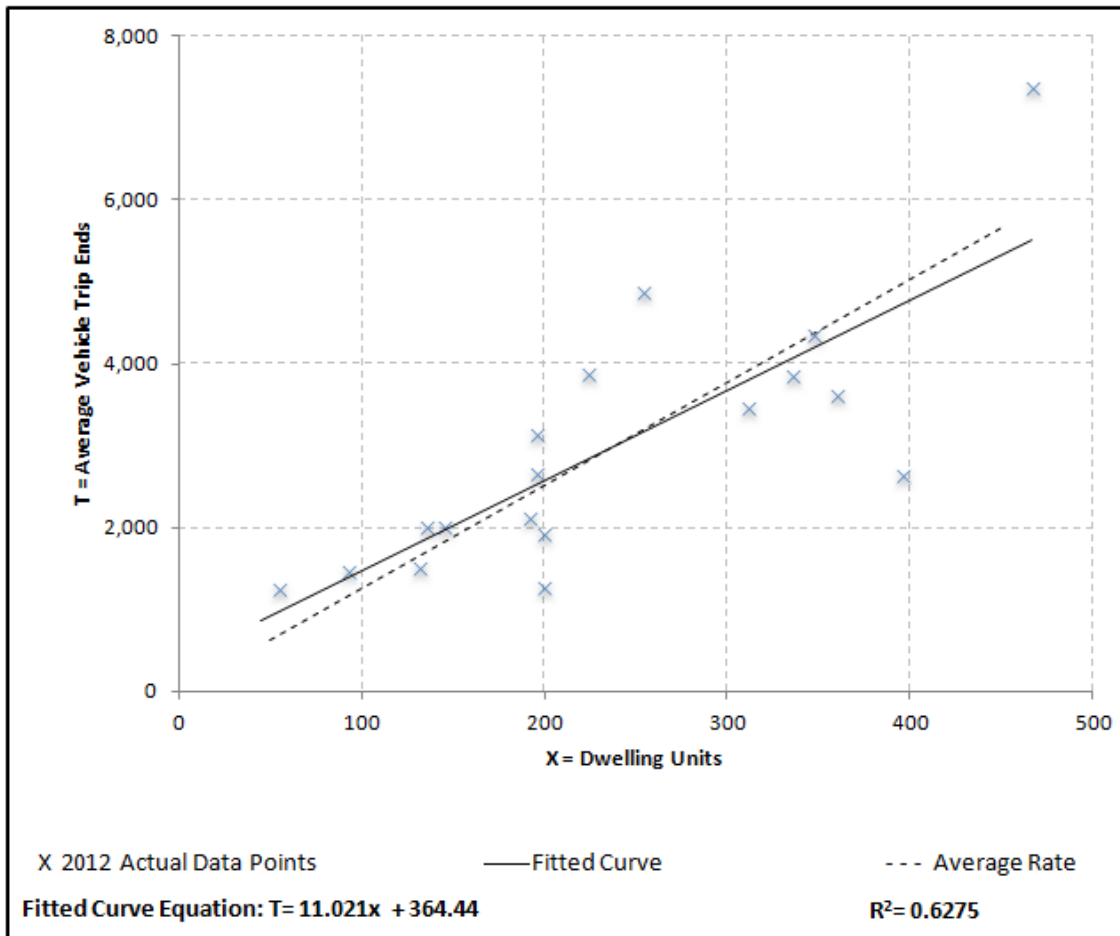
Average Vehicle Trip Ends vs: Dwelling Units  
 On a: Weekday

Number of Studies: 18  
 Average Dwelling Units: 236

Trip Generation per Dwelling Units

Average Rate	Range of Rates	Standard Deviation
12.57	6.38 - 22.58	4.15

Data Plot and Equation



# FDOT 2012 Study- Apartments

## Student Apartments

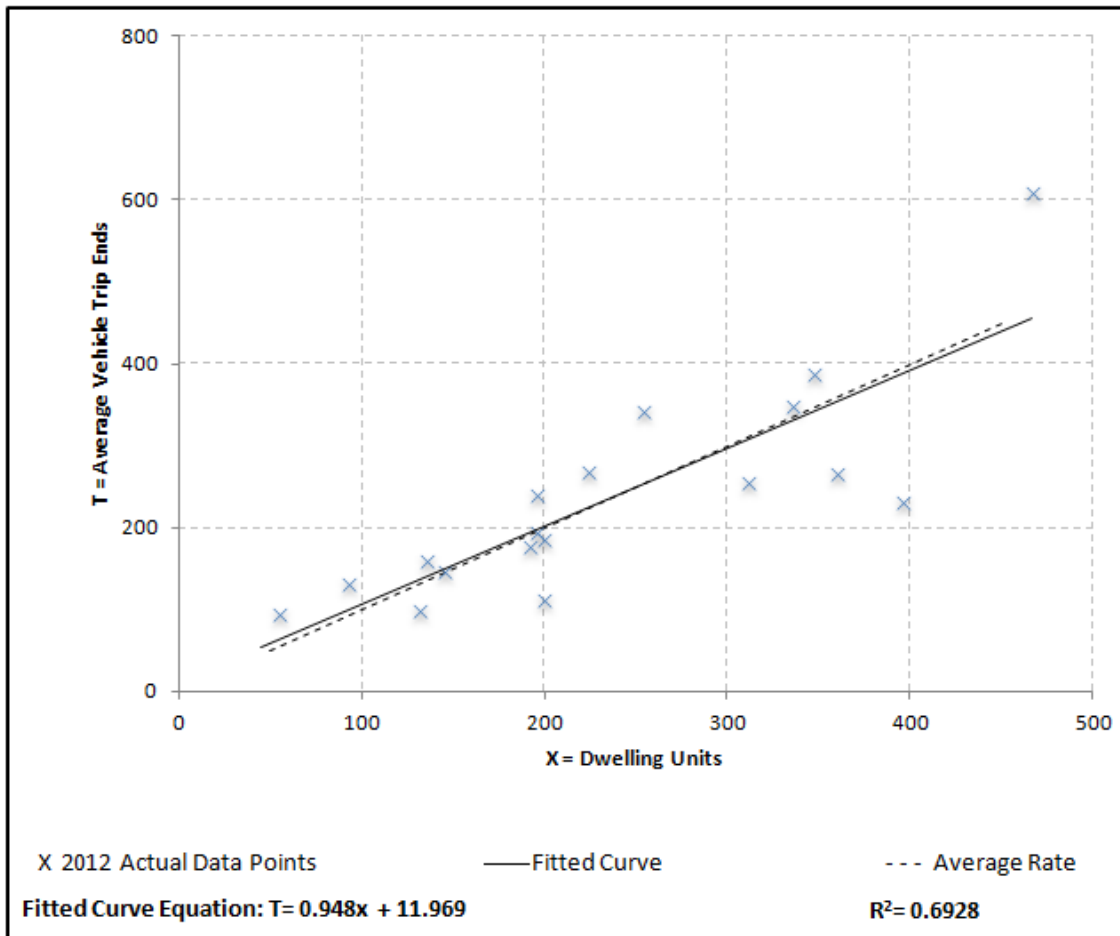
Average Vehicle Trip Ends vs: Dwelling Units  
 On a: Weekday,  
 Peak Hour of Adjacent Street Traffic,  
 One Hour Between 4 and 6 p.m.

Number of Studies: 18  
 Average Dwelling Units: 236

### Trip Generation per Dwelling Units

Average Rate	Range of Rates	Standard Deviation
1.00	0.55 - 1.70	0.30

### Data Plot and Equation



# FDOT 2012 Study- Apartments

## Student Apartments

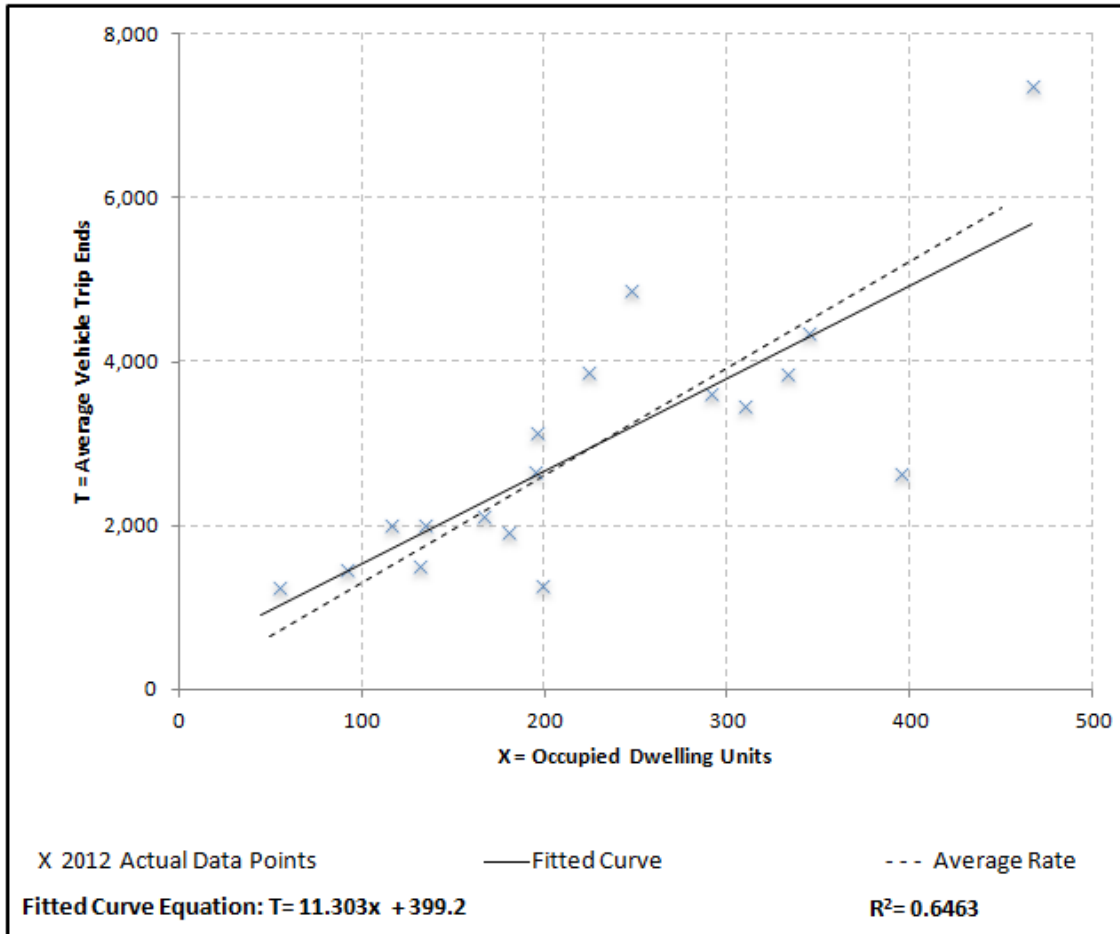
Average Vehicle Trip Ends vs: Occupied Dwelling Units  
 On a: Weekday

Number of Studies: 18  
 Average Occ. Dwelling Units: 227

### Trip Generation per Occupied Dwelling Units

Average Rate	Range of Rates	Standard Deviation
13.06	6.41 - 22.58	4.11

### Data Plot and Equation



Student Apartments

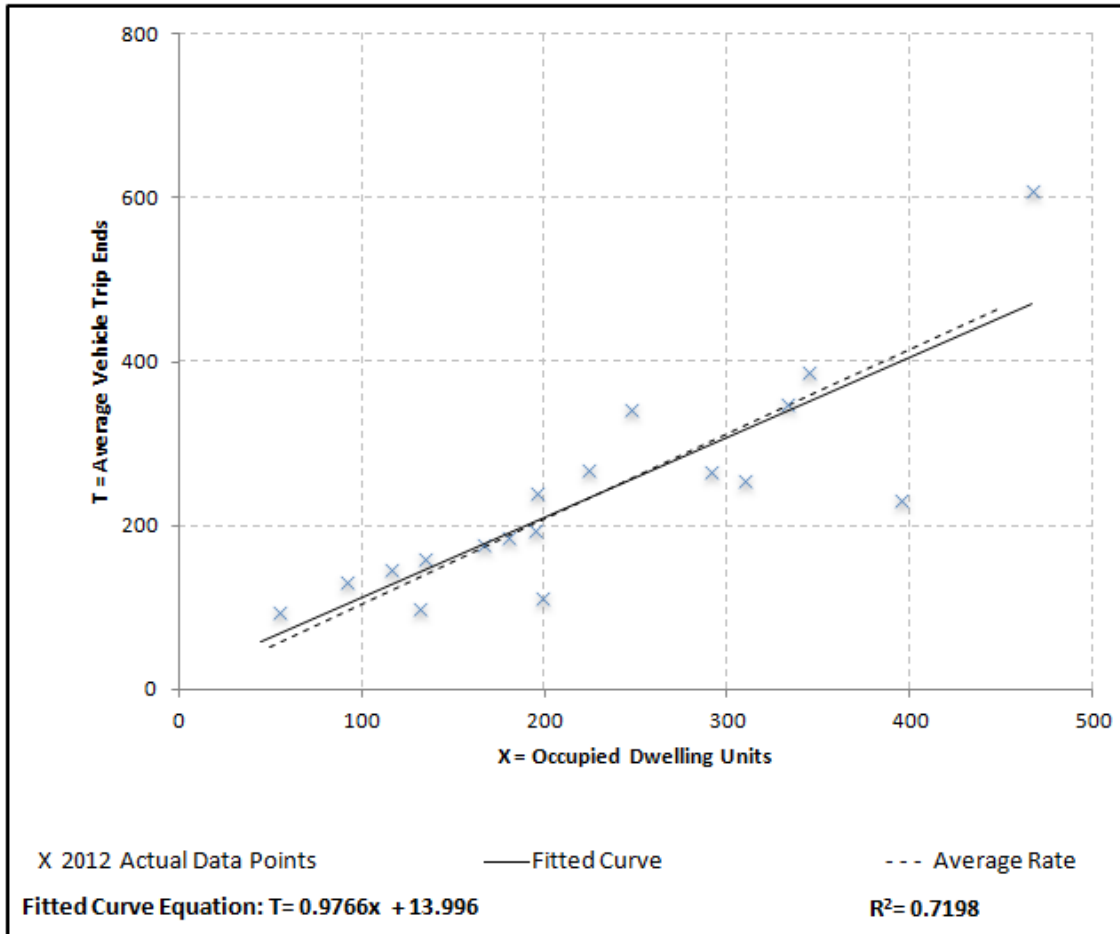
Average Vehicle Trip Ends vs: Occupied Dwelling Units  
 On a: Weekday,  
 Peak Hour of Adjacent Street Traffic,  
 One Hour Between 4 and 6 p.m.

Number of Studies: 18  
 Average Occ. Dwelling Units: 227

Trip Generation per Occupied Dwelling Units

Average Rate	Range of Rates	Standard Deviation
1.04	0.56 - 1.70	0.29

Data Plot and Equation



# FDOT 2012 Study- Apartments

## Student Apartments

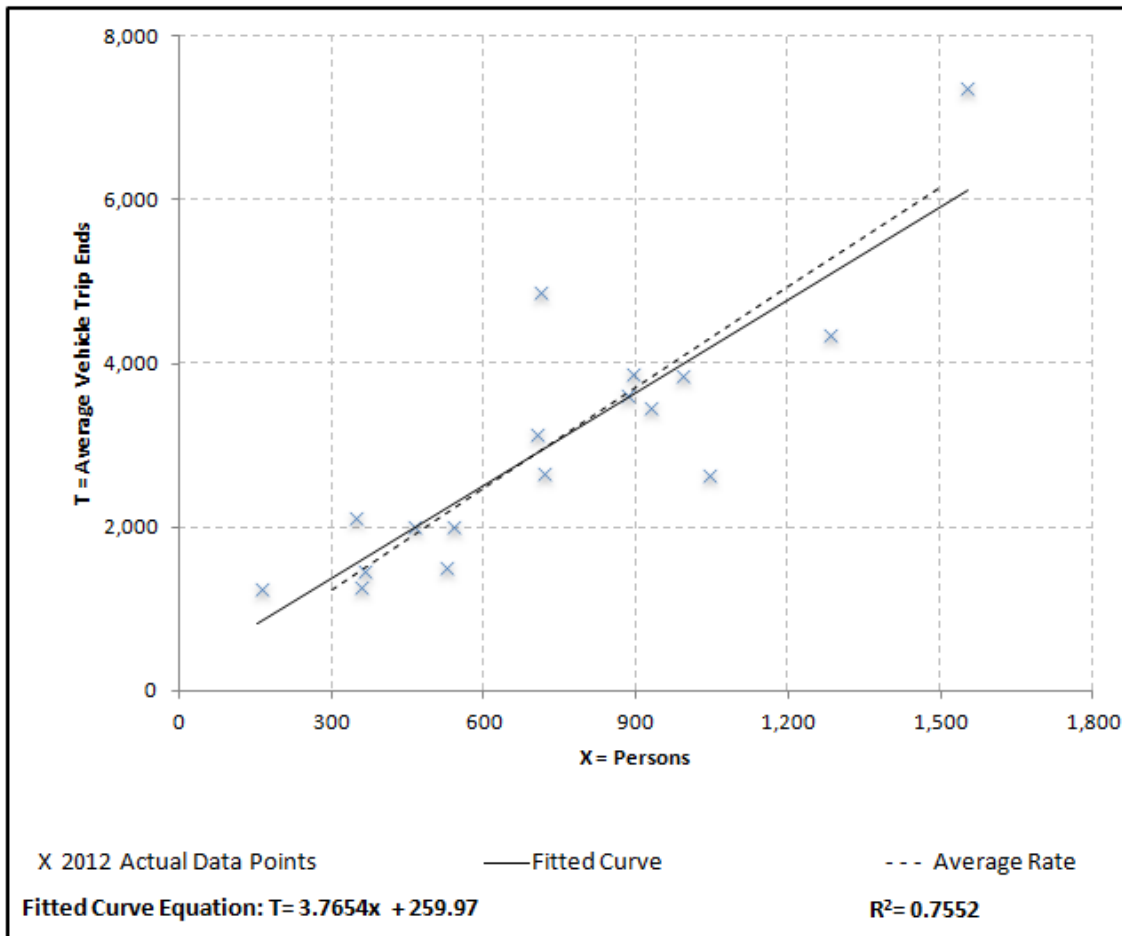
Average Vehicle Trip Ends vs: **Persons**  
 On a: **Weekday**

Number of Studies: 17  
 Average Persons: 718

### Trip Generation per Person

Average Rate	Range of Rates	Standard Deviation
4.11	2.52 - 7.62	1.35

### Data Plot and Equation



# FDOT 2012 Study- Apartments

## Student Apartments

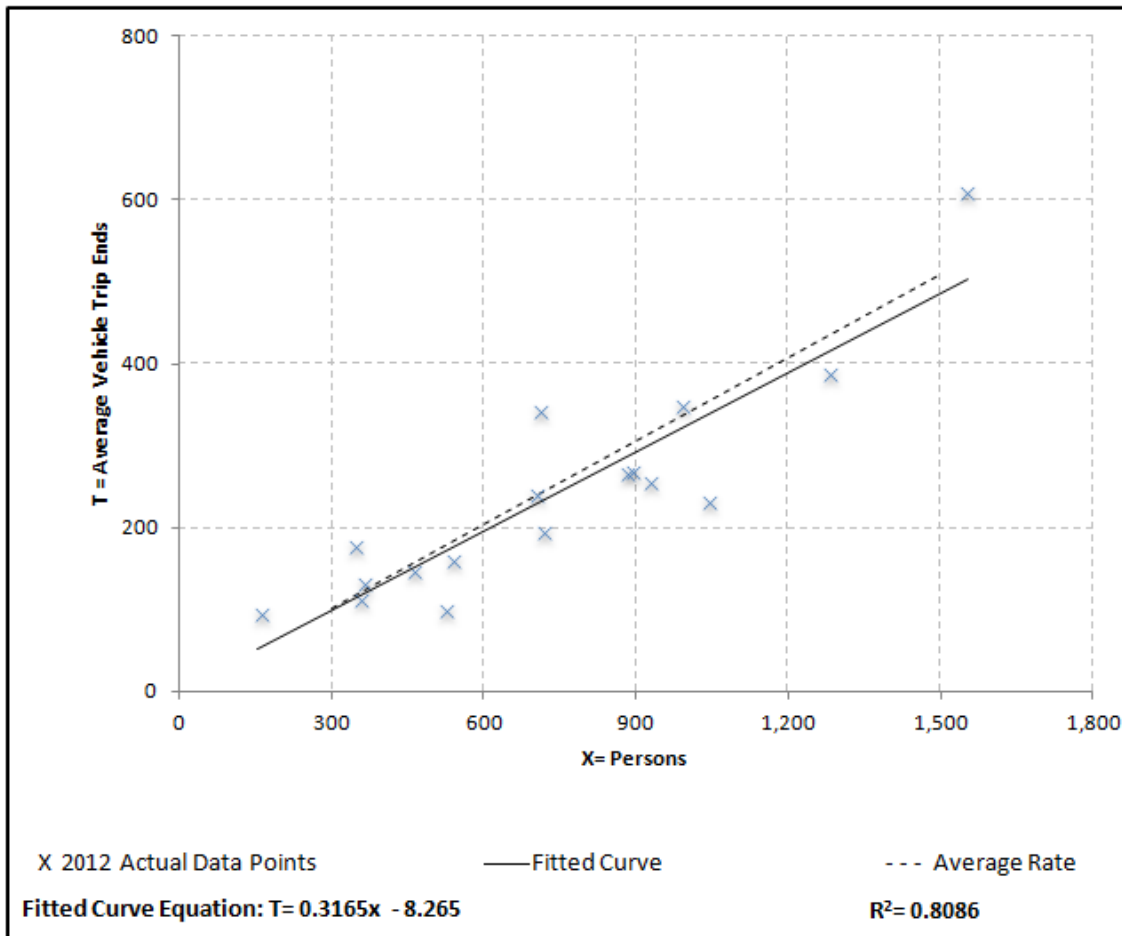
Average Vehicle Trip Ends vs: **Persons**  
 On a: **Weekday,  
 Peak Hour of Adjacent Street Traffic,  
 One Hour Between 4 and 6 p.m.**

Number of Studies: 17  
 Average Persons: 718

### Trip Generation per Person

Average Rate	Range of Rates	Standard Deviation
0.32	0.18 - 0.57	0.10

### Data Plot and Equation



# FDOT 2012 Study- Apartments

## Student Apartments

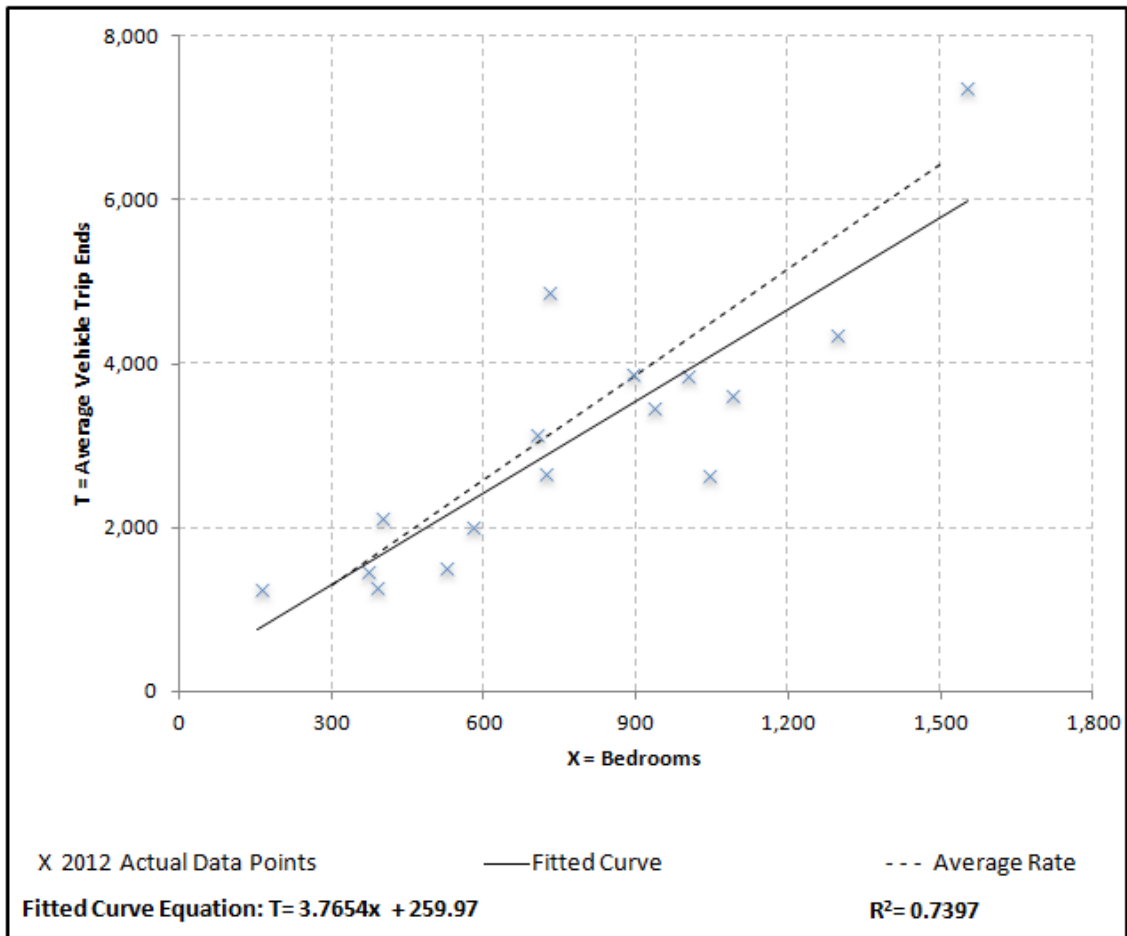
Average Vehicle Trip Ends vs: Bedrooms  
On a: Weekday

Number of Studies: 16  
Average Bedrooms: 718

### Trip Generation per Bedroom

Average Rate	Range of Rates	Standard Deviation
3.98	2.52 - 7.62	1.36

### Data Plot and Equation





# FDOT 2012 Study- Apartments

## Student Apartments

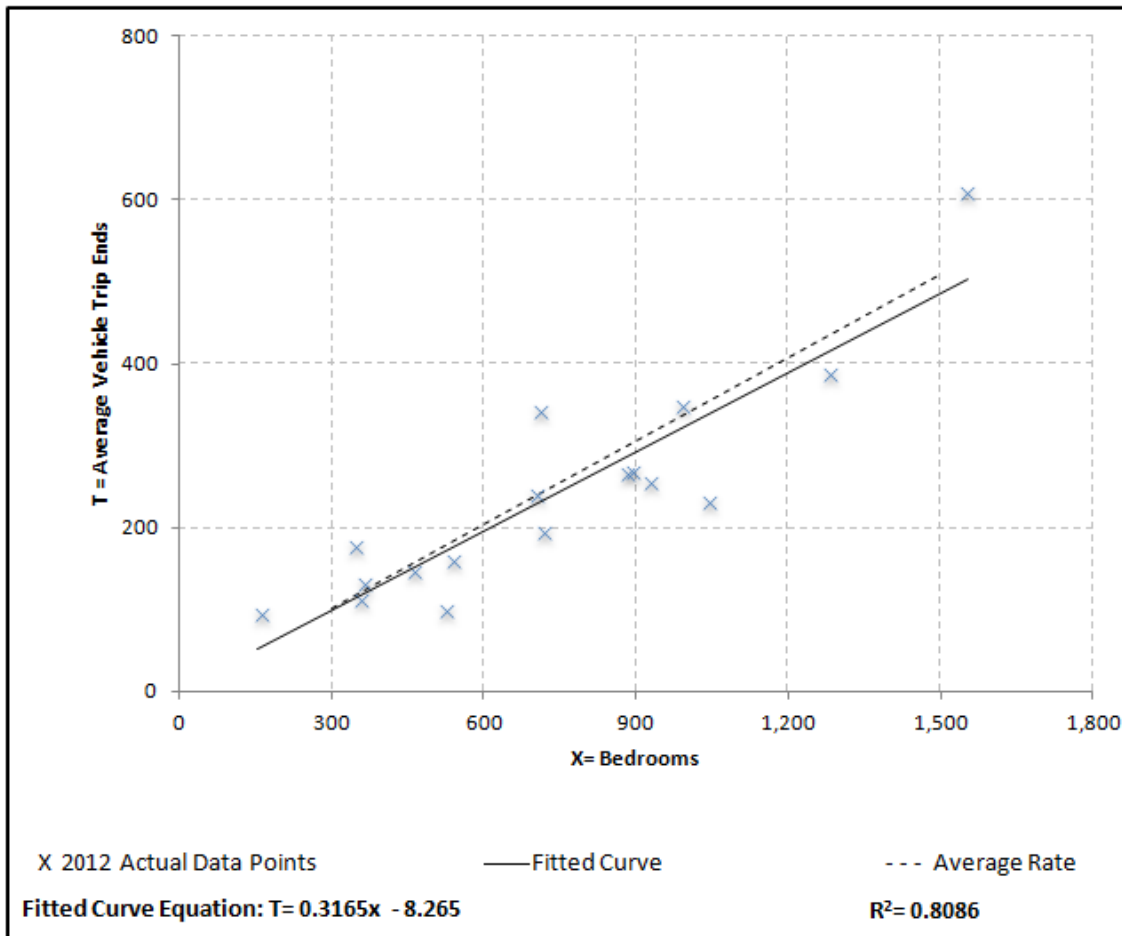
Average Vehicle Trip Ends vs: Bedrooms  
 On a: Weekday,  
 Peak Hour of Adjacent Street Traffic,  
 One Hour Between 4 and 6 p.m.

Number of Studies: 16  
 Average Bedrooms: 718

### Trip Generation per Bedroom

Average Rate	Range of Rates	Standard Deviation
0.31	0.18 - 0.57	0.10

### Data Plot and Equation



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## Student Apartments

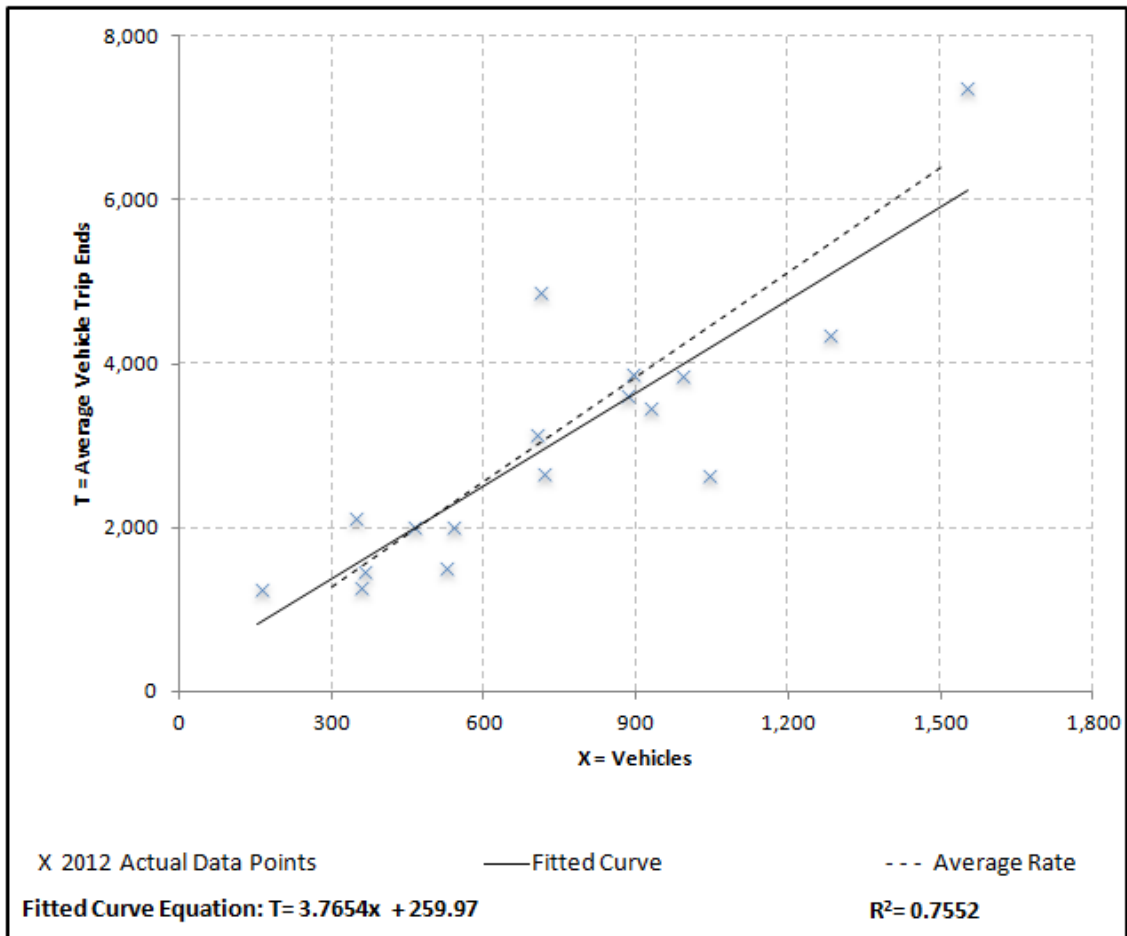
Average Vehicle Trip Ends vs: Vehicles  
 On a: Weekday

Number of Studies: 15  
 Average Vehicles: 718

### Trip Generation per Vehicle

Average Rate	Range of Rates	Standard Deviation
4.47	2.79 - 10.16	2.10

### Data Plot and Equation



# FDOT 2012 Study- Apartments

## Student Apartments

Average Vehicle Trip Ends vs: Vehicles  
 On a: Weekday,  
 Peak Hour of Adjacent Street Traffic,  
 One Hour Between 4 and 6 p.m.

Number of Studies: 15  
 Average Vehicles: 718

### Trip Generation per Vehicle

Average Rate	Range of Rates	Standard Deviation
0.35	0.21 - 0.76	0.15

### Data Plot and Equation

