Trip Generation Study of Coffee/Donut Shops in Western NY

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A TRIP GENERATION STUDY OF COFFEE/DONUT SHOPS IN WESTERN NEW YORK

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INTRODUCTION

The recently published Institute of Transportation Engineers Trip Generation Manual, *8th Edition* includes additional information for the new land uses 936 (Coffee/Donut Shop without Drive-Through Window) & 937 (Coffee/Donut Shop with Drive-Through Window). *However*, opportunity exists to more accurately forecast trip generation volumes from these type stores. Current data for land use ITE code 937 for coffee shops has large variations in rates and standard deviations, and does not contain fitted curve equations.

The purpose of this study is to develop best fit equations that will accurately predict morning peak hour trip generation volumes for Coffee/Donut shops.

Currently, the Trip Generation Manual contains three variables for determining trip generation volumes: gross floor area, number of seats, and peak hour adjacent street traffic. This study not only considers gross floor area and peak hour traffic volumes, but also the following site specific factors to determine if any statistical relationships exist: average daily traffic data, geographic and demographic variables.

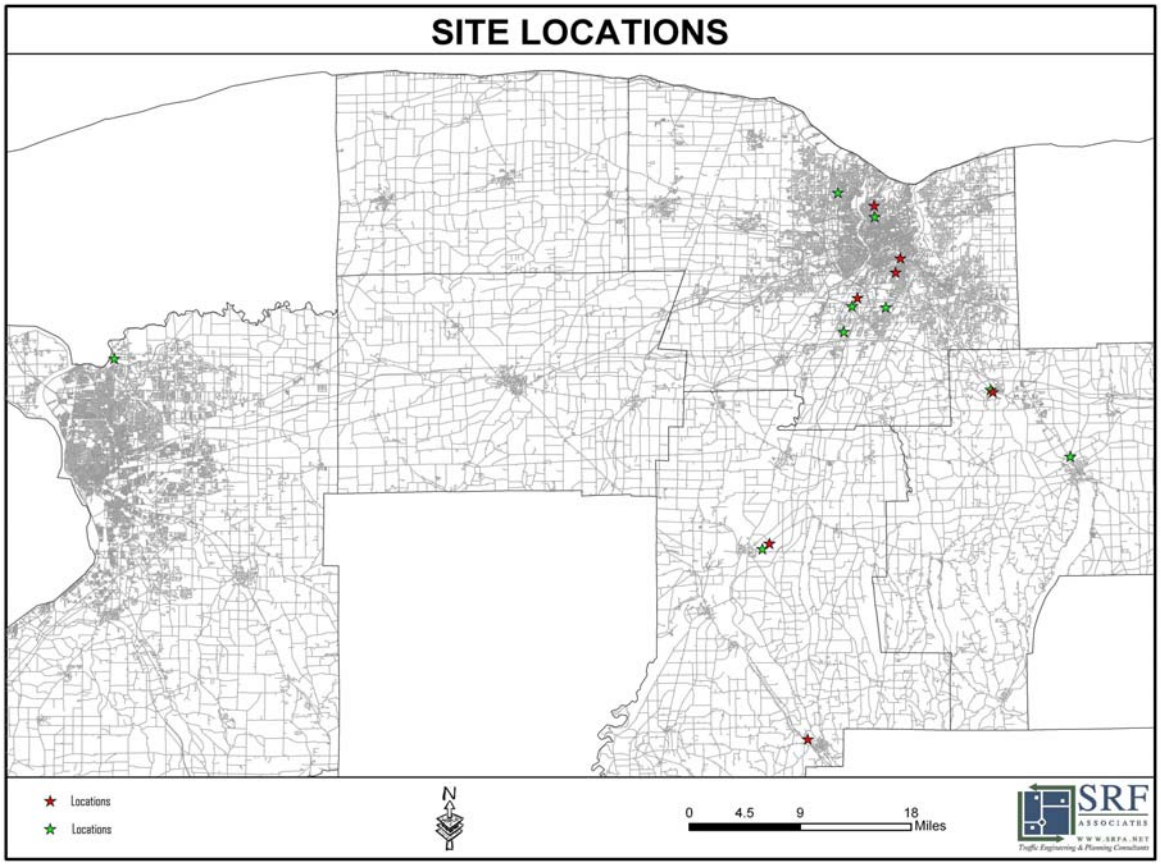
At a limited number of sites, video recording was utilized to document vehicles entering and exiting the site. A secondary benefit of using video recording for data collection is the ability to observe and document drive thru window operations and associated vehicle queues. Based on this limited data, a planning level vehicle queue length prediction equation was developed for the drive-thru service windows at Coffee/Donut shops.

DATA COLLECTION

Data were collected at 13 different coffee/donut shops around Western New York via manual traffic counts or video recordings of the drive thru lanes. Two national retail chains were used for data collection purposes. The majority of business conducted at these particular shops occurs during the morning peak hour period. Therefore, the trip generation data collection and subsequent analysis was limited to the AM peak hour period only.

A majority of the data was collected during the first half of December 2007 on typical weekdays; Mondays and Fridays were excluded from the data collection. 12 out of the 13 shops studied were stand alone buildings with one or two points of access; which made it easier to document trip generation volumes. The number of entering, exiting, parking lot and drive-thru vehicles was documented at each of the stores between the hours of 7:00 AM to 9:00 AM in 15 minute intervals. The intervals were reviewed to determine the peak hour of traffic generation.. It should be noted that 12 out of the 13 shops had drive thru windows, only one store did not.

The figure below indicates approximate locations of stores included in this analysis. The stores studied for this analysis are located in Erie, Monroe, Livingston, and Ontario counties in upstate New York.



The results of the data collection are shown in the table below.

TABLE I – TRIP GENERATION RESULTS

	TOWN/CITY	AM PEAK (Veh)			STORE SIZE (SF)	TRIP GENERATION RATE (TRIPS/SF)
		PARKED	DRIVE-THRU	TOTAL		
1	Rochester	73	125	198	1,800	**0.110**
2	Brighton	81	0	81	2,090	0.039
3	Brighton	41	98	139	2,087	0.067
4	Victor	35	81	116	1,894	0.061
5	Geneseo	37	33	70	1,250	0.056
6	Irondequoit	38	82	120	2,400	0.050
7	Henrietta	26	93	119	2,500	0.048
8	Henrietta	40	115	155	3,030	0.051
9	Victor	19	86	105	2,200	0.048
10	Greece	42	119	161	2,440	0.066
11	Geneseo	18	39	57	3,080	**0.019**
12	Irondequoit	38	61	99	3,200	0.031
13	Henrietta	30	97	127	3,500	0.036

The table above includes the existing store size (in square feet) and the associated trip generation rate. The trip generation rate was calculated by dividing the total number of trips by the square footage of the store.

Surprisingly, the trip generation rates vary significantly from 0.019 to 0.110 trips per square footage. For example, a 2,500 square foot store could have as many as 275 trips, or as little as 48 trips based on the high and low rates. Less than half of the stores have similar and/or comparable trip generation rates.

Results of this data and conversations with coffee/donut shop store owners led us to investigate other variables that may more accurately define trip generation characteristics of these types of stores.

ADDITIONAL DATA ANALYSIS

It is widely known that for many retail uses contained in the Trip Generation Manual, the square footage of a store is the first and most defining characteristic. In attempt to determine relevant correlating factors for the coffee / donut shop trip generation, we derived other independent variables for consideration. Data for the following variables were considered at all 13 locations included in this study:

- Number of through travel lanes adjacent to store,
- Population within 3/4 mile radius,
- Median age within 3/4 mile radius,
- Distance from interstate / highway,
- Average Daily Traffic volume on adjacent roadway,
- AM peak hour volume on adjacent roadway,
- Store size (square footage),
- Presence of drive-thru

The number of lanes adjacent to the store was determined by on-site observations. The population and median age within 3/4 radius of the store was determined by Census 2000 data. Average Daily Traffic (ADT) volumes on the adjacent roadway were obtained from most recent data available on the study section of roadway adjacent to the study store. AM peak hour volume on the adjacent roadway was obtained either from the ADT data or manual counts. Store size was either obtained from actual building plans or scaled accordingly from recent aerial photography.

Although there were many other factors that were considered, the following variables were not used for this analysis due to the difficulty of obtaining or uncertainty of the variables:

- Ethnic diversity,
- Number of seats,
- Hours of operation,
- Distance from similar store

The data was analyzed using STATGRAPHICS Plus version 5.0 software and the Multiple Regression Analysis. This software produces a "P-value" that indicates the confidence rate of the relationship of the variables being analyzed. For example, a P-value of 0.10 indicates a 90% confidence rate. The higher the confidence rate the better the statistical relationship between the variables being analyzed.

TABLE II – PRELIMINARY ANALYSIS RESULTS

	PARKING LOT TRIPS	**DRIVE - THRU TRIPS**
VARIABLE	**P-VALUE**	**P-VALUE**
ADT	0.9709	0.1799
Age	0.7168	0.1550
AM Major St	0.7679	0.2977
Dist from Interstate	0.8439	0.6850
Drive Thru Presence	0.1168	0.0588
Lanes	0.5318	0.1439
Population	0.5553	0.3581
Store Size	0.6501	0.4951
Model P-Value	**0.4106**	**0.0805**

The results in the table above illustrate P-Values below the desired 90% confidence rate for parking lot and drive thru trip variables using the multiple regression analysis. The data illustrates a better correlation between variables for drive-thru trips than parking lot trips.

The overall P-value for the models indicates a 92% confidence rate for drive-thru trips, but only a 59% confidence rate for the parking lot trips. As previously mentioned, the desired confidence levels for the overall models are above 90% for both parking lot and drive-thru trips.

In an effort to derive equations for both parking lot and drive thru trips with 90% or greater confidence rates three variables were removed from the analysis. These three variables were considered not statistically significant from the results of the first analysis. Therefore, the analysis was performed a second time with the following variables removed from the equation:

- Age,
- Distance from interstate,
- Average Daily Traffic

The results of the revised analysis are shown in the table below.

TABLE III – SECONDARY ANALYSIS RESULTS

	PARKING LOT TRIPS	**DRIVE - THRU TRIPS**
VARIABLE	**P-VALUE**	**P-VALUE**
Lanes	0.1964	0.0548
Population	0.0373	0.0137
Age	-	0.0785
Dist from Interstate	-	-
ADT	-	0.1435
AM Major St	0.2869	0.0234
Drive Thru_Y or N	0.0119	0.0166
Model P-Value	**0.0306**	**0.0122**

Although some P-values are above 0.10, the table above indicates generally acceptable P-values for the variables analyzed. The resulting equations are shown below:

Parking Lot Trips= 76.509 - 7.231 * Dist from Interstate + 0.003 * Population + 0.007 * AM Peak hour - 43.927 * Presence of Drive- thru
Model P - Value = 0.0306

Drive-Thru Trips = -113.414 - 21.215 * Number of Lanes on Major Street + 0.007 * Population + 2.108 * Median Age + 0.037 * AM Peak hour + 0.002 * ADT + 68.607 * Presence of Drive- thru
Model P - Value = 0.0122

Note: The value for drive-thru presence should be entered as "1" if a drive-thru exists, and "0" if a drive-thru is not present.

The overall P-values for the secondary model indicate confidence levels of 97% for the parking lot trips and a 99% level for the drive-thru trips.

Upon completion of determination of the equations listed above, two additional stores were counted to test the accuracy of the equations

derived with 97% and 99% confidence levels. The two additional locations were stores in Dansville and Buffalo, New York.

Based on the input variables for the Dansville store, the equations estimated the number of parked cars would be 39, the actual number was 37. The estimated number of drive thru trips was 17, and the actual number was 39. In total, the equations estimated a total number of 56 trips, when the actual number of trips was 76. This equates to a 26% difference. Although the actual size of this store is unknown, assuming an approximate size of 3,000 square feet using ITE Land Use code 937, yields trip generation of 169 entering and 163 exiting vehicles. The trip generation formulas developed estimated 56 entering and 56 exiting vehicles (drive thru + parked vehicles), while the actual counts where 76 entering and 76 exiting. It is evident that the ITE trip generation volumes over estimate the actual number of trips by more than two times.

Using the derived equations to estimate trip generation for the Buffalo store yields 66 parked cars, and the actual number of trips was 58. The estimated number of drive thru trips was 149, and the actual number of trips was 135. The total estimated trips was 215 and the actual recorded was 193. This equates to an 11% difference.

Although the results for the Dansville store were not as accurate as expected, it was noted that this store is located right next an interstate, which could have an impact on the trip generation results; even though the distance from the interstate variable was removed from the preliminary analysis because of the low confidence level. In summary, this site indicates the need for data from additional locations to more accurately define the trip generation equations and estimates.

VEHICLE QUEUING ESTIMATION

Once the estimated number of vehicle trips generated by a proposed coffee/donut shop has been completed, the next factor that should be considered in the site planning process is the number of vehicles that will queue during the AM peak hour at a drive-thru window. While trip generation is the key factor in estimating vehicle queues, the following factors must also be considered:

- Temporal distribution of traffic,
- Time to place order,
- Time at service window,
- Number of people at drive thru window

Two coffee/donut shops with drive-thru were observed during the AM peak hour periods to document variables shown in the list above; with the exception of the number of people at the service window. This data was directly obtained by the store manager on duty in the store at the time.

Considering that all of the factors that affect vehicle queuing vary from day to day, averages were developed based on our observations, and combined into a simplified planning level formula. This formula with averages (or defaults) can be used to determine vehicle queues based on confidence levels.

The formula is based on two user inputs; arrival rate (vehicles/hour) and service rate (vehicles/hour). The arrival rate is based on the expected number of vehicles that will use the drive-thru. Based on our observations, the average service time during the AM peak hour was 30 seconds per vehicle. This corresponds to two vehicles every minute or 120 vehicles per hour. A default of 120 vehicles per hour can be based for the service rate, unless more specific data is available. Regardless of the values used, the service rate must be higher than arrival rate for the formula to produce an accurate result.

Using arrival and service rates, as discussed previously, the following information can be determined:

- Average vehicle queue,
- Average time in the drive-thru,
- Average wait time,
- Maximum expected vehicle queue

Formulas were developed using the Stochastic Queuing Analysis method. To use this queuing analysis method for the drive-thru lane, the traffic intensity must be less than one. Traffic intensity is defined as:

$$\rho = \frac{\lambda}{\mu}$$

Where ρ = traffic intensity
λ = mean arrival rate per hour
μ = mean service rate per hour

The average vehicle queue in the drive thru lane can be calculated as follows:

$$E(n) = \frac{\rho}{1-\rho}$$

The results from this formula can also be used to calculate the average vehicle queue length in the drive thru. For example, an arrival rate of 60 vehicles per hour and a service rate of 120 vehicles per hour yields an average vehicle queue of one (1). Assuming one vehicle occupies approximately 25 feet, then the average queue length in the drive thru lane would be 25 feet. The start of the vehicle queue begins from the service window (not the ordering board) and extends backwards in the drive thru lane.

The average time vehicles spend in the drive-thru (in hours) can be calculated as follows:

$$E(v) = \frac{1}{\mu(1-\rho)}$$

The results from the equation shown above can be multiplied by 60 minutes/hour to determine the average wait time in minutes. This represents the total time in the drive thru; from arrival in the queue to queue departure.

The average wait time (in hours) vehicles spend in the drive thru from the time a driver leaves the ordering board until they arrive at the service window can be calculated as follows:

$$E(w) = \frac{\rho}{\mu(1-\rho)}$$

In order to estimate the probability of exactly 'n' vehicles in the drive-thru lane the following formula is used:

$$P(n) = \rho^n(1-\rho)$$

Where n = number of vehicles

The following formula calculates the 95% expected vehicle queue 'n' using the cumulative probabilities:

$$\sum_{n=0}^{n=\alpha} P(n) \geq 0.95$$

The preceding formula is calculated until a value greater than or equal to 0.95 is achieved. Once this value is attained, the resulting number of vehicles indicates a 95% confidence factor that there will be less than that number of vehicles in the drive thru lane. As previously mentioned, this value 'n' can be multiplied by 25' per vehicle to determine a corresponding queue length required for the drive thru lane; where the start of the vehicle queue begins from the service window (not the ordering board) and extends backwards in the drive thru lane.

These formulas assume that both arrival and service rates are random. This is based on our observations that vehicle arrivals are random, and that service times in the drive-thru vary based on type and number of items ordered. For example, service time for ordering a coffee is less than that of a customer who orders coffee and a breakfast sandwich or donuts.

It should be noted that the recommended default values for service rates were derived based on observations at two (2) sites. The arrival rates are based on the trip generation equations for drive thru trips. Due to the limited number of drive thru operations observed, the vehicle queuing equations should be used for planning purposes only.

FINDINGS AND CONCLUSIONS

The results of this analysis, while limited in the number of studies and geographical area, indicate that coffee/donut shop square footage is one of the least statistically significant variables. There are six (6) other important variables that should be considered when determining the estimated number of AM peak hour generated trips.

It has been shown that ITE Trip Generation Land Use code 937 (coffee/donut shop) square footage trip generation rates yield widely varied results from actual count data. Over estimation of trip generation volumes can potentially have a significant impact on a project during the approval process. Therefore, it is recommended that careful consideration be given when using the ITE Trip Generation data estimates for Land Use code 937.

In addition to the number of estimated AM peak hour trips, the vehicle queuing formulas will aid civil engineers, store owners, and approval agencies in the design of drive thru lanes for coffee/donut shops.