Estimating The Pass-By and Diverted Trips for Shopping Typed Land Use

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ABSTRACT

Trip generation represents a key input in traffic impact assessment. The accuracy and equitability of the traffic study hinge on the trip generation rates that are applied. Until recently, local engineers have utilized trip generation rates which have been produced abroad, especially the trip rates published by the Institute of Transportation Engineers (ITE). This study attempts to investigate and produce weekday trip rates and equations for shopping complexes in the Klang Valley. The focus of this study is on large shopping complexes, especially those with gross built up area of above 600,000 ft^2. In addition to establishing trip rates, this study also focuses on the rates for pass-by and diverted trips. Pass-by and diverted trips are traffic that already using the road network adjacent to the shopping complex and may attracted to the shopping complex. Extensive traffic surveys were carried out to determine the pass-by and diverted trips. Following which a correlation analysis was conducted to test the suitability of the various independent variables in estimating the observed traffic generation. The results showed that, the gross built up area and gross leasable area provide a good fit with the observed traffic volume. For the pass-by and diverted trips, traffic volumes on the adjacent streets yield the best estimates. Based on these analyses, trip generation rates for the pass-by and diverted trips during the generator peaks were established.

INTRODUCTION

The past ten years have witnessed major changes in shopping, working, leisure and social trip patterns. There is a rapid growth in car ownership due to the increased in personal income. This pattern has led to rapid expansion in different forms of large retail establishments and multi function complexes. Such development can at times be conceived and completed within a year.

However, the introduction of a single development of a huge proportion of a shopping complex is likely to have a great impact on the surrounding and will offset the Local and Structure Plan of a locality. This problem has led to the introduction of bylaws requiring traffic impact assessments and local traffic studies for newly proposed developments. These studies involved investigation on the impact of the proposed development on the adjacent road networks and junctions. An essential component in the analysis of these studies is the prediction of trips that will be generated and attracted by the proposed development. Trip generation is defined as the total number of inbound and outbound vehicle trips to or from a specific land use over a set period of time. The estimation of trip generation depends on the selection of existing development that adequately reflects the trip generation of the proposed development. The validity of trip generation rates of the existing development depends on a thorough review of comprehensive and relevant survey data. Regional differences are likely to have an impact on the validity of the trip generation rates, as do the age of the trip generation rates. This is because, the older the data, the less significant it becomes due to the changes in travel pattern over time.

TRIP GENERATION MODELS

The major traffic generation studies for offices, industrial and commercial development were undertaken in the 1960's and early 1970's, reviewed in the mid and late 1970's until 1980's [1]. This early information was generally analysed using regression techniques on a zonal basis and for the purpose of identifying the number of work trip ends generated by residential zones and attracted to the employment zones. Such a general information is useful for strategic planning, but not at a level where precise data is necessary to identify specific traffic problem, such as queuing and congestion at junctions in the proximity of the development. To achieve more localised data, land use and transportation studies were supplemented with surveys taken at the individual premises [2].

Trip generation models are available for different types of land use in many developed countries, the most notable of which are those presented by the Institute of Traffic Engineering's Trip Generation rates [3]. Osula [4] noted that, the ITE rates may not be adequate for use in a developing country. This is because of the differences in the cultural and socio-economic background of the trip makers and also in the types of land use that exist in these different setting.

The characteristics of land use have a major bearing on the trip generation rates. A residential land use would primarily function as a trip generator during the morning peak hour, and attraction in the evening peak. An office land use would operate oppositely. A shopping complex, may have different trip generation characteristics.

Shopping-Complex Types Land Use Trips

A model, which involves shopping complexes, retail establishments, banks, convenience markets and restaurants, have different trips compositions. Trips attracted to these types of development may comprise of the traffic which are already on the adjacent roads. This type of traffic is called pass-by traffic. An understanding of this phenomenon is essential, because the driveway volume at a generator is different from the amount of traffic actually added on the road network. The pass-by trips in a traffic impact analysis do not increase the volume of traffic to the road network adjacent to the project site. Previous researchers [5, 6, 7, and 8] have defined the proportion of pass-by traffic in terms of a percentage of the motorists entering the site. The Trip Generation Pilot Study of Malaysia [9] noted the percentage of pass-by trips in terms of motorists entering the site instead of the exiting traffic or total of in and outbound traffic. This is because of the short stop duration.

Another traffic adjustment factor for shopping type land use is the diverted traffic. Diverted trips are similar to the pass-by, but require a diversion from that road to gain access to the site. These roads could include streets or freeways adjacent to the project site but without direct accesses. Hence, diverted trips are not often required if the traffic study is limited to the site driveway or roads adjacent to the site. However, studies, which involve small or large areas, need to account for the volume of the diverted trips.

METHODOLOGIES IN ESTIMATING TRIP GENERATION

Trip generation is intended as a tool for traffic engineers, planners and authorities interested in estimating the vehicle trips likely to be produced and attracted by a land use. Three methodologies are often provided in determining the average number of trips generated by a land use. These are:

a) a weighted average trip generation rate or the number of weighted trip ends per one unit of independent variable,
b) a plot of actual trip ends versus the size of the independent variable for each study., and
c) a regression equation of trip ends which is related to the size of the independent variable

Generally, most of the land use models which combined independent variables and period in the calculation of trip generation, have a weighted trip generation rate. The plots and regression equations are provided only if sufficient data are available. In this study, the weighted average trip generation rate and regression analysis approaches were chosen to analyse the data.

Selection of Observation Sites

The Trip Generation Pilot Study of Malaysia [9] was primarily developed in view of the future traffic impact that may be underestimated due to the lack of a local database trip rates. The wide range of vehicle ownership rates throughout the country resulted in a wide range of trip generation characteristics specific to the particular areas of the country. The motor vehicles registration statistics as 31st December 1997 shows that, 35 % of all registered vehicles are registered in Kuala Lumpur and Selangor i.e., the Klang Valley. Based on this information, it is appropriate that the selected sites should be located in the Klang Valley. The selections of survey sites were influenced by the pre-determined criteria which had been set as the requirement of the site.

These requirements are:

a) site should be of a large size, functioning as a regional shopping complex which is not limited to only the localities. Generally, this involves shopping complexes which have a gross built-up area of above 600,000 ft^2 [10],
b) site should has adequate parking spaces to avoid the possibility of parking as a limiting factor in the trip generation characteristics of the shopping complex,
c) site should be a stand alone site i.e. not linked to an office tower or other land use categories which may differ in operation normally associated with shopping complex,
d) site does not cater or accommodate for through trips to adjacent land use,
e) site represents same variation especially in terms of the independent variables,
f) site is equipped with drop-off facilities which are easily identifiable,
g) site is a mature, thus should be in operation for more than 2 years, and
h) site requires an acceptable number of manpower in conducting the surveys.

Site reconnaissance was carried out and the lists of possible sites were reviewed to confirm their suitability. Four shopping complexes which fulfilled the pre-determined criteria were selected. The sites are:

a) Bangsar Shopping Complex located in front of Jalan Maarof,
b) Komplek Desa located in front of Jalan Kepong,
c) Phoenix Plaza located in front of Jalan Cheras, and
d) Summit Square located in front of Lebuhraya Kepong Selayang.

Data and Sampling

Data collection was carried out to gather information required to establish the trip rate for shopping type land use. Data should also have the information suitable to calculate the pass-by and diverted trips.

Technique

In view of the required information, survey should involved:
a) traffic counts
b) interview surveys
c) pedestrian counts
d) questionnaires

The traffic counts allow the enumeration of vehicles by vehicles entering and leaving the shopping complex. The counts also involved vehicle occupancy. Interview surveys were conducted randomly to obtain information and estimation of the number of people who parked off site. The information also explains the pass-by and diverted trips and mode of travel. Occupancy survey was conducted to determine the volume of person trip at the shopping complex. The questionnaire survey generally involved the collection of information from the shopping complexes on the various independent variables used in the analysis.

Sampling Size

Two sampling methods were applied. The first is 'judgement sampling' [10] which was used in the selection of four shopping complexes in the Klang Valley. A judgement sample is a sample for which judgement is used to select the representative elements from the population or to infer that it is representative of the population. The second is the simple random sampling that was applied in interviewing the patrons of the shopping complexes.

In this trip generation study, the sampling unit may be defined as shopping complexes located within the boundary of the Klang Valley which satisfy the criteria of the selection. The data collection involved cordoning off the selected shopping complex and counting the trips produced and attracted by it.

This unit provide data or the trips by N samples from the population, where the trip can be expressed as a rate by some independent characteristics of the shopping complex.

Data Analysis

The analysis of data in a trip generation study concentrates on the summary of the data and the estimation parameters. The data collection process is vital because the accuracy of the results depends on the quality of the gathered data. The data were analysed in accordance with the guidelines recommended by the Institute of Transportation [3].

The weighted average trip generation was examined in terms of standard deviation. The smaller the deviation, the more compact the curve peak. This explains that, most of the sites have trip generation values close to the average rate. The reliability of the regression equation for trip ends was examined using R^2 values, i.e., the Coefficient of Determination. The R^2 values explain how well the regression line fits the survey data points.

DATA PRESENTATION AND RESULTS

Actual surveys were conducted between 7:00 A.M to 12:00 NOON and 4:00 P.M to 10:00 P.M which encompasses the morning and evening peaks of the day.

Peak Periods

The peak traffic generation period for a shopping complex does not coincide with the peak traffic hour traffic movement along the carriageway. In view of these, the trip generation rates were estimated for two peak periods. These are, the AM and PM commuter peak (period where traffic are at maximum on the adjacent major roads) and, AM and PM generator peak (peak traffic movement periods at the shopping complex). Table 1 summarises the peak periods during which the traffic was observed.

Commuter Peak Hour Trip Rates

The observed traffic generation for the shopping complexes during the commuter peak hours is tabulated in Table 2.

The examined independent variables and their respective values are shown in Table 3. The weighted average and regression analyses were conducted to check the degree of correlation.

Table 4 shows the results of correlation analysis. Total leasable area and gross built-up area have a high degree of correlation with the vehicle trip ends for the A.M and P.M commuter trips. The number of carpark has an acceptable degree of association with the number of vehicle trips. Based on this, the trip rates were analysed for the 3 independent variables.

Table 1 Observed commuter and generator peaks at all sites.

Shopping Complex	commuter peak		generator peak	
	AM	PM	AM	PM
Bangsar	8:15 to 9:15	5:45 to 6:45	11:00 to 12:00	8:00 to 9:00
Kompleks Desa	8:15 to 9:15	5:30 to 6:30	11:00 to 12:00	8:15 to 9:15
Phoenix Plaza	8:00 to 9:00	5:45 to 6:45	11:00 to 12:00	8:00 to 9:00
Summit Square	8:00 to 9:00	5:45 to 6:45	11:00 to 12:00	8:15 to 9:15

Table 2 Observed trip generation during peak hours.

Shopping Complex	Observed vehicle trip ends	
	AM Peak	PM Peak
Bangsar	126	732
Kompleks Desa	144	808
Plaza Phoenix	178	958
Summit Square	131	731

Table 3 Details of the independent variables.

Shopping Complex	*LA* (ft^2)	*GFA* (ft^2)	*SHP (unit)*	*AREA (acres)*	*CP (unit)*	*AT* (ft^2)
Bangsar	245,592	605,000	210	3.35	560	68,420
Kompleks Desa	280,000	700,000	270	3.00	560	80,000
Phoenix Plaza	400,000	1,000,000	260	3.09	550	135,000
Summit Square	320,000	800,000	275	3.00	750	160,000

Note: LA is Total Leasable Area, GFA is Total Gross Floor Area, SHP is number of shop lots, CP is no of Car Parking Spaces, AT is Anchor Tenant built-up area, AREA total development area, VAR is volume on adjacent road, TSF is thousand square feet, ASC area of shopping complex.

Table 4 Correlation results of independent variables against vehicle trip ends.

Variables	AM commuter peak hour shopping trip ends	PM commuter peak hour shopping trip ends
LA	0.875	0.828
GFA	0.873	0.826
SHP	0.345	0.275
AREA	-0.307	-0.241
CP	-0.432	-0.516
AT	0.307	0.218

A.M. and P.M. Commuter Peak Trip Rates

Based on the degree of correlation, A.M. commuter peak trip rates were generated per thousand square feet (TSF) for the selected independent variables. Table 5 highlights the result of the analysis.

All shopping complexes generally have a low traffic generation rate during the A.M commuter peak hour. This is because, the A.M commuter peak hour occurs between 8:00 to 9:00 A.M, while the shopping complexes are only open for business after 10:00 A.M. The trips associated with shopping complex during A.M. peak are only trips made by the employees of the shopping complexes.

Traffic generation during the P.M peak is generally higher than the A.M commuter peak. This is because the P.M commuter peak involved traffic associated with patrons of the shopping complex. The trip rates were tested against the weighted average and best fit line of regression analysis. Total leasable area and gross built-up area provided a good fit. Car parking spaces yielded a poor fit. This indicates that many of the employees of the shopping complex travel on the public transportation.

Generator Peak Hour Trip Rates

The analysis indicates that total leasable area and gross built-up area provided acceptable degree of correlation. Anchor tenant is suitable for the A.M generator, while parking spaces may be useful for the P.M generator. These independent variables were used to establish the generator peak hour trips. The results of the analysis are shown in Table 6.

Table 5 A.M. and P.M. commuter peak trip rates.

Shopping Complex	A.M. COMMUTER PEAK				P.M. COMMUTER PEAK			
	AR veh/hr	veh/h/ TSF LA	veh/hr/ TSF GFA	veh/hr/ CP	AR veh /hr	veh/hr/ TSF LA	veh/hr/ TSF GFA	veh/hr/ CP
Bangsar	126	0.51	0.21	0.23	732	2.98	1.21	1.31
Kompleks Desa	144	0.51	0.21	0.26	808	2.89	1.15	1.44
Phoenix Plaza	178	0.45	0.18	0.32	958	2.40	0.98	1.74
Summit Square	131	0.41	0.16	0.17	731	2.28	0.91	0.97

Note: AR is adjacent road

Table 6 A.M. and P.M. generator peak trip rates.

Shopping Complex	A.M GENERATOR				P.M GENERATOR			
	AR veh /hr	veh/hr/ TSF LA	veh/hr/ TSF GFA	veh/hr/ CP	AR veh /hr	veh/hr/ TSF LA	veh/hr/ TSF GFA	veh/hr/ CP
Bangsar	945	3.85	1.56	13.81	1,008	4.10	1.67	1.80
Kompleks Desa	808	2.89	1.15	10.10	1,032	3.69	1.47	1.84
Phoenix Plaza	1,151	2.88	1.15	8.53	1,296	3.24	1.30	2.36
Summit Square	979	3.06	1.22	6.12	977	3.05	1.22	1.30

Table 7 Comparison of calculated trip rates.

Analysis Period	This study's trip rates	Trip Generation Pilot Study of Malaysia (1997)
A.M Commuter peak hour	0.46	0.44
P.M Commuter peak hour	2.59	2.92
A.M generator peak hour	3.12	3.18
P.M generator peak hour	3.46	3.93

VALIDATION OF THE TRIP GENERATION EQUATIONS

The Trip Generation Pilot Study of Malaysia [10] has calculated trip rates and equation for various land uses including the shopping complex. However, the calculations presented are only for the Gross Leasable Area. It is important that the calculated trip rates be validated in order the objective to determine the pass-by and diverted traffic can be ascertained. Thus, the results were compared with Trip Generation Pilot Study of Malaysia [10]. Table 7 compares between this study trip rates with the Trip Generation Pilot Study of Malaysia [10].

The student *t*-distribution was used to test the null hypothesis at 5 % level of confidence. The *t* score obtained from the samples is –0.2730. The critical value is 2.4469. Based on this, the results showed no significant difference. Thus, the process of estimating the pass-by and diverted traffic was carried out.

MODELLING THE PASS-BY AND DIVERTED TRIPS

Analysis were conducted for the generator peak periods, since this period has shown to be the major traffic generator. The results from the interview survey were used to model the composition of pass-by and diverted traffic. The observed traffic volume on the adjacent roads and the composition of pass-by traffic are summarised in Table 8.

Correlation analysis was conducted to determine the independent variables suitable for use in the modelling. The volume on adjacent roads, number of shoplots and area of the shopping complex can be used for the pass-by trips. While, total leasable area, gross built-up area and volume on adjacent road were good for the diverted trips. Table 9 provides the summary of the weighted average, regression equation on the independent parameters and the corresponding R^2.

Table 8 Traffic volume on the adjacent roads and composition of pass-by and diverted traffic.

Shopping Complex	A.M generator			P.M generator		
	volume on AR (veh/h)	volume of DT (veh/h)	volume of PB (veh/h)	volume on AR (veh/h)	volume of DT (veh/h)	volume of PB (veh/h)
Bangsar Complex	2,151	32	83	2,245	77	69
Kompleks Desa	4,178	26	104	4,168	95	92
Phoenix Plaza	3,743	40	102	3,993	100	80
Summit Square	881	37	92	1,052	86	73

Note:AR adjacent road, DT is diverted traffic, PB is pass-by traffic.

Comparison with the Institute of Transportation Engineering [2]

The Trip Generation Pilot Study of Malaysia [10] does not provide any trip rates or equations for the pass-by and diverted trips. Hence, comparison were carried out with the Institute of Transportation Engineers [3] equations. Table 10 compares this study pass-by trip rates with the Institute of Transportation Engineers [3].

Table 9 Weighted average and regression equations for the pass-by and diverted trips.

A.M Generator		P.M Generator	
Pass-by	***Diverted***	***Pass-by***	***Diverted***
Per VAR Weighted average: T=0.03(X_7) Standard Deviation: 0.01 Regression Equation: T=0.005(X_7)+82.23 R^2 = 0.56	er LA Weighted average: T=0.109(X_1) Standard Deviation: 0.04 Regression Equation: T=0.073(X_1)+11.22 R^2 = 0.59	Per VAR Weighted average: T=0.03(X_7) Standard Deviation: 0.01 Regression Equation: T=0.005(X_7)+62.35 R^2 = 0.60	Per LA Weighted average: T=0.287(X_1) Standard Deviation: 0.02 Regression Equation: T=0.118(X_1)+52.66 R^2 = 0.58
Per SHP Weighted average: T=0.08(X_3) Standard Deviation: 0.04 Regression Equation: T=0.244(X_3)+33.54 R^2 = 0.55	Per GFA Weighted average: T=0.03(X_2) Standard Deviation: 0.01 Regression Equation: T=0.028(X_2)+11.97 R^2 = 0.57	Per SHP Weighted average: T=0.31(X_3) Standard Deviation: 0.04 Regression Equation: T=0.207(X_3)+25.92 R^2 = 0.37	Per GFA Weighted average: T=0.115(X_2) Standard Deviation: 0.01 Regression Equation: T=0.047(X_2)+53.04 R^2 = 0.60
Per ASC Weighted average: T=30.70(X_4) Standard Deviation: 8.30 Regression Equation: T=-44.75(X_4)+234.65 R^2 = 0.57	Per AT Weighted average: T=0.306(X_6) Standard Deviation: 0.10 Regression Equation: T=0.111(X_6)+21.54 R^2 = 0.59	Per ASC Weighted average: T=25.24 (X_4) Standard Deviation: 6.49 Regression Equation: T=-40.39(X_4)+204.12 R^2 = 0.44	Per VAR Weighted average: T=0.031(X_7) Standard Deviation: 0.01 Regression Equation: T=0.005(X_7)+75.10 R^2 = 0.52

Table 10 Comparison with ITE [2] pass-by trip rates.

Origin of Rates	Trip Equations	
	X = VAR	X = TSF LA
ITE	$T=\left[\frac{157.357}{X}+0.022\right]^{-1}$ $R^2 = 0.26$	Ln(T) = -0.341 ln(X)+5.376 $R^2 = 0.34$
This research	T=0.005(X)+62.35 R^2 = 0.60	T=0.207(X)+25.92 R^2 = 0.37

Both of these equations differ in term of, the ITE equations were based on the fitted curve, while the study models were from the best-fit line. However, the study rates showed similarity with the Institute of Transportation Engineers [3], in that, as the volume on the adjacent road increases, the pass-by volume also increases. The difference in the equations can be attributed to the difference in travel characteristics between the two countries. The equation of gross built up area shows that many of the Malaysian shoppers do not seem to be discouraged by the size of the shopping center. This may be attributed to the numbers of off-site parking. The interview surveys showed that between 8-10 % of all vehicle trip ends are parked off-site.

CONCLUSIONS

This study was conducted to investigate the trip generation characteristics of shopping complexes. This is because unlike other land uses, a shopping complex has a unique trip generating pattern. The aim is to determine the pass-by and diverted trip volume, to enable a practical assessment on the impact of new shopping complexes. The analysis showed that, the gross leasable area and gross built-up areas are good variables to estimate the trip generation of a shopping complex. Pass-by trips is better represented by the traffic volume on the adjacent roads.

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