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Trip Generation for shopping malls in Developing Cities

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Abstract

This study develops trip generation models for shopping malls in Mumbai, one of the fast-developing cities. A total of eighteen shopping malls are selected to develop trip generation models using regression analysis. The factors that found significant in weekdays and weekend trip attraction models include built-up area, number of screen and seats in multiplex, number of kiosk and stores, number of parking spaces and gross floor area. Based on the video data collected at two shopping malls, it was found that the peak period is from 6 PM to 9 PM. The findings of this study can be used analyze the impacts of newly constructed shopping malls and plan transportation infrastructure in and around a shopping mall.

Keywords: shopping malls; trip generation; stepwise regression; Mumbai

1. Introduction

When a service facility such as shopping mall, school, college, bank, hospital, or commercial centre is planned, it is essential for traffic engineers and transportation planners to determine the expected traffic volume produced or attracted by such facility. Determination of a total number of trips (or expected traffic volume) produced from or attracted to given landuse is called trip generation modelling. The expected traffic volumes can help understand traffic impact on the adjacent street and traffic variation pattern in the facilities. When a new facility is being developed, estimates of traffic generated help in understanding parking space and nearby roadway capacities requirements. We can use the trip generation information to assess various impacts (traffic, environment, noise, etc) on the surrounding area. Most of the trip generation residential area or mixed type of land use. Limited studies are reported on the attraction type of land use like shopping malls, hospitals, restaurants, colleges, hotels and

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commercial establishments. This study focuses on trip generation of shopping malls of Mumbai.

1.1 Malls in India

India's retail sector has been undergoing structural changes for the last two decades. Lined with speciality retailers, shopping malls started doting the retail markets of the country's top cities during the late-1990's-early 2000's. Since then, the mall culture gradually pervaded the population, especially in the metros and mini-metros, marking the beginning of the modern retail movement in India. The transformation of the Indian retail market into an organised sector further aided the mall proliferation in major cities in India. From just a hand count of malls (around less than 10 in the entire country) in the early 2000's, the number of malls reported to be operational in 2016 was 612 (Malls of India 2017). It is estimated that 201 more malls are under development and likely to be operational by the end of 2019, taking the count of shopping malls in India to over 800. What is more intriguing is the current rate at which the number is growing; from around 470 operational malls in 2013, the number has grown to 612 malls in just three years.

The Malls of India (2017) study reports that India's total Mall Retail Area in 2016 is 175.5 million square feet with an average Gross Leasable Area (GLA) of 286,764 square feet per mall. The ratio between built-up area (BUA) and GLA is estimated to be around 1.6 which denotes that the average BUA of a mall in India is approximately 458,822 square feet. Additionally, the average number of stores per mall is estimated to be 102. Region-wise analysis of the shopping malls in the country reveals that the North region leads in the percentage of GLA share of operational malls, followed by West and Central, South and East. As far as the city type-wise classification is concerned, metro cities expectedly have the highest GLA share of shopping malls. In contrast, Tier 1 and Tier 2 cities share similar GLA percentage. Figure 1 (a) and (b) represents the GLA percentage region-wise and city type-wise, respectively.

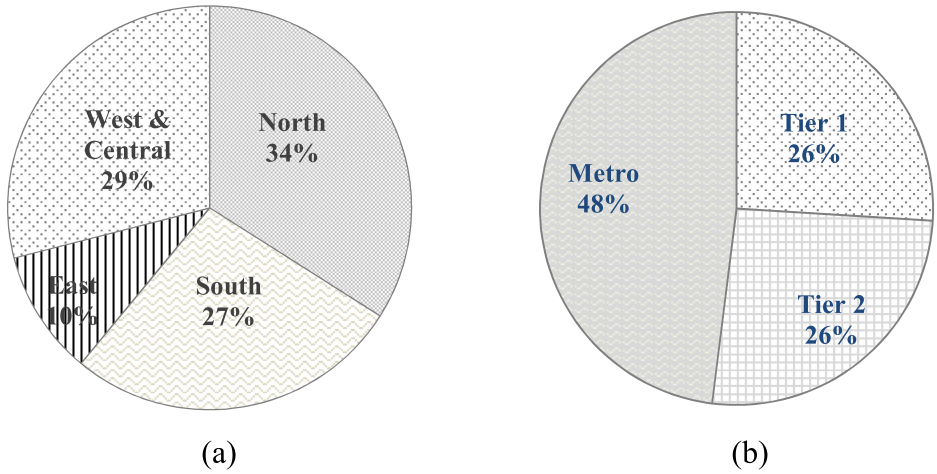


Figure 1: GLA Share (a) Region wise (b) City-type wise

According to the available data in Malls of India (2017), about 85% of the shopping malls are small-sized, having GLA between 100 thousand sq. ft to 500 thousand sq. ft. A small-sized mall has an average retail space of 233,000 sq. ft., a medium-sized mall has 667,000 sq. ft. and a large-sized mall has an average space of 1.3 million sq. ft. A medium-sized mall in India is 3 times the size of a small-sized mall, and a large-sized mall is twice as large as a medium-sized mall or six times larger than a small-sized mall. Region-wise analysis of the GLA share of the operational malls reveals that the East region has 89% of its malls as small-sized while the rest of the regions have GLA share of just below 60% of their malls as small sized. The North region has about 24% of its shopping mall GLA share as large-sized malls. City type-wise GLA share of the malls indicates that Metro cities have 20% of its malls as a large-sized mall and have the lowest percentage (about 53%) of its malls as small-sized when compared to Tier 1 and Tier 2 cities. Figure 2 (a) and (b) represent the size classifications of the operational malls based on regions and city types.

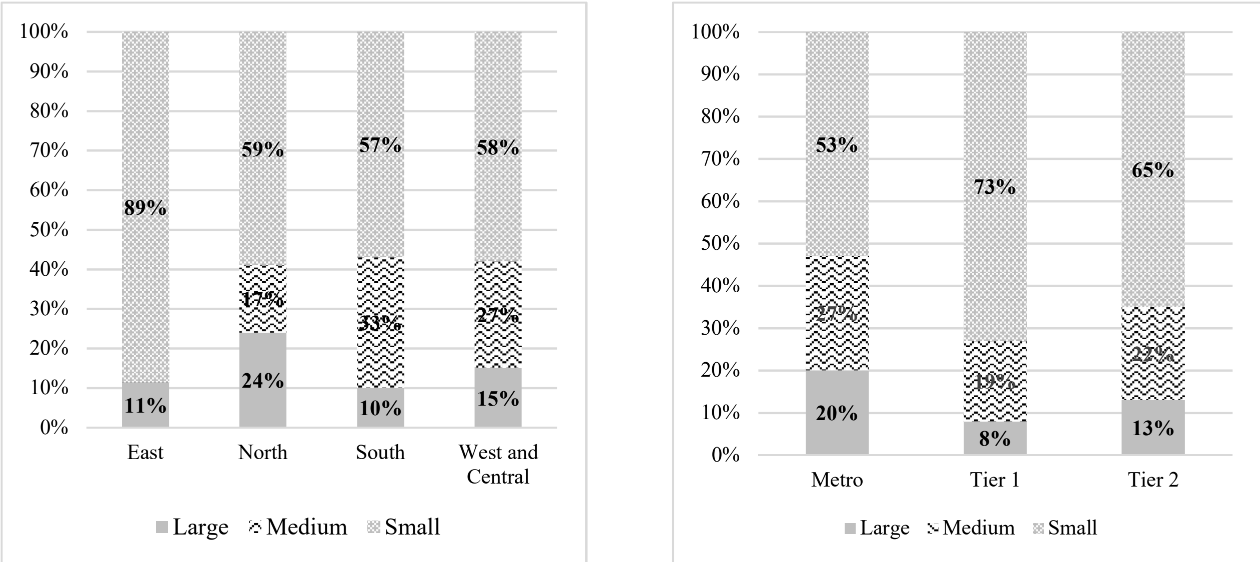


Figure 2: GLA Share of Operational Malls (a) Region wise; (b) City Type wise

1.2 Malls in the Mumbai region

Maharashtra has the maximum number of operational malls among all the states in India; it also shares about 22% of GLA of shopping malls in the entire country. One of the prominent epicentres of the shopping mall revolution in India in the last one and a half decades has been the capital of Maharashtra, Mumbai; it is also regarded as the country's financial capital. The twin cities of Mumbai and Navi Mumbai have about 53 operational malls as of 2016. With just a solitary mall in 2003 and about 22 malls in 2009, the number has more than doubled since then. Mumbai alone accounts for around 25% of the mall stock across the top 6 cities in India. Data on the space occupied by various segments in the shopping malls in Mumbai reveal that the Apparel sector occupies almost 1/4th of the space, followed by Departmental Store (these are general retail establishments which offer a wide range of goods across several product categories) and then Multiplex and Family Entertainment Centres (FEC). The details of the occupancy percentage of various segments are presented in Figure 3. Shopping malls in Mumbai continues to attract interest from foreign apparel retailers and domestic Food and Beverage (F&B) chains in the forms of pubs and cafes, among others.

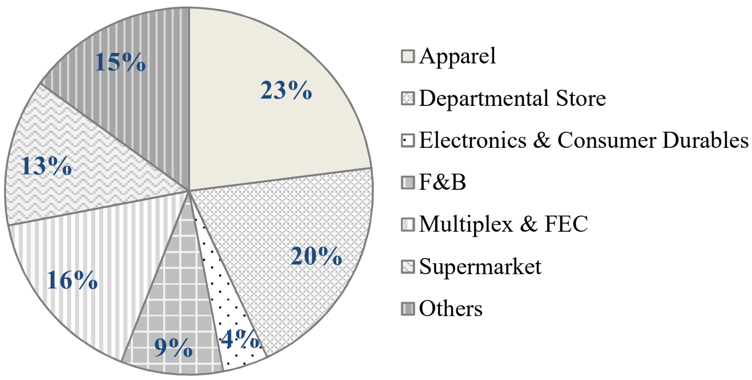


Figure 3: Category wise share of occupied space in malls

Undoubtedly, Mumbai has witnessed one of the steepest rises in India in the number of shopping malls over the last decade and a half. Being the country's financial capital, the presence of the finance powerhouses and institutions further boosts the economic activities that promote the shopping mall culture. With an increase in the overall income coupled with changing socio-economical lifestyle and improved affluence, consumer behaviour towards the organised sectors has made shopping malls increasingly attractive. This results in frequent visits to the malls and consequently higher shopping mall trips. The presence of a plethora of shopping malls in the city and the vibrant activities within them make Mumbai an interesting choice for the study of shopping mall trip generation. This study concentrates on identifying the factors that influence the number of shopping mall trips (persons and vehicles) in Mumbai, which may aid transport planners in policy decisions pertaining to such land-uses.

2. Literature Review of Trip Generation models

Many trip generation studies have been done by various researchers focusing on particular types of land use. Different land-use types require identifying factors that influence the trip generation for that particular type of land-use. This section attempts to review the existing literature on various types of trip attraction studies done in the past for various land-uses including shopping malls.

The study that focuses on shopping malls or shopping centres include New Hampshire Department of Public Works and Highways (1977), Faghri et al. (1999), Mamun et al. (2014), Uddin et al. (2012), Kikuchi et al. (2004), Peyrebrune (1996), Goldner and Da Silva Portugal (2002), and Al-Masaeid et al. (2018). The literature has many studies focusing on other landuses; for example, schools or universities (Arliansyah and Hartono 2015; Rahman 2009; Sian 2003; Ahmed et al. 2014), hospitals (Waloejo et al. 2013), restaurants (Ahmed et al. 2014), commercial areas in general (George and Kattor 2013; Sasidhar et al. 2016; Navya et al. 2013), suburban office buildings (Delaware valley regional planning commission 1996) and for mixed land use (Fillone et al. 2003). The variables considered for each of the land-uses are different and case-specific. For example, for school and university land-use, variables such as the number of students (Arliansyah and Hartono 2015; Sian 2003; Ahmed et al. 2014) and regional/zonal population (Arliansyah and Hartono 2015; Sian 2003) were the most used variables. Rahman (2009) evaluated the impact of holding capacity, cost index and accessibility on school trips and concluded that accessibility is the most important influencing factor for determining school trip generation. Arliansyah and Hartono (2015) found out that the number of students, the number of teachers and the number of offices and school building areas were the most significant variables in determining the zonal level school trip generation. Apart from the number of students and zonal population, Sian (2003) stated that vehicle ownership is also an important factor in determining the vehicular trip generation of schools. For the trip generation study of the hospital land-use (Waloejo, et al. 2013) related daily vehicle trips attracted to the parameters namely number of doctors/staff, a number of daily patients, the width of the in-service room, the width of parking lot and width of the building. Out of these, the number of daily patient and width of in-service rooms was most significant. As far as the restaurant land-use is concerned, Ahmed et al. (2014) related the trip generation to the gross floor area, number of parking spaces and number of seats. Several other studies in the literature attempt to model the trip attraction of commercial areas in general. George and Kattor (2013) found the number of commercial establishments, percentage of shops and percentage of banks to be the most significant variables determining the trip attraction of commercial land use, whereas, Sasidhar et al. (2016) concluded that the number of stores, floor area and the number of employees are the most significant factors. A study by Navya et al. (2013) on modelling the trip attraction model for CBDs found the number of employment opportunities and the number of commercial establishments as the most significant variables influencing the number of trips attracted. A study on the trip attraction for mixed land-use by Fillone et al. (2003) inferred that residential floor area, number of parking spaces, occupancy rates and commercial floor area are the most significant variables for mixed land-use.

The primary focus of this study is to develop trip generation models exclusively for shopping mall land-use. Few studies have been done in the past focusing on trips generated by shopping malls/ centres and their associated influencing attributes. The New Hampshire Department Study (1977) took into account the gross leasable area (GLA), traffic on adjacent highways and the age of the shopping mall to determine the daily average vehicular trips attracted by the mall. The study proposed two models: one model for the large-sized mall (GLA greater than 200,000 square feet) consisting only GLA as the influencing variable, and the other for the medium-sized mall (typically for 50,000 to 150,000 square feet) consisting of GLA, age of the malls and adjacent traffic as the influencing variables. The temporary variation of traffic over a day was also studied in this report. Peyrebrune (1996) and Goldner and Da Silva Portugal (2002) found that Gross leasable area is significant for predicting trip generation from shopping centres. Al-Masaeid et al. (2018) developed a trip and parking generation model for shopping centres, and they found that Gross floor area and the number of employees are the most significant variables. Faghri et al. (1999) develop a regression and Artificial Neural Network (ANN) model to analyse the relationship between the percentage of pass-by trips generated by shopping centres and the influencing factors. The results indicate that the ANN models can represent the relationship between the percentage of pass-by trips, GLA and ADT (average daily traffic), better than the traditional regression models. A couple of studies have been done for shopping malls in Dhaka, Bangladesh (Mamun et al. 2014; Uddin et al. 2012). Mamun et al. (2014) collected data from six medium and small-sized shopping malls in Dhaka and developed two macroscopic trip generation models. The first model has gross floor area (GFA), the number of parking spaces and the number of restaurants as the significant variables in determining the trip attraction of the mall, whereas, in the second model total number of stores is used instead of the GFA. The authors inferred that the total number of stores is a better predictor than the gross floor area. Uddin et al. (2012) related the number of stores and gross floor area, and total parking spaces to the trips attracted to shopping malls. Kikuchi et al. (2004) conducted a study in 18 shopping centres in Delaware to determine the trip generation by the malls. This study adopted two approaches, microscopic (based upon each store attraction), macroscopic (based upon whole shopping centre attraction) and considered the number of parking spaces, total floor area (cumulative floor area of all stores in the centre), the total number of stores, availability of supermarket and discount shop in the shopping centre as the independent variables for the determination of trip attraction rate. Kikuchi et al. (2004) developed two separate trip attraction models: one related trip attraction to the floor area and a number of stores, and the other has only parking spaces as the independent variable. The author also concluded that the gross leasable area is a better indicator of trip attraction than the gross floor area. It is observed from the literature that the trip attraction rates of the shopping malls generally relates to the size of the business like the gross floor area, parking spaces, number of stores, etc. The studies, however limited, done on the trip generation for shopping malls reveal vital insights into the variables that are most likely to influence the number of vehicles or persons attracted to the malls.

The form in which the dependent variable was used is another interesting feature of the trip attraction studies done in the past for various land-uses. The trip attraction can be expressed either in person trips or vehicle trips. The trip attraction rate can either be reported daily, hourly or any other forms like 15 minutes interval basis. From the review of the literature, several forms of the dependent variable are observed. A few studies reported the trip attraction rate as the daily vehicular traffic (New Hampshire Department of Public Works and Highways 1977; Waloejo et al. 2013; Sasidhar et al. 2016; Navya et al. 2013). A few studies used daily person trips (Arliansyah and Hartono 2015; Rahman 2009; Ahmed et al. 2014; George and Kattor 2013; Sasidhar et al. 2016) as the outcome variable; few studies also preferred person trips per hour (Uddin et al. 2012; Sian 2003; Fillone et al. 2003) while few used car trips per hour, generally peak hour (Ahmed et al. 2014; Fillone et al. 2003). Few researchers also used the number of persons per 15 minutes (Mamun et al. 2014, Kikuchi et al. 2004) as the dependent variable. As far as the model structure is concerned, the majority of the previous studies have adopted linear regression for developing the trip attraction equations (New Hampshire Department of Public Works and Highways 1977; Mamun et al. 2014; Uddin et al. 2012; Arliansyah and Hartono 2015; Sian 2003; Ahmed et al. 2014; Waloejo et al. 2013; Ahmed et al. 2014; George and Kattor 2013; Sasidhar et al. 2016; Navya et al. 2013; Delaware valley regional planning commission 1996; Fillone et al. 2003). However, Shafahi and Abrishami (2005) adopted a neural and fuzzy-neural model for determining trip attraction rate and compared it to linear regression model; the models based on the fuzzy-neural method performed better than a linear regression model. Arliansyah and Hartono (2015) used the Radial Basis Function Neural Network (RBFNN) model and similarly inferred that its performance was superior to the linear regression model. However, due to the simplicity and ease of estimation, linear regression models are observed to be the most widely used for trip attraction models in the existing literature.

3. Data collection and Analysis

For this study, eighteen shopping malls were selected within Mumbai Metropolitan Region. The basic information of all the selected shopping malls is obtained from their official website. Figure 4 shows the location of shopping malls that are considered in the present study.

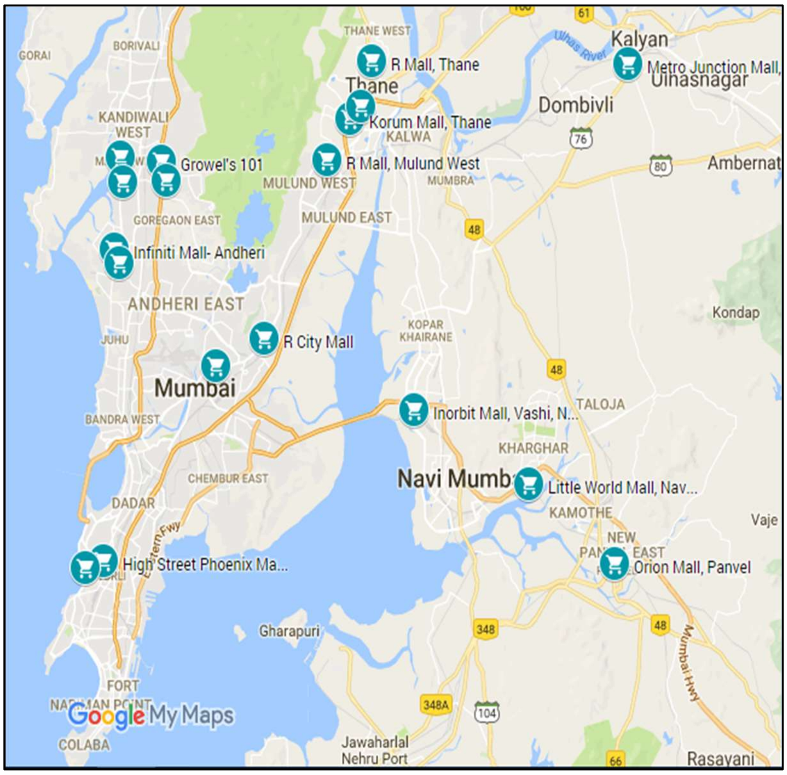


Figure 4: Selected shopping malls for Trip Generation modelling

Data regarding the total number of footfalls on weekday and weekend was obtained from the book, Malls of India (2017). The validation of the data is done using actual ground data collected at a few shopping malls (R-city Mall in Ghatkopar and Inorbit Mall in Malad). Apart from footfalls, other parameters considered for the study of trip generation in shopping malls are built-up area, gross-leasable area, number of stores, number of kiosks, number of two-wheelers and four-wheelers parking capacity, number of movie screens and number of seats in the multiplex.

3.1 Peak hour analysis for shopping malls of Mumbai

Analysing the peak hour of mall usage is important for shopping mall planning as well as for security purposes. To determine the peak hour of mall usage, two shopping malls in MMR are selected (i) R-city Mall, Ghatkopar; (ii) Inorbit Mall, Malad. From these selected malls, 24 hours of continuous data (number of footfalls) is collected and extracted at every 10 minutes time interval. Then, the total number of footfalls across six consecutive 10 minutes time interval (constituting an hour) for every such sequence is computed; the maximum of these summed hourly footfalls gives the peak hour for weekdays as well as for weekends. The peak hours for weekdays and weekends for R-city and Inorbit Mall are as shown in table 1.

Table 1. Overall Peak Hour Timings for selected shopping malls in MMR

Shopping Mall	Overall Peak Hour	
	Weekday	Weekend
R- City Mall, Ghatkopar	7:40 PM - 8:40 PM	6:20 PM - 7:20 PM
Inorbit Mall, Malad	7:30 PM - 8:30 PM	7:20 PM - 8:20 PM

The occurrence of peak hour on weekdays is earlier than on weekends. One reason for this can be that most people prefer to visit shopping malls on weekdays after their work/office hours. From this observation, consider the overall (entry and exit) peak period for any Shopping Mall in Mumbai region occurs between 6:00 PM to 9:00 PM.

3.2 Vehicle occupancy factors for shopping mall trips

This study is also used to calculate the occupancy factor for the car, two-wheeler, auto-rickshaw, and taxi visiting a shopping mall. Two-wheeler occupancy is easily captured from video data, but it is challenging to count the number of persons travelling inside car, taxi, and auto-rickshaw. Thus, the occupancy factor for the car, auto-rickshaw, and taxi were captured manually from Inorbit Mall, Malad (Table 2)

Table 2. Occupancy factor for shopping mall trips

Types of vehicles	Two-wheeler	Car	Auto-rickshaw	Taxi/Cab
Occupancy factors	1.615	2.215	1.829	2.065

From the collected data, the occupancy factor for two-wheeler is 1.615 person trips/two-wheeler, 2.215 person trips/car for car, 1.829 person trips/auto-rickshaw for auto-rickshaw and 2.065 person trips/ taxi for the taxi. These occupancy factors are used to convert vehicles trips into person trips.

4. Trip generation/attraction modelling

4.1 Trip rate analysis

The trip rate concept is one of the oldest and easy methods for trip generation modelling. The trip rates represent the sum of the persons or vehicular trips to and from a site divided by characteristics of the land use such as built-up area, gross leasable area, number of employees, number of stores (in case of a shopping mall) and number of parking spaces etc. This study uses the most appropriate and readily available land use measures for each type of land use, such as 1000 sq. feet of gross leasable area, 1000 sq. feet of built-up area and number of stores as a variable for trip rate analysis. Table 3 shows average weekday and weekend's person trip rates.

Table 3. Average weekday and weekend trip rates

	Trip Rates/1000 sq. ft. of GLA	Trip Rates/1000 sq. ft. of BUA	Trip Rates/No. of Stores
Weekday Trip Rates	152.94	98.64	505.54
Weekend Trip Rates	282.23	186.50	915.83

Note: Trip Rate = Person Trip Ends

4.2 Regression modelling

This study aims to develop trip generation models for shopping malls of the Mumbai Metropolitan Region. The trip generation equation for a specific land use type is the function of one or more independent variables associated with the land use. The selection of an independent variable for modelling is one of the important steps. Various independent variables such as built-up area, gross leasable area, number of parking spaces, number of stores, number of kiosks, number of multiplex screens and number of seats in multiplex etc., are considered for this study. The stepwise regression technique is adopted for this study to develop trip generation models. Stepwise regression technique automatically predicts the most suitable independent variables from the group of independent variables which explain the dependent variable. The statistical software used for the stepwise regression modelling is JMP Software.

4.3 Selection of variables for regression modelling

Correlation matrix can be used to determine the strength of association between the two variables thereby helping in choosing different combinations of independent variables. The correlation matrix of dependent and independent variables is presented in table 4. Generally, two variables having a high correlation need not be used in the same equation. From table 4, as we can see that the gross leasable area is highly correlated with the built-up area, number of stores, number of stores plus kiosk, and number of parking spaces. Built-up area is highly correlated with the number of stores, number of stores plus kiosk and number of parking spaces. Similarly, the number of stores is highly correlated with the number of parking spaces. This study has also considered other independent variables such as the population in the traffic analysis zone of the mall and population density within 10 km of buffer range, employment in the traffic analysis zone of the mall and employment density within 10 km buffer range, number of supermarkets in the shopping mall, number of restaurants etc.

Table 4. Correlation Matrix of Dependent and Independent Variables (n = 18)

	Y1	*Y2*	*Y11*	*Y22*	*GLA*	*BUA*	*Screens*	*NOSM*	*NOS*	*NOK*	*Store + kiosk*	*Screens*NOSM*	*NPS*	*log (store)*	*log(kiosk)*	*log (store + kiosk)*
Y1	1															
Y2	0.726	1														
Y11	0.909	0.748	1													
Y22	0.767	0.910	0.891	1												
GLA	0.689	0.624	0.682	0.675	1											
BUA	0.781	0.607	0.725	0.648	0.938	1										
Screens	0.787	0.602	0.697	0.600	0.732	0.680	1									
NOSM	0.798	0.596	0.724	0.623	0.701	0.479	0.970	1								
NOS	0.684	0.676	0.729	0.711	0.926	0.879	0.675	0.618	1							
NOK	0.242	0.438	0.383	0.455	0.486	0.387	0.301	0.273	0.446	1						
Store + kiosk	0.661	0.692	0.729	0.727	0.926	0.864	0.665	0.608	0.985	0.596	1					
Screens*NOSM	0.868	0.574	0.727	0.586	0.728	0.515	0.951	0.913	0.668	0.243	0.647	1				
NPS	0.525	0.562	0.606	0.612	0.868	0.774	0.719	0.691	0.795	0.625	0.835	0.649	1			
log(store)	0.622	0.584	0.776	0.725	0.797	0.775	0.539	0.514	0.919	0.457	0.914	0.547	0.730	1		
log(kiosk)	0.412	0.491	0.576	0.629	0.537	0.426	0.385	0.377	0.456	0.846	0.575	0.349	0.525	0.491	1	
log (store + kiosk)	0.604	0.581	0.780	0.738	0.785	0.755	0.521	0.500	0.886	0.571	0.907	0.525	0.749	0.988	0.598	1

*{Notations: Y1 = Number of Weekday Trips (in 1000); Y2 = Number of Weekend Trips (in 1000); Y11 = log (weekday trips); Y22 = log (weekend trips); GLA = Gross leasable area (in 10,000 sq. feet); BUA = Built-up-Area (in 10,000 sq. feet); Screens= Number of Screens in Multiplex; NOSM = Number of Seats in Multiplex; NOS = Number of Stores; NOK = Number of Kiosk; NPS = Number of Parking Spaces; Store+ kiosk = Number of stores and kiosk; Screen*NOSM = multiplication of number of screens in multiplex into number of seats in multiplex; log(store) = log of number of stores; log (kiosk) = log of number of kiosk; log (store + kiosk) = log of sum of store and kiosk)}*

4.4 Stepwise regression modelling

Multiple linear regression models for the trip generation were developed using JMP software (SAS Institute Inc. 2020–2021). In this software, several different procedures are available to develop multiple regression models. The 'tear-down' or 'backward elimination' method initially consider an equation containing all the available independent variables. It subsequently eliminates some of the independent variables to make the model statistically significant. The 'build-up' or 'forward selection' procedure strives for a similar outcome; however, it works in the opposite direction by inserting one more independent variable at a time. Stepwise regression is an improved version of the forward selection procedure. The independent variables in the model are re-examined at the end of each step. Stepwise regression evaluates the contribution of each independent variable in the model at the end of each step, regardless of when the independent variable has entered in the regression i.e. at the last step or at any of the earlier steps.

Table 5 shows the developed trip attraction models of different functional forms (linear–linear, linear-logarithmic and logarithmic-logarithmic). The overall goodness of fit of the model, captured by the coefficient of determination, R^2, and significance of variable is checked by t-values. All the estimated coefficients are statistically significant. This means the variables: built-up area, number of screens in multiplex, number of seats in multiplex, number of kiosk, number of stores are all important variables associated with the number of shopping mall trips. The positive coefficients of all variables indicate that an increase in any variables increase the total number of trips.

Table 5. Trip generation models for weekday and weekends

	Weekday Models						**Weekend Model**	
	Model 1		**Model 2**		**Model 3**		**Model 4**	
Dependent Variable →	Weekday trips (in 1000)		Weekday trips (in 1000)		Log (Weekday trips)		Log (Weekend trips)	
Independent Variables↓	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Constant	3.482	.369	18.485**	2.47	15.377***	3.529	3.778***	13.398
Built-Up-Area	2.906×10^{-5} **	2.41	2.154×10^{-5} *	1.96				
No. of seats in Multiplex	0.023**	2.69			15.66×10^{-5} **	2.93		
No. of screen*No. of seats in Multiplex			0.002 ***	3.76				
log (No. of store and Kiosk)					0.449 ***	3.67		
log (kiosk)							0.188*	1.911
log (store)							0.458**	2.910
R Square	0.743		0.806		0.757		0.623	
Adj. R Square	0.707		0.779		0.723		0.570	
AICc	159.1982		154.4029		-7.51248		1.072342	
BIC	159.1977		154.4024		-7.51296		1.071863	

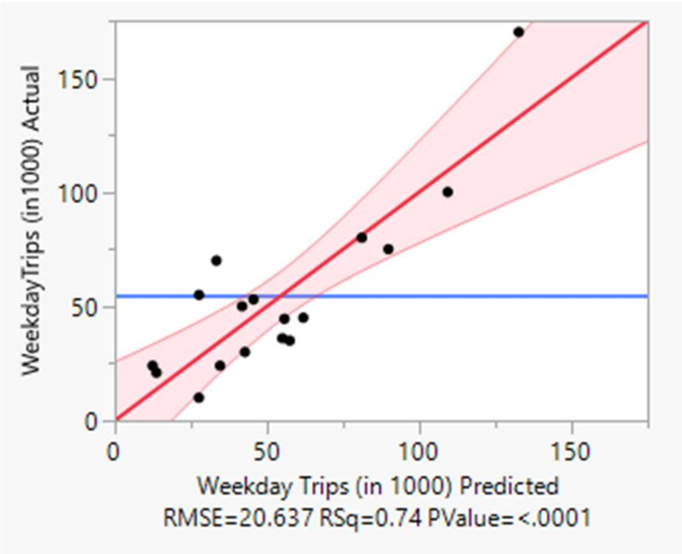
*Note: ***, **, * ==> Variables are significance at 1%, 5%, and 10% confidence level.*

We developed three models for weekday trips and one model for weekend trips, as shown in table 5. In model 1 (linear-linear functional form), the built-up area and number of seats in multiplex have a logically correct sign. This implies that if the built-up area and number of seats in the shopping malls increase, the number of weekday trips also increases. The R^2 value and adjusted R^2 value of the model is 0.743 and 0.707, respectively, which is significantly good. It shows that the developed model can explain 74.3% of the variation in the dependent variable (number of trips). On the other hand, the t-value of the number of seats in multiplex (2.69 > 2.11) and built-up-area (2.41 > 2.11) is higher than the t-critical value, which means that both variables are statistically significant at a 95% of confidence level.

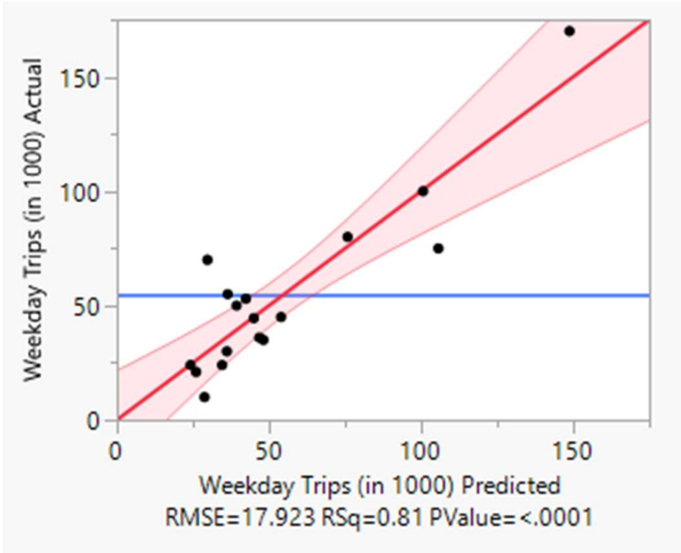
In model 2 (linear-linear functional form), built-up-area and interaction variable formed as a product of the number of screens in multiplex and number of seats in multiplex have a logically correct positive sign. It means if any of these two variable increases, the number of weekday trips also increases. The R^2 value and adjusted R^2 value of the model is 0.806 and 0.779, respectively, which is very good. It shows that the developed model can explain 80.6% of the variation in the dependent variable (number of trips). On the other hand, the t-value of built-up-area (1.96 > 1.74) and interaction variable of number of screen in multiplex and number of seats in multiplex (3.76 > 2.90) is higher than the t-critical value, which means that both variables are statistically significant at 90% and 99% of confidence level. As we can see here, the number of screens in multiplex along with the number of seats in multiplex (as an interaction variable) significantly improved the statistical fit of the model.

Model 3 (logarithmic-logarithmic functional form) shows that the number of seats in multiplex and number of stores and kiosks have a logically correct positive sign. That means, if the number of seats in multiplex and number of stores and kiosk increases then the number of trips also increases. The R^2 value and adjusted R^2 value of the model is 0.757 and 0.723, respectively, which is very good. It shows that the developed model can explain 75.7% of the variation in the dependent variable (number of trips in logarithmic form). On the other hand, the t-value of number of seats in multiplex (2.93 > 2.11) and number of store and kiosk in logarithmic form (3.67 > 2.90) is higher than the t-critical value, which means that both variables are statistically significant at 95% and 99% of confidence level.

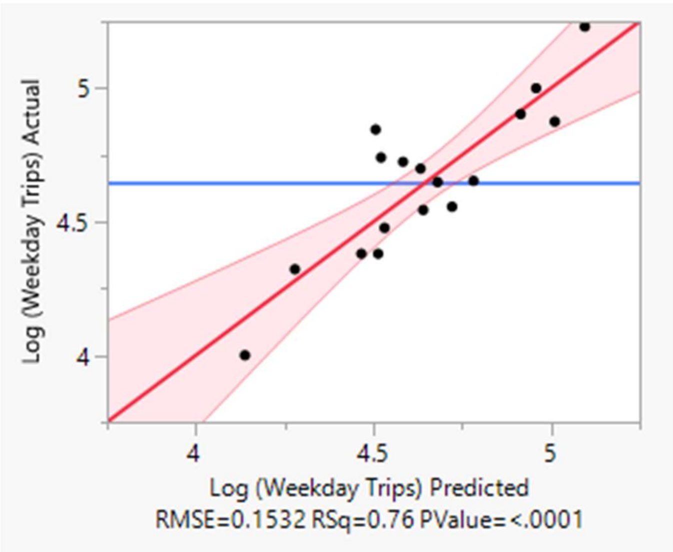
Compare the all three weekday's models, model 2 exhibits a better fit for the trip attraction for shopping malls. The linear-linear regression model (model 2) has a significantly higher R^2 value compare to the logarithmic-logarithmic regression model (model 3).



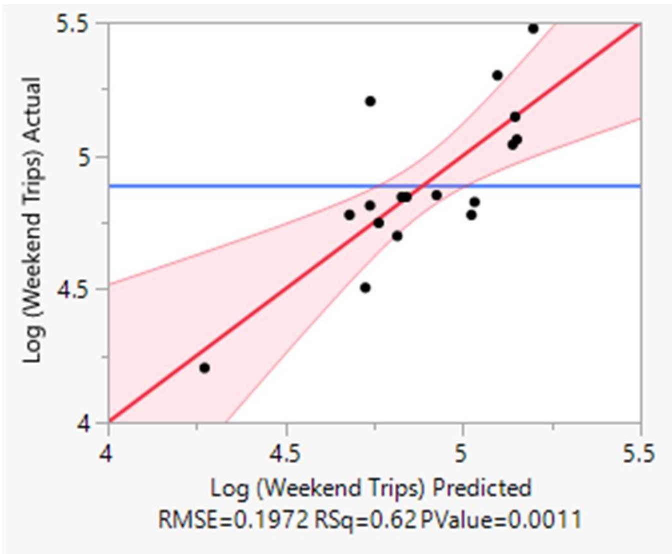
Model 1



Model 2



Model 3



Model 4

Figure 5: Actual versus predicted curve at 0.05 significance level

The developed weekend trip generation model is given as model 4 (logarithmic-logarithmic functional form). From the above equation, it appears that number of stores and number of kiosk as a separate variable in logarithmic form have logically correct sign. This implies that if number of stores and number of kiosk in the shopping malls increase, number of weekend trips also increases. The R^2 value and adjusted R^2 value of the model is 0.623 and 0.570, respectively, which is reasonable. It shows that the developed model can explain 62.30% of the variation in the dependent variable (number of trips in logarithmic form). The number of stores variable is found to be significant at 95% confidence level, whereas the number of kiosk variable is not found to be significant at 90% confidence level.

Figure 5 shows the actual versus predicted graphs of all models at 95% of confidence level (0.05 significance level); it provides a visual assessment of model fit. The points should be close to the fitted line for a good fit, with narrow confidence bands. From the figure, we can easily interpret that model 2 is best fitted among the developed trip generation models for shopping malls.

Note: *The number of footfalls in shopping malls is half of the number of trips. Developed models give a number of trips on weekday and weekends.*

5 Conclusion

In this study, trip generation equations for shopping malls of the Mumbai Metropolitan Region were developed. The trip generation was found to be related to five parameters Built-up area, number of screens in multiplex, number of seats in multiplex, number of kiosk and number of stores in shopping malls. The other parameters such as Gross-leasable area, number of parking spaces, population density, and employment density were found to have no significant impact or relationship with the number of trips generated from shopping malls. From this study, we can infer that the Built-up area (BUA) is a better parameter than the gross leasable area (GLA) for trip generation modelling in the context of shopping malls. The developed trip generation models can predict trip generations and help transportation planners predict trip generations more accurately for shopping malls in the local context.

The trip attraction models developed in the present study would be helpful in channelising traffic in the area around shopping malls and analysing the impact on traffic in the area surrounding a newly developed shopping mall. For further research, more independent trip attraction variables of activity centres such as average distance from home to shopping mall, accessibility of shopping malls, variety of stores and sales on products available in a shopping mall, average annual daily traffic volume on adjacent streets of the shopping malls and number of shopping malls in the vicinity of each mall may be incorporated. The trip generation rates and regression models achieved from this study can be used for further research to develop a database for Mumbai's shopping malls and the shopping malls of an entire country. The variables used in Mumbai models are likely to be important determinants of footfalls in any major cities in India. The parameters are also likely to be comparable. Therefore, although not exact, the developed models can be reasonably useful for understanding the trip generation rates at other metropolitan cities in the country. However, checking the transferability of the presented models in other cities and developing generalized models using the data from other cities can be a future scope.

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