

Traffic Impact Analysis for Proposed Construction in Warangal City



Bollini Prasad, Balendra Mouli Marrapu

Abstract: Traffic congestion is reaching intolerable levels in many cities in both developed and developing countries. New building developments are cited as one of the major causes of congestion in the cities. The uncontrolled growth of these developments adversely affects the quality of life and aggravates environmental and safety problems. Generally, it is seen that the new constructions are initiated and developed without giving due consideration to the ability of the existing transportation facilities to handle the additional traffic. Though the demand and supply characteristics of a transportation system must complement each other, it is not practically feasible to increase the supply infinitely to meet the demand. Hence, it is evident that Traffic Impact Analysis plays an important role in managing and reducing the uncontrolled development and its negative impacts on transportation system, environment and economy. A traffic impact analysis is an engineering study which assesses the adequacy of the existing or future transportation infrastructure to accommodate additional trips generated by a proposed development, redevelopment or land rezoning. The purpose of a traffic impact analysis review is to assess potential traffic impacts, identify acceptable mitigation strategic plan for the transportation requirement of future development, and maintain a balance between land use and quality of transportation services. An attempt has been made in this study to carry out traffic impact analysis for a proposed development in Warangal city. In this work, trip rate for the proposed development is computed on the basis of trip rates of similar existing developments. Combined Trip distribution and Assignment has been carried out using Traffic count based distribution model. Future condition Analysis has been done and appropriate mitigation measures are suggested.

Keywords : Traffic Impact Analysis, Traffic congestion, land use, trip generation, trip distribution.

I. INTRODUCTION

New developments are considered as one of the major causes of congestion as well as accidents. This is due the fact that commercial developments such as multiplexes, shopping complexes or educational institutions such as

schools and colleges form hubs of activity, there by generating large number of trips. Failure to address the management of land development and subsequent need for improved transportation planning and facilities will result in premature degradation of the transportation system. Thus a traffic impact study assesses the adequacy of the existing or future transportation infrastructure to accommodate additional trips generated by a proposed development, redevelopment or land rezoning. The purpose of a traffic impact analysis review is to assess potential traffic impacts, identify acceptable mitigation strategic plan for the transportation requirement of future development, and maintain a balance between land use and quality of transportation services. Thus the practice of traffic impact studies is widely adopted as a tool to guide appropriate land-use developments and to keep transportation systems operating effectively and efficiently. With the influx of large-scale developments, there is a tremendous increase in the traffic which in turn leads to congestion and safety hazards. However, one should not be blinded by the negative consequences of such developments as they are a major source of economic returns and indicators of the quality of life in a society. Therefore, instead of inhibiting the developments appropriate measures needs to be taken to contain the adverse effects. These impacts may be transportation related or environmental in nature. Traffic impact analysis are necessary in order to find out the negative impacts of a new development and for finding the mitigation measures to improve the transportation system so that a balance is achieved between supply and demand. It helps to check the adequacy of existing and future infrastructure to accommodate the new generated trips. Thus, it is useful in confining the uncontrolled and haphazard developments.

II. TRAFFIC IMPACT ANALYSES

A traffic impact analysis begins with trip generation, progressing to distribution and assignment, future condition analysis and culminates only after mitigation measures have been suggested. Among these, Trip generation is the most critical element of the site impact analysis. Traffic count based distribution model is used for the distribution and assignment of new generated trips. The future conditions analysis has been done to determine the impact of trips generated by the development on the performance of the transportation system.

2.1 Trip Generation Rate Analysis

Trip generation is the process used to estimate the amount of travel associated with a specific land use or development.

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The new trips generated from a site can be calculated based on the regression analysis or trip generation rate. Trip generation equations and rates are prepared based upon the type of land use. The dependent variable trips are represented

As a function of independent variable GFA in sqft. The total trips generated from the proposed development are calculated based on the trip generation rate and regression equation. Trip rate estimated using the regression analysis is adopted only if the R-squared value is greater than 0.75. In the other cases weighted average trip rate has been taken and is checked using the criteria specified by the Florida Department of Transportation. As per the criteria a low standard deviation of less than 110 percent of the average rate is good.

2.1.1 Commercial Complex

From the trip generation survey conducted for different commercial complexes having area varying from 4400 to 96000 sqft the trips generation equation has been developed for new site. The total trips generated from each complex are shown in the Table 1. The trip generation equations for the commercial complex are as shown in the Table 2

Table 1: Commercial Complex Areas and Trips

Complex	Area	Morning Peak hr	Evening Peak hr	Daily trips
Green Square plaza	96000	560	624	5452
C.P Reddy Complex	57600	355	400	3704
Jeevanlal Complex	40500	211	263	2184
Sahoder Reddy Complex	52000	169	228	1987
Ravindra	19200	50	57	648
Reliance	13100	81	136	639
Spencers	12000	61	87	481
Surabhi Food Court	4400	14	18	209

Table 2: Commercial Complex Trip Generation Equation

Time period	Shopping Complex	
	Regression Equation (Y = Trips and x =Area)	R ² value
Morning Peak Hour	$Y = 0.0058x - 26.54$	0.93
Evening Peak Hour	$Y = 0.0063x - 7.27$	0.94
Daily	$Y = 0.058x - 237.53$	0.95

2.1.2 Theatre

The trip generation rate is calculated based on the number of seats (independent variable). The total trips generated from each theatre are given in the Table 3. The trip rate of the multiplex theatre is as shown in the Table 4. The Standard Deviation obtained is less than 110 percent of the average rate. Hence the obtained rate is good.

Table 3: Theatre seats and Trips

Theatre	Seats	Morning Peak hr	Evening Peak hr	Daily Trips
Ashoka	880	119	297	600
Amrutha	875	110	275	550
Sri Devi	858	115	287	580
Vijaya Taxis	810	95	239	480

Table 4: Multiplex Theatre Trip Rate

Time period	Rate (Trips/Sqft)	SD
Morning Peak Hour	0.128	0.008
Evening Peak Hour	0.321	0.02
Daily	0.646	0.042

2.1.3 Govt. Offices

Based upon the existing trip generation characteristics of KUDA office and R and B department the trip generation rate has been calculated. The trips generated from the govt. offices are given in the Table 5. The trip generation rates for the govt. offices are shown in the Table 6. Since only two observations were available, weighted average trip rate has been calculated. The standard deviation was found out to be less than 110 percent of average rate. Hence, this rate is adopted.

Table 5: Govt. Office Area and Trips

Govt. offices	Area	Morning Peak hr	Evening Peak hr	Daily trips
R and B	13900	61	61	316
KUDA	29600	81	61	411

Table 6: Govt. office Trip rate

Time period	Trip Rate (Trips/Sqft)	SD
Morning Peak hr	0.0033	0.001
Evening Peak hr	0.0028	0.002
Daily trips	0.0167	0.006

By using the regression equation and trip generation rate the total trips generated from the new development is calculated. The obtained results are presented in Table 7.

Table 7: Summary of Daily and Peak Hour Trip Generation

Proposed Land Use	GFA (sqft)	Daily Trips	Morning Peak Hr Trips	Evening Peak Hr Trips
Govt. Offices	250000	4178	816	701
Commercial Complex	92000	5132	508	577
Multiplex Theatre	8000	226	45	112
Total	350000	9536	1369	1390

III. ESTIMATION OF NEW TRIPS

Total number of trips generated by a land use is affected by the internal trips and pass-by trips.

Diverted trips are not affected to this land use, since there is no other roadway to provide direct access to the site.

According to the ITE recommendations pass-by trip and internal trip rate has been applied based on the land use. The Tables 8, 9 and 10 represent the estimation of new trips in morning and evening peak hour and daily.

IV. TRIP DISTRIBUTIONS AND ASSIGNMENT

Traffic count based distribution model is the adopted distribution model for the site impact study. The distribution model is developed according to the relationships between the site origin-destination (OD) trips and the link traffic counts of the surrounding roadways.

Table 8: Estimation of Morning Peak Hour New Trips

Land Use	Trips	A	B=A*Rate	C=A-B	D=C*Rate	E=C-D
		Total trips	Internal trips	External Trips	Pass-By trips	New Trips
Govt. offices	Enter	575	29	546	82	464
	Exit	241	12	229	34	195
	Total	816	41	775	116	659
Shopping complex	Enter	269	13	256	90	166
	Exit	239	12	227	79	147
	Total	508	25	483	169	314
Multiplex Theatre	Enter	37	2	35	12	23
	Exit	8	0	7	3	5
	Total	45	2	43	15	28
Site Total	Enter	881	44	837	184	653
	Exit	488	24	463	116	347
	Total	1369	68	1301	300	1000

Table 9: Estimation of Evening Peak Hour New Trips

Land Use	Trips	A	B=A*Rate	C= A-B	D= C*Rate	E= C-D
		Total trips	Internal trips	External Trips	Pass - By trips	New Trips
Govt. offices	Enter	442	22	420	63	357
	Exit	259	13	246	37	209
	Total	701	35	666	100	566
Shopping complex	Enter	329	16	312	109	203
	Exit	248	12	236	82	153
	Total	577	29	548	192	356
Multiplex Theatre	Enter	75	4	71	25	46
	Exit	37	2	35	12	23
	Total	112	6	107	37	69
Site Total	Enter	846	42	803	197	606
	Exit	544	27	517	132	385
	Total	1390	70	1321	329	992

Table 10: Estimation of New Daily Trips

Land Use	Trips	A	B=A*Rate	C= A-B	D= C*Rate	E= C-D
		Total trips	Internal trips	External Trips	Pass-By trips	New Trips
Govt. offices	Enter	2340	117	2223	333	1889
	Exit	1838	92	1746	262	1485
	Total	4178	209	3969	595	3374
Shopping complex	Enter	2668	133	2535	887	1648
	Exit	2463	123	2340	819	1521
	Total	5132	257	4875	1706	3169
Multiplex	Enter	115	6	109	38	71

Theatre	Exit	111	6	105	37	68
	Total	226	11	215	75	140
Site Total	Enter	5123	256	4867	1259	3608
	Exit	4412	221	4192	1118	3074
	Total	9536	477	9059	2377	6682

4.1 Model Description

Relationships between Origin-Destination Trips and Link Counts are shown in Figure 1

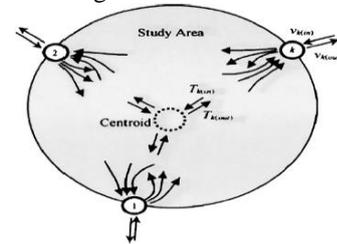


Figure 1: Trip Distribution Modelling (a)

The fundamental concept underlying the model is that, for a particular street link, its new generated trips from a site can be determined by the virtue of a correlation coefficient which is evaluated by the likelihood of traffic patterns of the total trips generated from the study area and the inbound or outbound traffic passing through this link. Here link traffic volumes are considered as the basis for combined distribution and assignment of the newly generated trips. The sums of all link counts could be expressed as follows:

$$V_{in} = \sum_k u_{k(in)}; V_{out} = \sum_k u_{k(out)} \quad (k=1, 2 \dots n) \quad (1)$$

where,

V_{in}, V_{out} = inbound and outbound area volumes;

$u_{k(in)}, u_{k(out)}$ = inbound and outbound link traffic volumes observed at the k^{th} entrance.

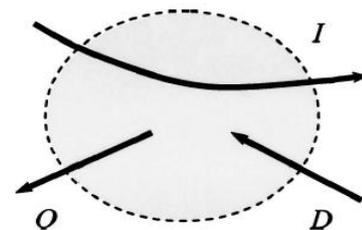


Figure 2: Trip distribution Modelling (b)

As shown in the Figure 5.2, the total link counts are composed of two parts: through trips -without their origins and destinations within the study area and generated trips - with either their origins or destinations within the study area. Algebraically, this can be stated as

$$O + I = V_{out}; \quad D + I = V_{in} \quad (k = 1, 2 \dots n) \quad (2)$$

Where I = through trips that have neither origins nor destinations in the study area. Equation 3.3 can be rewritten as

$$O = F_{out} V_{out}; \quad D = F_{in} V_{in} \quad (3)$$

Where F_{in}, F_{out} = through-trip coefficients which vary between 0 and 1.

Eq.5.3 shows that the volume of OD trips generated from a study area is a function of the total link counts obtained at the entrances to the area.

4.2 Correlation Coefficient Distribution Model

From the traffic survey conducted at each entrance to the study area, time series of traffic data are obtained as follows:

$$u^1_{k(in)}, u^2_{k(in)}, \dots, u^t_{k(in)}, \dots; u^1_{k(out)}, u^2_{k(out)}, \dots, u^t_{k(out)}, \dots \quad (k = 1, 2 \dots n; t = 1, 2 \dots m) \quad (4)$$

Where $u^t_{k(in)}$, $u^t_{k(out)}$ =inbound or outbound traffic volumes observed at the k^{th} entrance within the t^{th} interval.

According to Eq. 5.3 the OD trips corresponding to the t^{th} interval would be

$$O^t = F^t_{out} \cdot \sum_k u^t_{k(out)} = F^t_{out} \cdot V^t_{out}$$

$$D^t = F^t_{in} \cdot \sum_k u^t_{k(in)} = F^t_{in} \cdot V^t_{in} \quad (k = 1, 2 \dots n; t = 1, 2 \dots m) \quad (5)$$

It is assumed that during a short time period, F^t_{in} and F^t_{out} ($t=1, 2 \dots m$) remain unchanged, then

$$O^t = F^t_{out} \cdot V^t_{out}; \quad D^t = F^t_{in} \cdot V^t_{in} \quad (t=1, 2 \dots m) \quad (6)$$

The likelihood of time variations of O and $u_{k(out)}$, or D and $u_{k(in)}$, can be evaluated by the following correlation coefficients:

$$r^2_{k(O)} = \frac{\left[\sum_t (u^t_{k(out)} - \bar{u}_{k(out)}) \cdot (O^t - \bar{O}) \right]^2}{\sum_t (u^t_{k(out)} - \bar{u}_{k(out)})^2 \cdot \sum_t (O^t - \bar{O})^2} \quad (k = 1, 2 \dots m) \quad (7)$$

$$r^2_{k(D)} = \frac{\left[\sum_t (u^t_{k(in)} - \bar{u}_{k(in)}) \cdot (D^t - \bar{D}) \right]^2}{\sum_t (u^t_{k(in)} - \bar{u}_{k(in)})^2 \cdot \sum_t (D^t - \bar{D})^2} \quad (k = 1, 2 \dots m) \quad (8)$$

According to Eq. 5.6 and also since

$\bar{O} = F_{out} \cdot \bar{V}_{out}$ and $\bar{D} = F_{in} \cdot \bar{V}_{in}$, the correlation coefficient can be rewritten as

$$r^2_{k(O)} = \frac{\left[\sum_t (u^t_{k(out)} - \bar{u}_{k(out)}) \cdot (V^t_{out} - \bar{V}_{out}) \right]^2}{\sum_t (u^t_{k(out)} - \bar{u}_{k(out)})^2 \cdot \sum_t (V^t_{out} - \bar{V}_{out})^2} \quad (k=1, 2 \dots m) \quad (9)$$

$$r^2_{k(D)} = \frac{\left[\sum_t (u^t_{k(in)} - \bar{u}_{k(in)}) \cdot (V^t_{in} - \bar{V}_{in}) \right]^2}{\sum_t (u^t_{k(in)} - \bar{u}_{k(in)})^2 \cdot \sum_t (V^t_{in} - \bar{V}_{in})^2} \quad (k = 1, 2 \dots m) \quad (10)$$

Using the Eq. 5.9 and 5.10 the correlation coefficient can be found out. The Table 5.11 and 5.12 show the correlation coefficient obtained for morning and evening peak hours.

Eq.5.9 and 5.10 shows that the correlation coefficients between the site related OD trips and the individual link counts obtained at each entrance is equivalent to those between the total link counts and the individual link counts, given that the through-trip coefficients remain the same in a certain time period. The values of the correlation coefficients vary between 0 and 1. The bigger the $r^2_{(O)}$, or $r^2_{(D)}$, the more likely a trip generated from the site will pass through the k^{th} entrance, and the higher the probability that this trip will pass through the k^{th} entrance. Therefore, it seems reasonable to suppose that the probability that a trip produced from or attracted to the study area would be present at the k^{th} entrance is proportional to the $r^2_{(O)}$, or $r^2_{(D)}$. Furthermore, this probability is defined as

$$P_{k(O)} = r^2_{k(O)} / \sum_k r^2_{k(O)}$$

or

$$P_{k(D)} = r^2_{k(D)} / \sum_k r^2_{k(D)} \quad (k = 1, 2 \dots n) \quad (11)$$

Where $P_{k(O)}$, $P_{k(D)}$ = probabilities that a trip generated within the study area is observed at the k^{th} entrance.

Eq.5.12 allows a mechanism to build the following distribution model

$$\Delta T_{k(out)} = \frac{\Delta u_{k(out)} \cdot \Delta O \cdot r^2_{k(O)}}{\sum_k \Delta u_{k(out)} \cdot r^2_{k(O)}} \quad (k = 1, 2 \dots n) \quad (12)$$

$$\Delta T_{k(in)} = \frac{\Delta u_{k(in)} \cdot \Delta D \cdot r^2_{k(D)}}{\sum_k \Delta u_{k(in)} \cdot r^2_{k(D)}} \quad (k = 1, 2 \dots n) \quad (13)$$

Where ΔO , ΔD = site-related OD trips; $\Delta T_{k(in)}$, $\Delta T_{k(out)}$ = site-related inbound or outbound additional trips on the k^{th} entrance; $\Delta u_{k(in)}$, $\Delta u_{k(out)}$ =inbound or outbound additional traffic volume that will be expected in the future year on the k^{th} entrance.

The input data and Iteration Algorithm is given below. There are three groups of data that need to input in the model:

1. ΔO or ΔD , the additional trips generated from the new site.
2. $r^2_{k(O)}$ or $r^2_{k(D)}$ ($k = 1, 2, \dots, n$) the correlation coefficient
3. $\Delta u_{k(in)}$ or $\Delta u_{k(out)}$ ($k = 1, 2, \dots, n$) the additional traffic volumes that will be expected at the k^{th} entrance to the study area in future year.

Iteration Algorithm for finding out $\Delta T_{k(in)}$ or $\Delta T_{k(out)}$

$\Delta u_{k(in)}$ or $\Delta u_{k(out)}$ consists of two parts and can be represented as follows.

$$\Delta u_{k(in)} = \delta u_{k(in)} + \Delta T_{k(in)}$$

$$\Delta u_{k(out)} = \delta u_{k(out)} + \Delta T_{k(out)} \quad (k = 1, 2 \dots n)$$

1. Let $\Delta T^0_{k(in)}, \Delta T^0_{k(out)} = 0$ ($k = 1, 2 \dots n$)
2. Let $m = m+1$, and $\Delta u^m_{k(in)} = \delta u_{k(in)} + \Delta T^{m-1}_{k(in)}$; $\Delta u^m_{k(out)} = \delta u_{k(out)} + \Delta T^{m-1}_{k(out)}$ ($k = 1, 2 \dots n$);
3. Determine $\Delta T^m_{k(in)}$ and $\Delta T^m_{k(out)}$ ($k = 1, 2 \dots n$) by using the correlation coefficient distribution model;
4. If $|\Delta T^m_{k(in)} - \Delta T^{m-1}_{k(in)}| \leq \epsilon$, and $|\Delta T^m_{k(out)} - \Delta T^{m-1}_{k(out)}| \leq \epsilon$, ($k = 1, 2, \dots, n$; ϵ is an acceptable error), then stop; otherwise, go to step2.



By following the above iteration process the trip has been distributed and it is given in the following Tables 5.13 and 5.14.

Based on the above eq.5.12 and 5.13 the traffic can be distributed. The trip distribution for morning and evening peak hour traffic is as shown in Tables 5.13 and 5.14.

The morning peak hour and evening peak hour new generated traffic from the development are assigned to different links are as shown in the Figure 5.3 and 5.4.

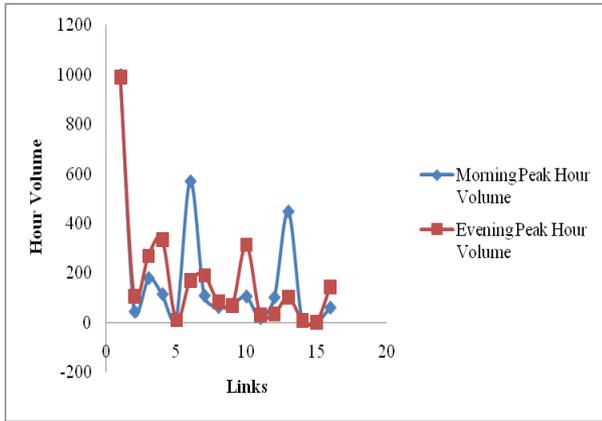


Figure 3: Morning and Evening Peak Hour Trip Assignment

4.3 Future Condition Analysis

The purpose of the analysis of future conditions for site impact analysis is to determine the impact of trips generated by the development on the performance of the transportation system. The volume to capacity ratio has been calculated and presented in the Table 5.16. The impact of the new development on each link can be identified by comparing the future condition analysis without development and with development.

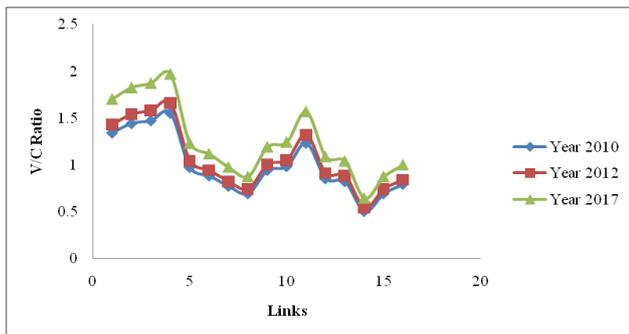


Figure 4: V/C Ratio of Links without development

From the Table 5.16 it can be understood that the link 1, 2, 3, 4 and 11 exceeds its capacity in the existing condition itself. Link 5 and 9 volume is near to reach its capacity. V/C ratios of links by including development are presented in Figure 5.

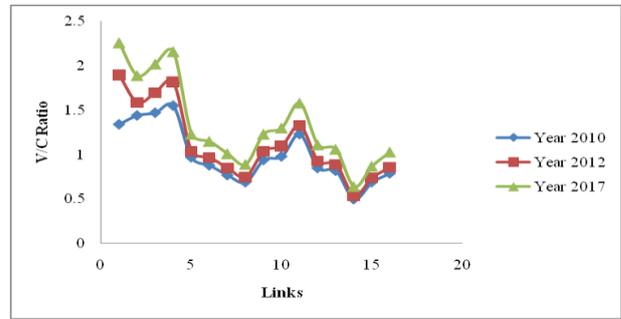


Figure 5: V/C Ratio of Links with development

From the Table 5.17 it can be understood that due to the development mostly affected links are link 1, 2, 3, 4, 6 and 10 since the probability of new generated trips to choose these links are more.

4.4 Parking Requirement Analysis

Parking is one of the serious problems that need to be confronted while carrying out the traffic impact analysis for a new development. Before any measures for the betterment of the conditions can be formulated basic data pertaining to the availability of parking space and parking demand are essential. Therefore, it is deemed necessary to include parking demand analysis in addition to v/c ratio calculation to check the negative impacts of the proposed site. Here parking requirement at the proposed site is calculated based on 0.01 probability of rejection. i.e. by considering the chance that out of 100 vehicles one vehicle is not getting space for parking. Using the probability of rejection equation the number of spaces required can be calculated.

$$P = (A^M/M!)/(1 + A + A^2/2 + \dots + A^M/M!)$$

Where P- probability of rejection

M- the number of parking spaces

A- Parking Load

The calculation is tabulated in Table 5.18.

Table 5.18: Peak Hour parking Requirement

Proposed land use	Incoming flow (cars)	Avg. parking duration (hrs/vehicle)	Parking Load	Required parking space
Govt. Office	90	0.93	84	100
Commercial complex	32	0.36	12	20
Multiplex Theatre	5	2.7	14	23

Minimum parking requirement for the development is 143 ECS. The parking space planning to provide is one car space for every 80 sqft build up area. Since the available parking space is more than the required the parking space provided is adequate.

V. CONCLUSIONS

For developing trip generation equation the gross floor area is considered as the independent variable for both govt offices and commercial complexes. For multiplex theatre number of seats is considered as independent variable. Regression analysis has been carried out for commercial complex trip generation and the R2 value obtained is more than 0.75.

Hence, it is clear that a significant relation exists between gross floor area (independent variable) and the number of trips generated (dependent variable). For govt. offices and multiplex theatre the trip generation rate has been calculated based on the weighted average rate. Since the Standard Deviation of the rates obtained is less than 110 percent of the average rate, the computed rates are acceptable by ITE standards. Therefore, it could be summarized that in situations where number of observations are less, weighted average trip rate is a useful method of trip generation. The traffic count based trip distribution model has been used to distribute and assign the traffic in the road network. One of the advantages of this model is that it does not rely on the land use characteristics and requires only traffic volume counts. It is therefore observed that the model is suited for small cities where land use data is either unavailable or incomplete. The future condition analysis without the development and with development has been done. The link 1, 2, 3, 4 & 11 exceeds the capacity in the existing condition itself. So immediate up gradation of these links are required as they are inadequate to cater to the transportation demand. Parking requirements for the future development has been estimated and it is found that the proposed parking is adequate.

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