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Effect of Encroachment on Level of Service of Urban Road: A Case Study of Ahmedabad City

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Abstract- The present work aims at analyzing the impact of Encroachment on traffic characteristics of urban roads. Study was conducted on urban road in Ahmedabad city. The encroachment factors were limited to vendors, on-street parking, pedestrians walking on carriage ways and crossing pedestrians. Observations were made using videography. To estimate combined effects of above mentioned factors, Encroachment Index is used to determine level of Encroachment. Vehicular speeds and capacity were estimated for with encroachment and without encroachment conditions. It was observed that vehicular speed decreases as encroachment level increase at different traffic volumes. Study shows reduction in speed. Speed-Density curves developed for both conditions and threshold values of Speed are suggested for LOS.

Keywords- Urban roads, Encroachment, Speed, Flow, Density, LOS.

1. INTRODUCTION

Rapid urbanization has resulted in increase in vehicular growth. This increase in vehicular population along with shortage of urban road space is consumed in the form of Encroachment. Encroachment like buses stopping at bus stops, parked vehicles, pedestrian traffic, frequent side roads, turning movements, trading activities, road side markets, etc. which affect the smooth flow of traffic are unique features found along urban roads in developing countries. These encroachment along with heterogeneous traffic conditions prevalent in developing countries, have a detrimental effect on level of service and capacity of urban roads as well as pose a serious threat to the safety of road users. Quantification of these encroachment factors is a challenging task to traffic engineers.

Road side markets along urban roads are very common in India. These markets act as pseudo bottleneck points and confusion zones to the traffic. Widening and strengthening of existing road is not solution to improve prevailing Level of service and capacity of that road due to several socio-economic factors and prevailing Land use patterns. In present study quantifying impact of Encroachment on speed, Level of service and Capacity of Indian urban road. Mid-block section on selected stretch of Ahmedabad city was selected as study section. During market timing presence of vendors, Pedestrians, on-street parking, and crossing pedestrians are considered as encroachment factors which are create resistance for through traffic movement. Traffic data and Encroachment data were collected from videos. Speed-density Graphs were developed for both conditions of with encroachment and without Encroachment. To indicate level of encroachment, used encroachment Index based on distance and area of individual encroachment factor. From data analysis suggest LOS criteria in the form of speed ranges and Encroachment indices and also compare capacity with HCM 2010 and INDO-HCM criteria. Outcome of the study will help policy makers to take decisions regarding strict imposition of laws to restrict development of such road side market areas and create more provisions for service roads and off-street market places.

2. LITERATURE REVIEW

(Amudapuram mohan rao et.al, 2016)[1] In the present study they took three types different side friction for a study such as on street parking, bus bay-stop, and curb side bus stops. They found average reduction in speed because of the side friction, 49-57% stream speed reduction found because of the bus stops and bays, where 45-67% speed reduced by on-street parking, by using both type of PCU values found that 10-53% capacity reduction in bus bays and bus stops, where 28-63% in on-street parking area location.

(Chinguma, 2007)[2] Studied the effect of side friction factors on urban traffic performance indicators speed and capacity. The side friction factors considered in this study include pedestrians, bicycles, stopped and parked vehicles on road.

(Gandupalli srinivasa rao, 2012)[4] PCU factors are calculated for different categories of vehicles and it is found that PCU for a vehicle is different on different on different sections. Then developed equation for stream equivalency factor (K) which is depends on traffic composition and a regression equation. Estimate capacity for different conditions. It conclude

that there was a considerable reduction in capacity due to side friction factors.

(Gaurav s chauhan et.al, 2017)[5] This paper consists of the concept of redesigning roads. It is case study of Medical road, Aligarh. It conclude different criteria to achieve solution for a problem, some beneficial ways used were controlling expansion of unauthorized construction, redesigning of roads.

(Karl-l. Bang, 2014)[9] Selected two different types of roads for data collection viz, urban roads and interurban roads. Using parameters and by giving weight to above parameters they concluded that on interurban roads free flow speed is reduced to factor 0.76 and capacity is almost reduced to 20%. Similarly, for urban roads speed is reduced to factor 0.59.

(Pallavi gulivindala et.al, 2018)[10] Pedestrian equivalency unit was estimated for converting frequency of vehicle type stopped on the road. It conclude that there was 51 % reduction in speed and 9% reduction in capacity. Also developed speed prediction model.

(Pratik u.mankar et.al, 2016)[11] It consist Capacity of urban roads is find out by green shield model and the results are compared with Microscopic simulation model through VISSIM. It was case study on stretches of Nagpur. Generate graph of capacity Vs width of carriage way, to estimate the capacity of road with change in width of carriage way.

(Salini S et.al, 2014)[12] The aims at analysing the impact of road side frictions on traffic characteristics

of urban roads. Multiple linear regression analysis was chosen to relate the factors contributing to

Table 1 : Inventory data

Road inventory data of Chanakyapuri road		
Sr. no.	Description	
1	Pavement type	Bituminous
2	Road type	6-Lane divided
3	Carriage way	11 m
4	Median width	0.9 m
5	Footpath width	2-2.5m

reduction in speed caused by side friction factors. It concluded that the hindrance offered by buses stopping at bus stops is to a higher extent than that due to pedestrians and parking.

(Sudipta pal et.al, 2016)[13] In the present study a methodology has been demonstrated to quantify roadside friction considering projected area and position of friction elements on carriageway. Impact on travel speed has been quantified and speed flow curves have been developed for different side friction levels. The criteria for five LOS have been recommended considering operational speed.

3. STUDY AREA

In this study chanakyapuri road was selected as study area located in Ahmedabad city. Location and selected road shown in fig. 1 and fig. 2 respectively. Heterogynous traffic found on selected road. At chanakyapuri road, in evening encroachment was found daily and in morning road is free from encroachment. Thus comparison would be possible at chanakyapuri road.

Inventory data of chanakyapuri road is shown in Table 1.

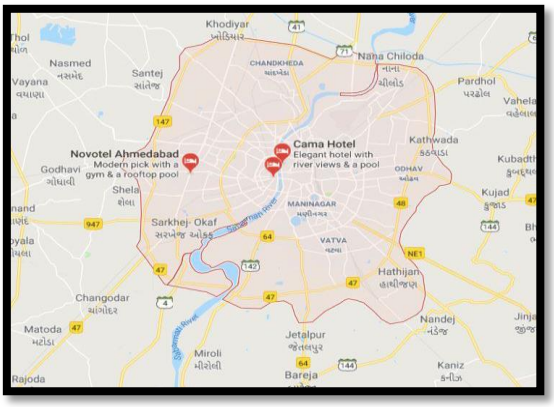

Figure 1 : Map of Ahmedabad city

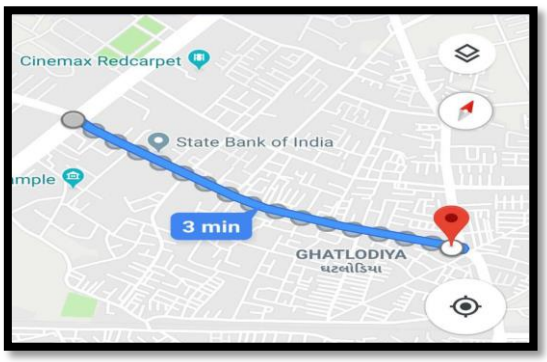

Figure 2 : Chanakyapuri Road

4. METHODOLOGY

Methodology adopted for this study was describe in below numbers of sections.

5. DATA COLLECTION

For this study, Videography was adopted for data collection. Videography done on chanakyapuri road for mid-block section length of 30 m. For encroachment data 3.5 m strip marked along the road. Videography done for peak hours in morning (without encroachment condition) and in evening (with

encroachment condition). From videos different data likes traffic data, speed data and Encroachment data were collected.

5.1 *Traffic data*

Road Classified volume count survey was carried out for study section for morning and evening time. It was observed that traffic composition in study section was heterogeneous. The proportion of two wheeler was more compare to other types of vehicles. The traffic composition shown in table 2.
Traffic flow (veh/5 min.) observed for morning and evening periods at 5 min. interval of time and flow were converted into veh/hr. Then all the flow data (veh/hr) were converted in PCU/hr.

Table 2 : Traffic composition

Type of vehicle	Morning	Evening
Bicycle	1.89%	3.96%
2W	71.08%	70.39%
3W	10.58%	12.56%
4W	14.64%	11.54%
LCV	1.45%	1.06%
HCV	0.19%	0.16%
BUS	0.16%	0.33%
Total	100.00%	100.00%

5.2 *Speed data*

Individual spot speeds of vehicles estimated from videos for each 5 min. of time interval. Two sets of spot speed data were collected, one set for without encroachment condition (morning) and another set for with encroachment condition (evening). For this study, need section speed, thus from spot speed data, space mean speed of each 5 min. interval were calculated.

6. ENCROACHMENT INDEX

During market time (evening) there were found numbers of vendors, pedestrians, cycles, rickshaws, four wheelers etc. as encroachment factors on carriage-way. Due to these factors through traffic was continuously disturb. These factors affect smooth flow traffic, also affect when flow was low.
There were different types of encroachment and it was very difficult to estimate effect of individual, thus introduced Encroachment Index to estimate combined effect of all factors of Encroachment.
For Encroachment data, Carriage way divided in three strips in longitudinal direction for representative length of 30 m. One strip called edge strip near to footpath where more encroachment found, it was decided based on repeatedly visited to market. Another two strip called Middle strip 1 and middle strip 2 from Edge strip to median of road. Figure 3 shows Detail of Edge strip and middle strip marked on carriage way.
Various Encroachment elements have different effect on traffic speed based on their physical dimensions and position on carriage-way. An Index namely 'Encroachment Index' has been proposed to quantify encroachment. All encroachment element has different weight factor based on dimensions and positions. Numbers of encroachment multiply by respective weight factors to estimate 'Encroachment Index' (EI) for that particular instant time.
Concept of Weight factor was developed to assign different weight to each element based on their contribution towards disturbance to through traffic. Weight factors were calculated based on projected area of respective friction element and their distance from carriageway edge. Weight Factor is summation of Area Ratio (AR) and Distance Ratio (DR), Mathematical formula as below,

$$\textbf{Weight Factor} = \textbf{Area Ratio} + \textbf{Distance Ratio}$$

Estimation of weight factors is summarised in Table 3. Finally weight factors were scaled considering pedestrian standing on edge strip as a unit of encroachment. Values of scaled Wright factor shown in Table 4. From videography noted numbers of those elements approach in different strips for each 5 min. interval. To calculate encroachment index, summation of all multiplication of individual weight factors and numbers of elements observed. Mathematical equation shown as below.

$$Encroachment\ Index\ (EI) = \sum WF * N$$

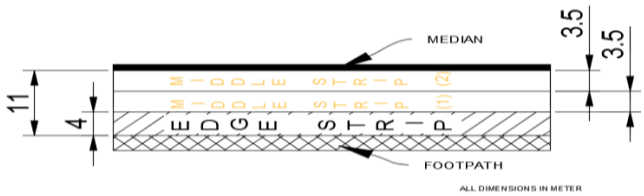

Figure 3: Details of Edge strip and Middle Strip

Table 3 : Estimation of Weight factors

Weight factor estimation for study road						
Sr. no.	**Details of Encroachment elements**	**Projected area (sq. m) (Ai)**	**Distance of cw edge(footpath) from strip mid point (Di)**	**Area ratio AR = Ai/Ap**	**Distance ratio DR = Di/De [De = 2.75 m]**	**Weight factor (Wi) = AR + DR**
Edge strip = 4 m						
1	Pedestrian (Ap)	0.50	2	1.0	1.0	2.0
2	Cycle	0.85	2	1.7	1.0	2.7
3	2W	1.20	2	2.4	1.0	3.4
4	Vendor (Laari)	2.75	2	5.5	1.0	6.5
5	3W (Rickshow)	4.48	2	9.0	1.0	10.0
6	4W	5.39	2	10.8	1.0	11.8
7	LCV	12.81	2	25.6	1.0	26.6
Middle strip (1) = 3.5 m [Di = 4 + 1.75 = 5.75]						
1	Pedestrian	0.50	5.75	1.0	2.88	3.88
2	Cycle	0.85	5.75	1.7	2.88	4.58
3	2W	1.20	5.75	2.4	2.88	5.28
4	Vendor (Laari)	2.75	5.75	5.5	2.88	8.38
5	3W (Rickshow)	4.48	5.75	9.0	2.88	11.84
6	4W	5.39	5.75	10.8	2.88	13.66
7	LCV	12.81	5.75	25.6	2.88	28.50
Middle strip (2) = 3 m [Di = 4 + 3.5 + 1.75 = 9.25]						
1	Pedestrian	0.50	9.25	1.0	4.63	5.63
2	Cycle	0.85	9.25	1.7	4.63	6.33
3	2W	1.20	9.25	2.4	4.63	7.03
4	Vendor (Laari)	2.75	9.25	5.5	4.63	10.13
5	3W (Rickshow)	4.48	9.25	9.0	4.63	13.59
6	4W	5.39	9.25	10.8	4.63	15.41
7	LCV	12.81	9.25	25.6	4.63	30.25
Crossing = 6 m [Di = 4.0 + 3.5 + 3.5 = 11.0]						
1	Pedestrian	0.50	11	1.0	5.50	6.50

Table 4 : Scaled weight factor

Scaled Weight factor					
sr. no.	Details of Encroachment elements	Edge strip	Middle strip (1)	Middle strip (2)	Crossing
1	Pedestrian	1.00	1.94	2.81	3.25
2	Cycle	1.35	2.29	3.16	
3	2W	1.70	2.64	3.51	
4	Vendor (Laari)	3.25	4.19	5.06	
5	3W (Rickshow)	4.98	5.92	6.79	
6	4W	5.89	6.83	7.70	
7	LCV	13.31	14.25	15.12	

7. DEVELOPMENT OF SPEED-DENSITY CURVE

To study the variation of speed profile with operating volume, speed-density curve were developed. Speed and traffic flow data were collected for each 5 min. interval. Spot speed data were converted in to space mean speed using below equation.

$$\textbf{Space mean speed} = \frac{n}{\sum \frac{1}{Vi}}$$

Where, n = numbers of vehicle observed and V_i = spot speed of individual vehicles. Density values were calculated from speed-flow data using fundamental relationship among traffic parameters (speed = flow x density).

Speed-density curves were developed to establish the relationship of observed data as shown in figure 4.

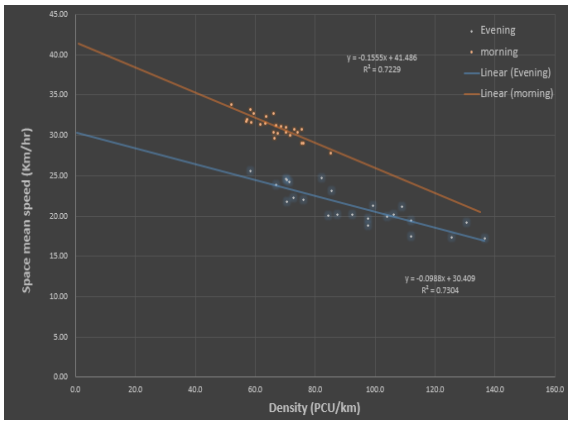

Figure 4 : Speed Density Curve (morning and evening)

8. DEVELOPMENT OF SPEED-ENCROACHMENT (%) CURVE

Encroachment Indexes were calculated for each 5 min. interval of time and corresponding space mean speed for that time. Indexes were converted in percentage. Speed vs encroachment (%) was developed to establish relationship observed data as shown in figure 5.

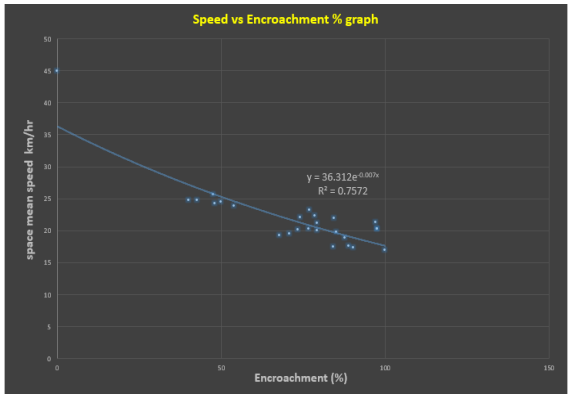

Figure 5 : Speed-Encroachment (%) curve

9. EFFECT OF ENCROACHMENT ON SPEED

Due to Encroachment, they were consumed width of carriageway. Thus congestion was very major problem created and through traffic faced speed reduction. It was challenging to found the reason behind speed reduction. There are two conditions arise, one is speed reduction due to increase in flow or density and second is speed reduction due to encroachment. Generally speed reduce with increase in density of traffic but it was found that speed reduced when density is low, there was encroachment play role in speed reduction. Also found that speed was minimum when encroachment level and density both higher. Table 5 shows results of density, encroachment (%) and speed for each 5 min. interval.

Table 5 : Density, Encroachment and Speed for 5 min. Interval

Sr. no.	Density (PCU/km)	Encroachment (%)	Speed (km/hr)
1	81.9	40	24.80
2	70.0	43	24.73
3	58.3	48	25.71
4	70.3	50	24.57
5	71.3	48	24.31
6	66.7	54	23.89
7	72.6	79	22.30
8	76.0	74	22.09
9	85.3	77	23.18
10	70.4	84	21.90
11	106.1	98	20.24
12	99.2	97	21.36
13	112.0	89	17.56
14	92.4	98	20.27
15	97.5	85	19.80
16	103.9	79	20.01
17	108.7	79	21.23
18	87.1	77	20.24
19	97.4	88	18.86
20	125.3	84	17.47
21	136.4	90	17.35
22	130.3	68	19.31
23	111.9	71	19.58
24	84.2	73	20.18

10. EFFECT OF ENCROACHMENT ON LEVEL OF SERVICE

There were 6 threshold values suggested for Level of service. These values suggested for morning time means without encroachment conditions. The range of speed and corresponding range of density shown in table 6. Figure 6 shows prevailing Level of service for

without encroachment condition for study road. From figure 6, Data collected for morning peak traffic hour has prevailing LOS B and data collected for evening peak encroachment and traffic hours has prevailing LOS D as shown in figure 6.

Table 6 : Recommended LOS criteria

LOS	speed Range (km/hr)	corresponding Density Range (PCU/hr)
A	>36	< 40
B	29 to 36	40 to 78
C	23 to 29	78 to 119
D	19 to 23	119 to 158
E	11 to 17	158 to 196
F	< 11	>196

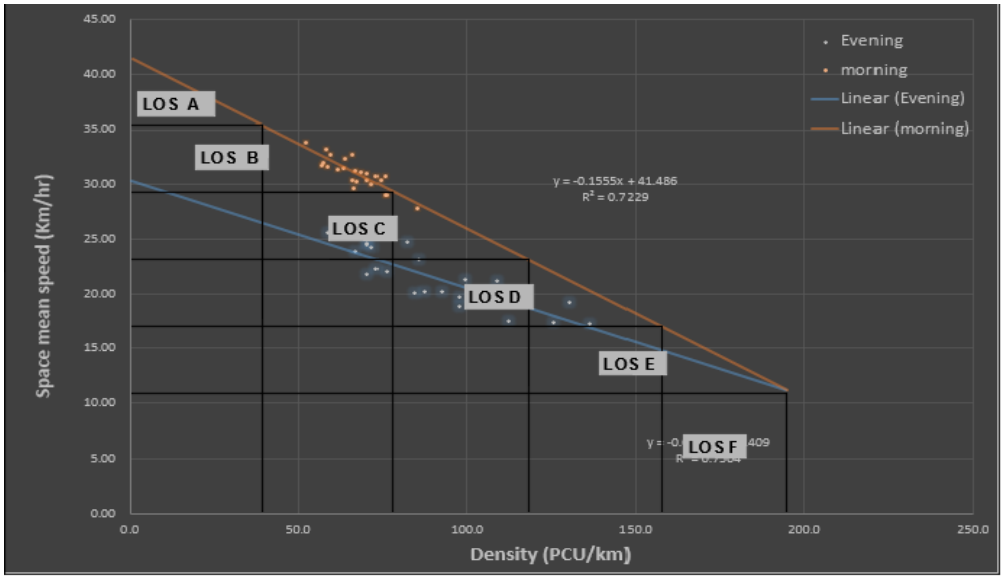

Figure 6: Prevailing LOS for without encroachment condition

11. CONCLUSION

In this study a methodology has been demonstrate to quantify encroachment considering projected area position of elements on carriage way. To estimate combined effect of all elements introduced 'Encroachment Index'. Impact on speed has been quantified and observed that average 31.56% reduction in speed when encroachment found compare to without encroachment condition. The criteria for LOS have been recommended considering speed range. It was observed that for with encroachment condition has LOS D and for without encroachment condition has LOS B. Encroachment consume minimum width of carriageway width of 4 m.

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