Research Paper Engineering

Evaluation of Level of Service through Congestion & a way of Congestion Mitigation

*Mr. Nikunj K. Patel ** Mr. Sanjay G. Patel
*** Dr. H.R. Varia

* M.E. Student, L.D.College of Engineering, Ahmedabad

** Asst. Engineer, Roads & Buildings Dept., Government of Gujarat

*** Asst. Professor, Government Engineering College, Bhuj, Gujarat, India

ABSTRACT

The rapid urbanization and growth of private vehicle ownership have caused an increase in road traffic congestion and degradation of level of service in most of the urban areas in India. All these roads do not follow the standard lane dimensions. Due to the encroachment of abutting lands & non-availability of land, in many situations only partial widening of roads has taken place. In this paper, the objective is to understand the traffic congestions on such roads in terms of road congestion and level of service characteristics; and thereby explore the benefits, if any, from such an increase in road width. Modeling of congestion has captured mixed traffic operations on such roads. As a result, it is possible to set the measures of level of services. The effect of encroachments and on-street parking on congestion level has been quantified.

1. INTRODUCTION

Due to rapid urbanization, the tremendous rise in number of vehicles is variably accompanied by ever increasing volume of traffic and intense traffic congestion on roads. Almost every city in our country is facing acute traffic problems in regards to accidents, delay, congestion, pollution and parking. These problems contribute not only for loss of human lives but also loss of precious man power and traffic congestion involves additional fuel consumption, ultimately results in financial loss. It is mainly due to heterogeneity in traffic composition; increase travel demand, traffic congestion, government policies and political interference. The growing problem of congestion continues to reduce travel speed year after year for all modes of transport. The distance in cities is measured in terms of minutes away rather than in terms of kilometers, thus travel time is viewed as efficiency of roadway.

2. LEVEL OF SERVICE AND CONGESTION

In the present study, the level of service evaluated through the congestion level on urban roadways. Capacity standards are fixed normally in relation to the Level of Service (LOS) adopted for design. Level of Service is defined as a qualitative measure, which describes operational conditions within the traffic stream, and their perception by motorists and passengers

As the traffic volume on road increases, there is a reduction in speed due to loss of freedom of movement. The free flow speed and rate of change of speed with volume level depend on roadway, traffic and control conditions. The area under the observed speed flow curve is a measure of loss of freedom of movement and therefore, congestion is expressed as a percentage of loss in freedom of movement. A road is consider have a congestion value of zero at free flow operation, a 100 % congestion at maximum flow or the capacity, and more than 100 % congestion at unstable or forced flow conditions. So any operating condition in a stable zone will have a congestion value between zero and 100 %.

The IRC (1990) and HCM (2000) have defined six different levels of service A to F, by taking only the operating speed level as a measure of effectiveness (MOE). On the basis of congestion level, more rational LOS boundaries can be developed. In this study, 10 different LOS has suggested according to congestion level. The variation of Congestion due to change in traffic and control conditions can be captured through Modeling.

3. DATABASE

For the quantification of congestion, the speed-flow relationship is the basic requirement. There are three basic traffic variables: speed, flow, and density, but in the search of a more rational quantification, the operating speed and traffic volume have been found to be most suitable traffic variables. As the flow and speed are functionally related, the quantification of congestion has been done on the basis of speed-flow relationship under the prevailing roadway, traffic and control conditions.

In order to estimate level of service through congestion on urban road links, two heavy traffic carrying roads in Ahmedabad were considered for the present study. One is Delhi Darawaja road and another is Gitamandir Kalupur road. Both roads are divided and carrying heterogeneous traffic volume. The required data for analysis are operating traffic volume (V), realised stream speed at operating traffic volume (Ss), free flow speed (Sfs), capacity of road section (C), composition of traffic and width of the road section. In the present study, the videographic method has been used for collection of traffic data. A continuous videographic survey has been carried out for 5 hours in the morning and for 5 hours in the evening. In addition free flow speed of each roads was also measured during off peak period. Suitable PCU values were adopted according to IRC, for converting heterogeneous traffic into a stream of homogenous traffic. The scatter of the speed flow data and the converted maximum hourly volume depend on the actual duration of counting. After observing the variation of scatter speed flow data and maximum flow with change in duration of counting, duration of 5 min has been found to be optimum for computing the hourly flow values.

Roadway Features and Data Collection Technique

Name of the road	No of lane/ direction	Carriageway Width(m)/ Direction	Surface type	Data collection technique
Gandhi bridge to delhi darwaja	2	8.00	Bitumen	Videography
Gitamandir to kalupur	3	11.00	Bitumen	Videography

4. METHODOLOGY AND ITS APPLICATION

The free flow speed used in the model is the representative free flow speed for the stream. The free flow speed of the stream was estimated after observing the maximum observed speeds by different vehicle types during off peak period. The observed maximum speeds varied depending on the types of vehicles. The free flow speed for the model was adopted based on (1) the maximum observed speeds of all vehicle types present in the stream, and (2) the observed trend of the speed-flow data for the traffic stream. The stream speed was computed as the weighted average speed as shown in Eqn.(1)

$Ss = \sum Pi\ Ssi$ … (1)

Ss = Stream speed at a flow level,

Pi = Proportion of vehicle type i during the interval of counting,

Ssi = Observed speed of vehicle type i, at the same flow level.

For Delhi Darwaja Road,

The peak hour in morning is 9:45 a.m. to 10:45 a.m., and in evening the peak hour is 6:15 p.m.to 7:15 p.m. The speed-flow relationship shows the maximum volume is 4200 pcuph and the maximum weighted average speed is nearly 40 kmph. If the vehicles are considered according to its type then the maximum speed of 2W is 56 Kmph, 3W is 48 Kmph, Car is 52 Kmph and Bus is 45 Kmph.

For Gitamandir-Kalupur Road,

The peak hour in morning is 10:30 a.m. to 11:30 a.m., and in evening the peak hour is 6:30 p.m. to 7:30 p.m. The speed-flow relationship shows the maximum volume is 6800 pcuph and the maximum weighted average speed is nearly 40 kmph. If the vehicles are considered according to its type then the maximum speed of 2W is 54 Kmph, 3W is 50 Kmph, Car is 52 Kmph and Bus is 45 Kmph. The speed-flow, speed-density and flow-density relationship , for 5 min. interval traffic volume data.

In present study the proposed model is given below. Let, n different vehicle types are moving in traffic stream, and

Pi = Proportion of vehicle type 'i' in the stream.

Sfs = Free flow speed of the stream in Kmph.

V = Operating total traffic volume in PCUPH.

C = Capacity of the road section in PCUPH, and

Ss = Realised speed of the stream in Kmph at operating volume V.

$Ss = Sfs\ (1- a\ (V/C) \sum Pi\ mi)$ … (2)

Where,

a and mi ('i' = 1,2,3,…n.) are the parameters to be calibrated from the observed data.

The loss in freedom of movement is the area under the speed-flow envelop between free flow operation and the operating point.

Where, $b = \sum Pi\ mi$ …(3)

The congestion is the percentage loss in freedom of movement under prevailing roadway, traffic and control conditions. Therefore, the modelled congestion (CGV) at an operating flow level V is expressed as given in Eqn.(4)

$CGV = (V/VL)\ b+1 \times 100$ …(4)

In this study, the congestion model suggested by Maitra (1997), used for the quantification of congestion. Where,a and b are the parameters to be calibrated from the data set.

Where, V (Flow as per main curve) = (Observed speed for any observed flow)1/ b

CGV = {[(observed speed at observed flow)1/ b] / VL } b+1 x 100

Vehicle type	2W	3W	Car	Bus	Cycle	Smv
Compositon(%)	65.0	9.0	8.0	2.0	14.0	2.0
PCU	0.75	2.0	1.0	2.2	0.5	2.0
Capacity	4300 pcuph					
Free speed	45 kmph					
A	0.62					
Mi	0.35	3.3	4.44	1.58	2.8	32.21
B	Maximum=1.66		Minimum=0.43		Average=1.11	
	0.90					
MAE(calibration)	2.05 kmph					

5. CONGESTION MODELLING

The congestion is functionally related to the speed-flow variation. Therefore, Modelling congestion predominantly depends on the Modeling of speed-flow behaviour under prevailing roadway, traffic and control conditions. The prevailing operating conditions can be a combination of static (e.g. carriageway width, permanent encroachment), partially dynamic (e.g. on street parking for few hours) and completely dynamic (e.g. mix of traffic) causal influences. In the present study, the growth of congestion with increase in volume level has been modelled as a function of composition of traffic (i.e. completely dynamic influence) for a fixed roadway and control conditions. The congestion (%) found out by using the above questions (1) to (4).

The IRC Guidelines and HCM (2000) have defined the Level of Service as the semi quantitative measure for describing the operational conditions for traffic stream as it is felt and perceived by drivers and passengers from the use of roadway section. This definition of level of service generally describes the operating conditions in terms of features such as speed and travel time, freedom to maneuver, traffic interruptions, comfort, convenience, and safety. However, accounting for most of the factors qualitatively, and taking the operational speed level as only qualitative measure of effectiveness (MOE), the complete range of operations has been grouped into six different levels of service (A-F). Whereas, the quantified congestion is a measure of loss in freedom of movement that accounts for the variation of speed levels with increase in traffic volume under prevailing roadway, traffic and control conditions. Therefore, the congestion level is a logical and better MOE to define LOS in a qualitative manner.

The degradation of quality of operation and increase in congestion level due to traffic volume is not uniform at all flow levels. To represent the variation of level of service through congestion in complete manner, 10 different levels of service has been proposed with congestion levels of 5, 10, 20, 30, 40, 50, 60, 80 and 100 % distinguishing nine LOS (A-I) within the stable flow zone, and one LOS (J) with congestion more than 100 %, indicating the unstable (forced) flow. The limiting values of congestion for different level of service are consistence with usual shape of the speed-flow curve with the relatively lesser speed drop near free flow operation and sharp drop near the capacity flow. The service volumes are governed by congestion levels, and therefore, any change in prevailing roadway, traffic and control conditions would normally be reflected by the changes in service volumes corresponding to various levels of service. (Maitra, 1997)

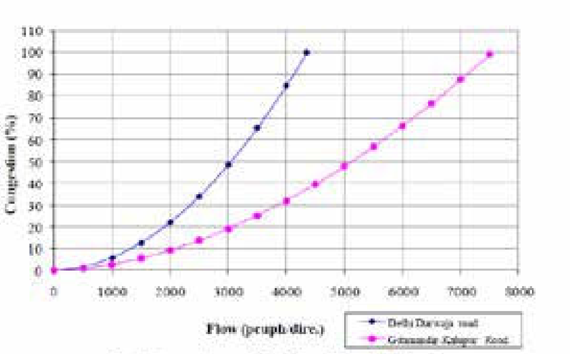
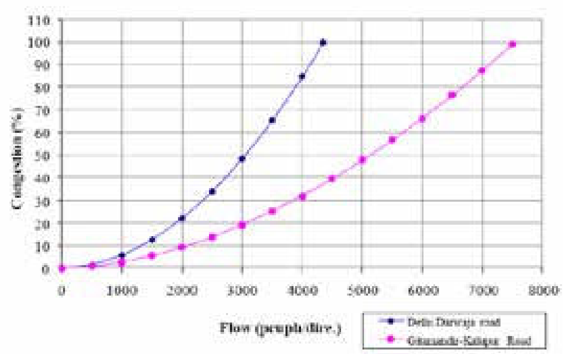


Fig. 1 Congestion with Flow Levels for Both Roads

Los	Congestion	Limiting service volume in pcuph and speed (kmph)			
		Delhi darwaja road		Gitamandir – kalupur road	
		Limiting service volume in pcuph	Speed (kmph)	Limiting service volume in pcuph	Speed (kmph)
A	5	950	60	1380	60
B	10	1333	55	2047	58
C	20	1904	50	3048	50
D	30	2333	43	4285	45
E	40	2714	40	5142	39
F	50	3095	34	5666	33
G	60	3333	29	6142	28
H	80	3851	23	6666	22
I	100	4350	19	7145	18
J	> 100	> 4350	< 19	>7500	< 18

6.RESULT AND DISCUSSION

The congestion on two roads estimated at incremental flow levels. The estimated modelled congestion levels are shown in Fig.1. A comparison of congestion levels on both roads shows that, the congestion increases with an increase in traffic volume. However, the increase in congestion becomes faster at higher volume levels. Although, the widths of study roads are different, the congestion on both roads is nearly same at lower volume levels, about 500 pcuph. However, as the volume increases, and approaches towards the capacity, the congestion is affected by road width.



For an example, shown in above Fig., at 2000 Pcuph on Delhi Darwaja road (8.0 m wide) congestion is 23 %, whereas, on Gitamandir- Kalupur road (11.0 m wide) congestion is 10 %. At 3000 pcuph on Delhi Darwaja road (8.0 m wide) congestion is 48 %, whereas, on Gitamandir road (11.0 m wide) congestion is 19 %. Similarly, at 4000 pcuph on Delhi Darwaja road (8.0 m wide) congestion is 84 %, whereas, on Gitamandir road (11.0 m wide) congestion is 32 %. Therefore, partial widening provides a relief to traffic at higher flow levels. However, the relief is only marginal as the widening is partial. An additional lane width is likely to bring substantial improvement as compared to partial widening.

Public Transport Usage – A Way of Congestion Mitigation:- The realized benefits by discouraging the use of private and para-transit vehicles, while promoting public transport usage have been investigated. For this purpose, certain amount of passenger's demand of two wheelers, cars and auto-rickshaws was transferred to bus taking the average occupancy of 2W, 3W, Car and Bus as 1.5, 3, 2.5 and 40 respectively. This results in the increase of bus PCU while the private vehicles or auto rickshaws PCU in the traffic mix reduced. The congestion models developed on these two roads have been used to assess the realized benefits at various levels of demand transfer from private to public transport.

On Delhi Darwaja Road, a composition of 65% two wheelers, 9% three wheelers and 8% car, the congestion has been modelled at 10%, 30%, and 50% reduction in 2w usage while adding corresponding equivalent number of bus in the stream. Each level of transfer will change the volume level and composition of traffic slightly. The flow level before transferring demand from 2w to public transport has been designated as a base flow (0 % transfer). The modelled congestion at different flow levels has been estimated for various levels of demand transfer from 2w to public transport and similarly, for 3w and car are shown in Fig.2.

It is observed that if the transfer is more, there is a reduction in congestion level. At low flow levels nearly 500-1000 pcuph the congestion level is not significantly reduced, that compared to higher flow level. So it is a state particularly during peak period at which the flow level is high then the congestion reduction is more by public transport usage. Therefore, substantial relief in congestion can be achieved through the increased use of public transport rather than the private vehicles.

Similarly, on Gitamandir-Kalupur Road, for a composition of 59% two wheelers, 13 % three wheelers and 7 % cars, the congestion has been modelled at 10%, 30% and 50% reduction in the 2w, 3w and cars. The various levels of demand transfer of private to public transport on this road are also shown in Fig 3.

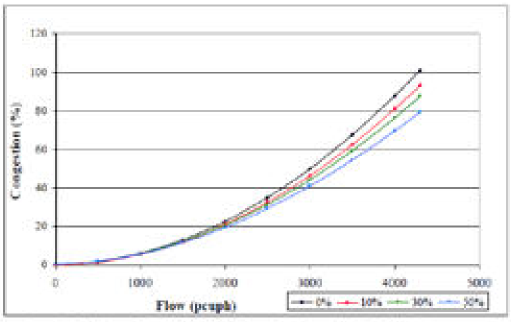


Fig. 2 (a) Various Levels of Demand Transfer from 2W to Public Transport

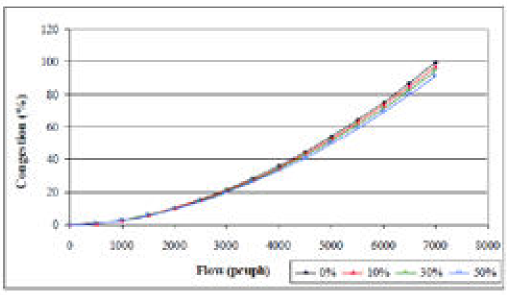


Fig. 3 Various Levels of Demand Transfer from 3W to Public Transport

7. CONCLUSION

Some of the major conclusions are given below.

- A quantification of congestion is possible by including the both the operational and volume characteristics of traffic movement. The percentage loss in freedom of movement is a measure of congestion level.
- On the basis of congestion level, more rational LOS boundaries can be developed. In this study, 10 different LOS has suggested according to congestion level.
- The variation of congestion due to change in traffic and control conditions can be captured through Modelling. The calibrated coefficients of model are capable in capturing the contribution of different vehicles in the traffic stream.
- The calibrated coefficients are used to find out Modelled speed and from this the absolute mean error (MAE) in the speeds. If the MAE value is low then the quality of model is good. In the present study, the MAE value for Delhi Darwaja Road is 2.05 Kmph and for Gitamandir-Kalupur Road is 2.13 Kmph.
- Using the congestion model, it is possible to quantify the deterioration in quality of operating conditions in terms of congestion level and LOS due to change in roadway and control conditions. The effect of carriageway width on congestion level has been quantified.
- The effect of encroachments and on-street parking on congestion level has been quantified. In present study, on Delhi Darwaja road the intensity of on-street parking and encroachment is high at evening time compare to morning time so, it can be say that the congestion level at evening time is higher than morning on that road.
- Modelling congestion can be used as a tool for assessing the benefits from the augmentation of supply and improved control strategies on urban roads.
- Promoting the usage of public transport while discouraging private modes and Para transit modes is an effective way of congestion mitigation on urban roads. Discouraging private modes and promoting the usage of public transport can reduce the congestion by 5 to 10 %.

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