Estimation of Level of Service through Congestion – A Case Study of Ahmedabad City

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Abstract – *Traffic congestion is established phenomenon in developing countries. The tremendous rise in number of vehicles causes increase in traffic congestion and degradation of level of service. While an appropriate policy for congestion mitigation, it is required to have more realistic meaning of traffic congestion and its quantification technique. By combining Volume and operational characteristics 6 level of services have been defined which takes congestion as measure of effectiveness.*

***Key Words*: Congestion, Capacity, Measure of Effectiveness, Operational Characteristics, Volume Characteristics**

1. INTRODUCTION

In the last two decades, rapid growth and urbanization brings significant issues to the under developing countries. Mainly all these issues leads towards drastic impact to the settlement. One of the main problems faced by all classes of population is road transport related problem. The tremendous rise in number of vehicles is variably accompanied by ever increasing volume of traffic and intense traffic congestion on roads. Traffic congestion on urban roads has become a serious concern to transportation engineers due to its uncontrolled growth and resulting huge economic loss, additional delay, and user cost. Traffic congestion is mainly due to heterogeneous traffic composition, increase in travel demand, government policies and political interference.

The traffic congestion refers to urban mid block congestion and congestion at or near intersection. This paper presents methodology for quantification of congestion on urban mid block section. Here, the scope is limited to congestion at mid block [6]

2. QUANTIFICATION OF CONGESTION

Many researchers quantified congestion by using either operational characteristics or volume characteristics. The operational characteristics include speed, delay, travel time, density, and acceleration noise. Volume characteristics include traffic volume and volume to capacity ratio. Speed and density varies depending on the volume of traffic. IRC (1990) and HCM (2010) consider level of service as a qualitative measure which takes into account speed, travel time, comfort, convenience, traffic interruption and safety. It takes only speed as a measure of effectiveness and defined six level of service which are A to F. Congestion takes into account both operational and volume characteristics. So, it is better measure of effectiveness to define LOS in quantitative manner.

Here, 6 level of service has been defined with congestion levels of 20, 40, 60, 80, 100% distinguishing LOS (A-E) within the stable zone and LOS (F) with congestion more than 100%, indicating unstable flow.

3. MODELING OF CONGESTION

The urban and suburban traffic congestion clearly refers to urban mid block congestion and congestion at or near the intersections. The paper was presented which gave methodology for the quantification of congestion on urban mid block sections. Congestion has been quantified by taking into account both the operational and volume characteristics. The congestion has been modeled by using level of service [6].

$$s = s_f \left(1 + a \left({}^{V}/_{C} \right)^{b} \right) \qquad \text{Eq. (1)}$$

$$V_L = \left[\frac{1}{a}\left(1 - \frac{S_L}{S_f}\right)\right]^{1/b} \qquad \text{Eq. (2)}$$

$$CG_v = \left(\frac{V}{V_L}\right)^{b+1} \times 100 \qquad \text{Eq. (3)}$$

$$b = \sum Pi\, mi \qquad \text{Eq. (4)}$$

Where,
S = realized speed of the stream in km/hr
S_f = free flow speed of the stream
V = operating total traffic volume in PCU per hour
C = Capacity of the road section PCU per hour
S_L = Speed at operating volume V_L

V_L = operating volume at 100% congestion level

a and b are parameters to be calibrated from the data set

The modeled congestion level expressed in Eq. (3) is similar way of expressing congestion as volume to capacity ratio. It takes into account the effect of operational characteristics, through the exponent (b+1). Eq. (3) indicates that congestion on similar roads may be deferent at respective volume levels, depending on prevailing roadway, traffic and control conditions. The exponent (b+1) also supports the nonlinearity in the deterioration in level of service with negligible effect of traffic volume at lower volume levels, and sever effect at higher traffic volume near capacity.

4. MODELING METHODOLOGY

Quantification of congestion has been applied on two roads varying in roadway, traffic and control conditions. The model requires the input of basic parameters which are capacity of road, limiting speed values representing 100 % congested operation, and free flow speed. The data collected by videography provides traffic composition, traffic volume, and corresponding speed level covering peak and off-peak hours, for the development of the congestion model.

Table – 1: Study Area

No	Name of the Road	No of Lane/direction	Width/direction	Data collection technique
1	Income tax to Usmanpura	6 lane	10 m	Manual
2	Gurukul-Manavmandir	4 lane	7 m	Videography

The capacity values for Gurukul to Manavmandir road and Income tax to Usmanpura road has been taken 4500 PCUPH and 6500 PCUPH. However, IRC-1990 has suggested capacity value 4200 PCUPH and 6200 PCUPH. The free flow speed in off peak hour is 48 km/hour for both the roads. The classified traffic counts are available for every five-minute interval and converted into hourly traffic volume in PCUPH.

With the knowledge of the capacity of road C, free flow speed S_f ,operating volume p_i, and traffic stream speed S, the Coefficients a and m_i of the congestion model has been calibrated after making logarithmic transformation of Eq. (1).

The traffic composition and adopted PCU values [3] for Gurukul to Manavmandir road are shown in Table 2. Table 3 shows the calibrated coefficients of the model along with t values, R^2, and F value. It is observed that the magnitude of all the coefficients, except those of cycle and 2W are found significance against a t value of 2.013. The R^2 value found out to be 0.94 which is good. F value obtained is greater than F critical value, so the values are not occurring by chance. Mean absolute error is 3.73, which is low. The goodness of fit statistics indicates the quality of model.

Table – 2: Composition of traffic for Gurukul – Manavmandir Road

Vehicle Type	Proportion	PCU
Two Wheeler (2W)	0.53	0.75
Three Wheeler (3W)	0.15	2
Car	0.26	1
Bus	0.01	2.2
Cycle	0.04	0.4
LCV	0.01	1.4

Table – 3: Summary of model for Gurukul to Manavmandir Road

Vehicle type	a	m_i	t value	t critical	R^2	F value	F critical
2W	0.701	0.4529	0.944	2.013	0.97	232.4	2.34
3W		10.995	9.058				
Car		-2.8692	2.197				
Bus		19.216	5.947				
Cycle		-2.3777	1.561				
LCV		44.599	4.303				

The traffic composition and adopted PCU values for Income tax to Usmanpura road are shown in Table 4. Table 5 shows the calibrated coefficients of the model along with t values, R^2, and F value. It is observed that the magnitude of the coefficients of 2W, 3W and Bus are found to be significant against a t critical value of 1.94. The R^2 value found out to be 0.89 which is fairly good. F value is greater than F critical value, so the values are not occurring by chance. Mean absolute error is 4.81 which is fairly low. The statistics shows that the quality of model is good.

In a mixed traffic condition, the contribution of different vehicle type in creating congestion is different. In the model, the effect of different vehicle type is captured through m_i. the contribution of a vehicle type depends on prevailing roadway, traffic, and control conditions.

Table–4: Composition of traffic for Income tax - Usmanpura Road

Vehicle Type	Proportion	PCU
Two Wheeler (2W)	0.53	0.75
Three Wheeler (3W)	0.21	2
Car	0.17	1
Bus	0.04	2.2
Cycle	0.03	0.4
LCV	0.02	1.4

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Table – 5 : Summary of model for Income tax to Usmanpura Road

Vehicle type	a	m_i	t value	t critical	R^2	F value	F critical
2W	0.844	1.9846	6.082	1.943	0.8916	69.95	2.31
3W		2.6004	4.039				
Car		-0.9710	1.021				
Bus		-3.5104	2.5608				
Cycle		-0.5958	0.3533				
LCV		3.4787	1.7106				

5. CONGESTION LEVEL AND LOS

Congestion levels 20, 40, 60, 80, and 100 % which represents 5 level of service A-E respectively, congestion level greater than 100% represents level of service F. Service volumes and speed at different congestion level is given in Table 6 and Table 7.

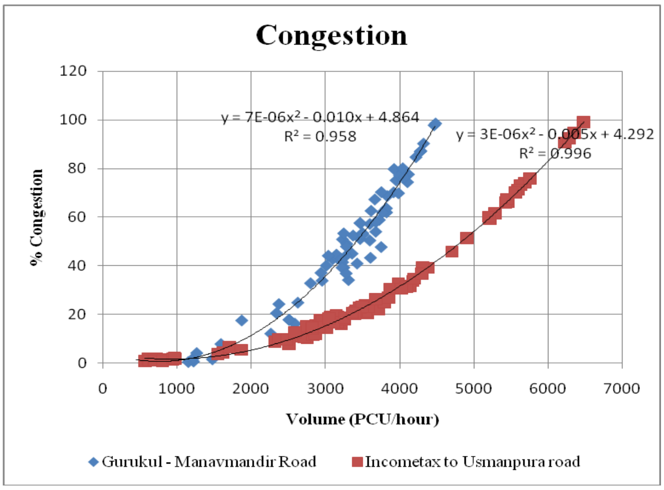

Chart – 1 : Variation of Congestion with flow level on both the roads

Table – 6: Limiting Service Volume and Speed at different Congestion level on Gurukul to Manavmandir Road

LOS	Congestion %	Gurukul – Manavmandir Road	
		Limiting Service Volume (PCU/hour)	Speed (km/hour)
A	0-20	2349	44
B	20-40	3065	36
C	40-60	3610	31
D	60-80	4067	26
E	80-100	4475	19
F	>100	>4475	<19

Table – 7: Limiting Service Volume and Speed at different Congestion level on Income tax to Usmanpura Road

LOS	Congestion %	Income tax to Usmanpura Road	
		Limiting Service Volume (PCU/hour)	Speed (km/hour)
A	0-20	3268	40
B	20-40	4382	32
C	40-60	5222	28
D	60-80	5925	24
E	80-100	6470	20
F	>100	>6470	< 20

6. CONGESTION MITIGATION

The most significant in an urban area is how to deal with road congestion. The congestion on urban road reaches its peak normally during the peak period of the day. It is observed that during peak period the operating level of service becomes much poorer than desire level. This peaking nature of traffic in urban area necessitates formulation of certain policy measures to mitigate congestion and hence restore required level of service. The various policy measures for reducing urban road congestion can be classified in following three categories: 1) Augmentation of supply, 2) Improvement in control strategies, 3) Demand management

In the present study, the congestion model is calibrated for the mixed traffic operations prevailing in the developing countries. The model is capable to combine the effect of wide variety of roadway, traffic and control conditions on the quality of operation. This modeling approach has been used as a useful tool for providing a sound analytical basis to the various aspects related to above mentioned policy for congestion mitigation. Using this model some important aspects such as congestion pricing, traffic management and effect of enhancing the public usage related to congestion mitigation have been addressed.

With the knowledge of the modeling of the congestion for roads with various carriageway widths, the realized benefits from augmentation of supply side can be assessed. While it is possible to estimate the realized benefits from the additional traffic lanes or increased traffic lane width for a known flow level, the required supply level for maintaining the desired level of service can be assessed by modeling.

For example, a flow level of 3000 pcuph indicates congestion level of 40 % on the Gurukul to Manavmandir road (7 m width) which is 4 lane divided road, 2 lanes in each direction. On other basis of modeling of congestion on different categories of roads say, Income tax to Usmanpura road (10 m) which is six lane divided road, it can be said that one additional lane or increased carriageway width (changing the carriageway width by adding 3 m width) will bring down the congestion level 15 %. Therefore, for demand level 3000 pcuph, one additional lane will reduce congestion more than 50%.

7. CONCLUSION

The congestion can be perceived as a quantitative loss in freedom of movement under prevailing roadway, traffic and control conditions. The area under the observed speed-flow variation is a measure for the loss of freedom of movement. A quantification of congestion is possible by including the both operational and volume characteristics of traffic movement. The percentage loss in freedom of movement is a measure of congestion level. The variation of congestion due to change in traffic and control conditions can be captured through modeling. The calibrated coefficients of model are capable in capturing the contribution of different vehicles in the traffic stream. The effect of carriageway width on congestion level has been quantified. By increasing a lane or increasing the carriageway width, the congestion can be reduced by 30-50%.

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