Traffic Congestion Modelling with Reference to Speed Profiles under Mixed Traffic Conditions: A Case Study of Surat Corridor

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Abstract

Significant growth in population, urban activities, travel demand and traffic flow has been observed in most of our metropolitan cities in recent time, leading to considerable travel time delays. And it is the important transportation parameter to indicate the efficiency of the movement of the people and freight. This paper precisely attempts to address the traffic congestion measurement employing travel speed profiles obtained from V-Box. Though number of traffic congestion measuring indices are available today the simplest and an effective way of presentation of congestion of enroute stretches is missing. The present study emphasize on this particular approach to make use of speed profile diagrams by conducting speed and delay survey studies on 'Udhana- Sachin' one of the stretches of major corridor in Surat. The travel speed indices have been developed to describe the traffic congestion scenario on the road stretch.

Keyword- Traffic congestion; V-Box; Travel Speed Index; Congestion profile, Speed Profile

I. INTRODUCTION

The high rate of urbanization experienced in developing countries poses a great challenge to infrastructural development in most cities. The percentage urban population in India has gone up gradually from 1901 to 2001. Thus urbanization in India has been top heavy or oriented towards larger cities. An increasing concentration of urban population in Class I cities and metropolitan cities in particular can be observed over the past several decades.

Rapid urbanization trends observed in Indian metropolitan cities have resulted in significant growth in travel and traffic demands today. Eventually there is rise in urban trip rates, vehicle population and auto-air pollution, needing proper understanding of their impacts on the road. Traffic Congestion is one of the serious urban problems and is the major concern of traffic engineers as well as travelers. As such the traffic congestion disturbs the travel plans owing to increase in travel time. Thus there is loss of time, money value and working efficiency.to understand the nature of congestion and to control its growth, a system for measuring the severity of traffic congestion is needed. Such a measure provides the base for traffic engineers and policy makers to identify problems and determine the mitigation strategies. The congestion measurement has been carried by using different approaches which comprise the travel time delay and travel speed as the base parameters and free flow speeds or light traffic has been the base line to indicate the congestion level. The congestion and delay measurements can be at isolated spots like intersections, bottlenecks of the midblock centers. There are certain studies which covers the road stretches, road network or specific areas such as railway station areas, bus stand areas, commercial areas etc.

In the present study, a major traffic corridor (Udhana- Sachin) of Surat city, where the intense mix traffic flow observed is taken up. Both micro and macro level analysis is carried to recognize the congestion level on 2km stretch from Udhana Gate to Udhana Village. The aim is to develop 'Mixed Traffic Congestion Model' (M-TCM) through the speed profiles obtained with V-Box apparatus.

II. CONGESTION: DEFINED

Congestion is one of major issues that most metropolises are facing today. Many researchers have provided different definitions for traffic congestion. However, there is no universally accepted definition of traffic congestion depending what measures they have adopted to adjust the delays. Congestion has been defined as the situation when traffic is moving at speeds below the designed capacity of a roadway. Congestion was also defined as state of traffic flow on a transportation facility characterized by high densities and low speeds, relative to some chosen reference state (with low densities and high speeds). Wenjie Zhang et al. defined congestion as a situation in which demand for road space exceeds supply. Congestion is the impedance vehicles impose on each other, due to the speed-flow relationship, when the use of a transport system approaches capacity. Morris I. Rothenberg defines urban highway congestion as "a condition in which the number of vehicles attempting to use a roadway at any given time exceeds

the ability of the roadway to carry the load at generally acceptable service levels". The concept of levels of service (LOS) is well established in highway capacity analysis procedures. In such a criterion, congestion occurs by judging V/C (volume over capacity ratio) when it exceeds a certain threshold. Travel Time Index (TTI) is another criterion to express congestion level, which is defined as the ratio of real travel time to free flow travel time. Vuchic.V.R. and Kikuchi, S. defined congestion as the situation when vehicular volume on a transportation facility (street or highway) exceeds the capacity of that facility. According to Lomax et al., Traffic congestion is travel time or delay in excess of that normally incurred under light or free-flow travel conditions

III. CONGESTION PARAMETERS

Traffic congestion on urban roads are measured mainly adopting travel time, delays and travel speeds prevailing on a particular route or corridor as briefed below. Traffic volume, composition, interruptions due to intersections, road side pressures, pedestrian encroachments are other important attributes associated with the travel time, delays and speeds.

A. Travel Time and Delay

Congestion can be measured in terms of travel time or delay in excess of that observed during free flow or normal condition. Other than average travel time studies, some of the travel time indices were used for congestion measures. Travel Time Index compares peak period travel and free flow travel while accounting for both recurring and incident conditions. Travel Rate Index computes the amount of additional time that is required to make a trip because of congested conditions on the roadway. The buffer index calculates the extra percentage of travel time a traveler should allow when making a trip in order to be on time 95% of the time. Different threshold values have been used for delay measures. Threshold values for speed and LOS were set up to define condition of congestion. Lindley (1987) used a threshold of congestion to begin at a volume to capacity (v/c) ratio of 0.77 (or the speed of 55 mph corresponding to v/c ratio of 0.77).

B. Speed Parameter

The prevailing traffic speed at any section of a roadway affects the quality of traffic at a time. Literature suggest several speed measures besides average travel speed. Several approaches were made based on speed. One of the efforts made were Quality of transmission index (Qindex) which is a function of average speed and sum of speed changes. Speed reduction Index is measure represents the ratio of the decline in speeds from free flow conditions.

IV. STUDY CORRIDOR

A. City Background

Surat which is the second largest metropolitan center and fastest growing industrial city in Gujarat is considered for the study purpose. The City of Surat (Municipal Corporation of Surat) has an area of 326.52 square kilometres and a population of 44.61 lacs (2011). Surat is the 34th-largest city by area and 4th-fastest developing cities in a in a study conducted by the City Mayors Foundation, an international think tank on urban affairs. The city registered an annualised GDP growth rate of 11.5 per cent over the seven fiscal years between 2001 and 2008.

B. Study Corridor

Study corridor selected for the present study extends from Udhana Darwaja to Udhana Village (2km) in Udhana Sachin corridor (Fig. 1).

Fig. 1: Study corridor

V. SURVEY DATA

A. Traffic Volume Survey

Traffic volume and composition studies are carried out using video graphic technique at the identified locations to capture the traffic flow for one hour duration during the peak period for both direction flows. Traffic volume and composition for every 5 minutes is extracted for the study analysis.

B. Speed and Delay Survey

Speed and travel time are the most commonly used indicators of performance for traffic facilities and networks. It indicates the level of service and identifies the problem locations. Delays are often used to measure the performance of traffic flow.

In the present study of 2km stretch, speed and delay study is conducted from Udhana Darwaja to Udhana Village in 3W using V-Box apparatus. The survey is done by completing 6 trips in peak hour. GPS fitted probe vehicle is deployed along the study route to conduct this survey during the evening peak hour. The speed profile is plotted from the data using performance box software.

VI. MICRO-LEVEL CONGESTION ANALYSIS

A. Identification of Congestion Stretches

From the speed and delay survey conducted in the whole stretch using V-Box, speed Vs distance plot is obtained as shown in Figure. 2. Dots are indicating the speed points provided by V-Box. The average speed line observed for the peak period with average value of 18 kmph is marked as 'SP' on the figure.

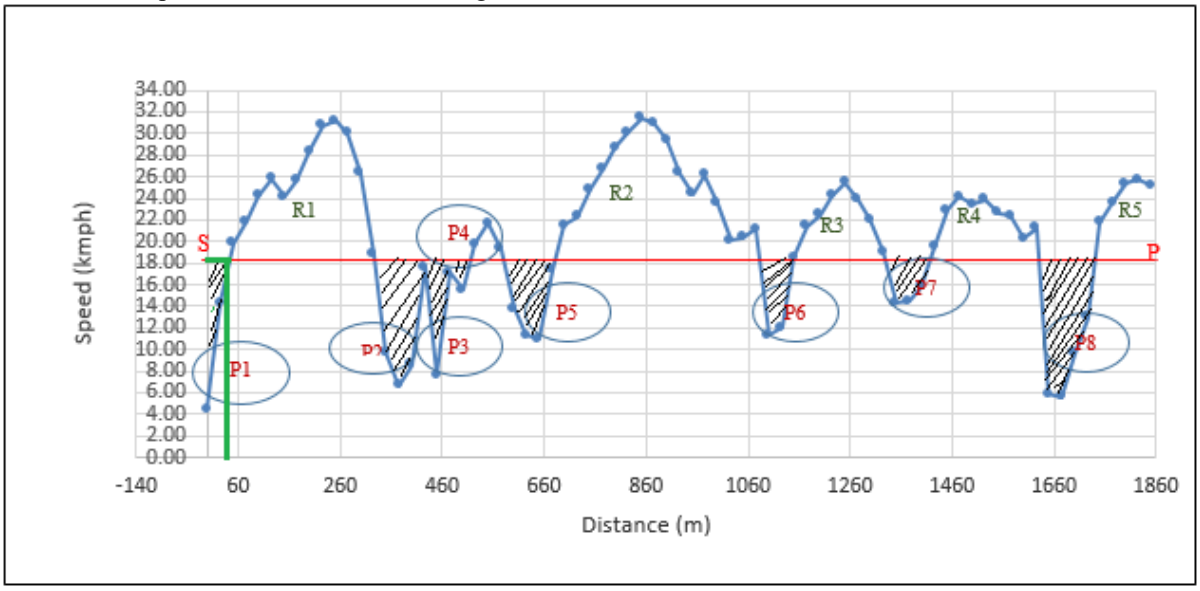

Fig. 2: Speed Profile for Udhana Darwaja-Udhana Village stretch of Udhana-Sachin corridor

P1 to P8 are the points where the observed speeds are the lowest. These are the congestion spots of the study stretch (Figure 2). Now the hatched areas under the speed profile below the average speed line SP reflect the congestion levels. The points R_1 to R_5 are the indicators of higher speed stretches with reference to average speed. The congestion patches are identified referring to the speed profile intersecting points on the average speed line.

B. Development of Travel Speed Index (TSI_{avsp})

The proposed study method intends to measure the congestion through Travel Speed Index (TSI) defined as:

$$\text{TSIavsp} = \frac{\text{Congestion patch area}}{\text{Maximum congestion patch area}}$$

The congestion patch area (a1) is marked below the average speed profile line covering the low speed profile as shown by the speed profile, whereas maximum congestion area (a2) is marked below the speed profile line for the congestion stretch up to zero reference speed to show the maximum congestion when vehicle is in stopped condition. a1 and a2 patches are shown below.

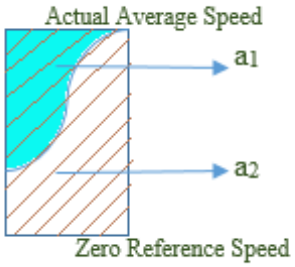

Fig. 3:

Similarly, it is also possible to compute the TSI values for other specified/desired speeds with reference to LOS. The desired speed can be free flow speed, speeds corresponding to LOS, off-peak or peak speeds. In the present study, TSI are calculated considering both the average speed and the desired speed of 30 kmph as typical cases to highlight the TSI values.

TSI measures the relative congestion. The reduction in speed from the actual average speed and the stretch length of the congestion, matter in formulation of the patch. Table 1 provides the TSI values across the study stretch of 2 km Udhana Sachin corridor with reference to the above Figure 2. The highest value being 0.49 at the beginning portion where intersection influence prevails at Udhana Gate. The lowest congestion patch is at P_4 with TSI of 0.12. Speed reductions can be due to the intersections, narrow road stretch, flyover entry points, parked vehicles, pedestrian encroachment etc. and which are to be noted during the survey.

Congestion Patch	*Chainage (m)*	*a1*	*a2*	*TSI*	*Influencing Factors*
P1	*0*	*450.5*	*928.27*	*0.49*	*Intersection Interruption*
P2	*338*	*768.31*	*1583.84*	*0.49*	*Entry Point to flyover*
P3	*442*	*399*	*819.19*	*0.49*	*Narrow Road Stretch*
P4	*499*	*70*	*600.67*	*0.12*	*Intersection Interruption*
P5	*596*	*418*	*1856.72*	*0.23*	*Pedestrian Encroachment*
P6	*1102*	*396*	*1064.98*	*0.37*	*Narrow Bridge*
P7	*1340*	*219.5*	*1392.59*	*0.16*	*Parked Vehicles*
P8	*1652*	*853*	*1829.45*	*0.47*	*Intersection Interruption*

Table 1: TSI for Actual Average Speed (18 kmph)

VII. MIXED TRAFFIC CONGESTION MODELING

Travel Speed Indices (TSI) defined and worked out provide the scenario of traffic congestion with reference to speed profiles. Here the traffic speed is important parameter of congestion measurement. However the speed depends upon the traffic volume, composition. Traffic interruption and road conditions. These parameters necessarily to be addressed to evaluate the traffic congestion levels through developing appropriate models. Regression model is considered here to determine the statistical relation between the input variables and the output variable i.e. TSI. The major inputs for the model are shown in the Table 2.The volume here is in vehicles/hour. The % two wheeler is not considered here as input for its strong correlation with the traffic volume with reference to correlation analysis. Other two important inputs considered here are Friction Spots and Speed drop Factor. Friction spots are identified on every km study stretch with reference to the speed profile obtained through V-Box. Speed Drop Factor here is difference between referred speed and actual speed at the friction spots. As such six survey trips were carried to cover the 2km to get the 12 data sets on 1 km basis. The traffic volume, composition, friction spots and speed drop factors are noted for the 12 data sets as mentioned in Table 2 and are considered in developing the regression model.

Data Sets	*TSI*	*Veh (000)/hr*	*% 2W*	*% 3W*	*% 4W*	*% CV*	*Friction Spots*	*Speed Drop factor*
1	*0.27*	*5.79*	*61.9*	*22.15*	*9.73*	*6.21*	*2*	*10*
2	*0.34*	*5.79*	*61.9*	*22.15*	*9.73*	*6.21*	*4*	*11.4*
3	*0.23*	*5.11*	*57.51*	*23.94*	*13.61*	*4.93*	*5*	*9*
4	*0.24*	*5.11*	*57.51*	*23.4*	*13.61*	*4.93*	*4*	*12.6*
5	*0.42*	*4.98*	*58.31*	*24.09*	*11.81*	*5.78*	*2*	*16*
6	*0.28*	*4.98*	*58.31*	*24.09*	*11.81*	*5.78*	*2*	*13*
7	*0.21*	*3.95*	*69.3*	*16.71*	*8.8*	*3.7*	*3*	*12.7*

8	*0.35*	*3.95*	*69.3*	*16.71*	*8.8*	*3.7*	*4*	*9.2*
9	*0.33*	*4.86*	*64.7*	*21.48*	*8.64*	*4.26*	*3*	*12*
10	*1.33*	*4.86*	*64.7*	*21.48*	*8.64*	*4.26*	*3*	*18*
11	*0.29*	*5.68*	*64.3*	*21.94*	*10.13*	*3.48*	*5*	*12*
12	*0.27*	*5.68*	*64.3*	*21.94*	*10.13*	*3.48*	*4*	*14.25*

Table 2: Mixed Traffic Inputs

The multiple regression model developed for prediction of Traffic Congestion (M-TCM) is of the form:

$$TCI = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + a_6x_6$$

Here TCI –Traffic Congestion Index
x_1 -Vehicles (000) per hour
x_2 -percentage composition of three wheelers
x_3 -percentage composition of four wheelers
x_4 -percentage composition of commercial vehicles
x_5 -Friction Spots
x_6 -Speed Drop factor

From the regression analysis the R^2 value is obtained as 0.838. This shows a good correlation between input and output variables.

The model obtained is

TCI= -0.677 -0.296(Vehicles (000)/hour) +0.076(% 3W) -0.141(%4W) +0.143(%CV) +0.186(Friction Spots) +0.086(Speed Drop Factor) (R^2= 0.702)

The model inputs of mixed traffic volumes and % cars are indicating negative impact on Traffic Congestion Index (TCI). As traffic on our roads comprises of 60-70% of two wheelers, with increase in volume number of two wheelers increase and the speeds move up resulting in reduced TCI. Similarly as car population increases, composition of other vehicles are reduced and cars speed up. On other hand, impact of three wheelers and commercial vehicles will be significant on speed reduction resulting in higher TCI values. The role of number of friction spots and as well Speed Drop Factors is to drop the speed of the traffic flow and thereby increase in TCI values. Friction spots and speed drop factors are related to the mode interactions in the stream. It is as good as traffic impedance having negative impacts on the speed profiles. Higher the index value that is nearing to 1, the congestion is quite high. If TCI is 0, it can be stated that the traffic flow is at the desired speed.

VIII. CONCLUSION

One can work out the TSI values for peak and off- Peak situations and identify the congestion patches along the route for every km of length to develop the priority basis of improvement for the route on short term and long term basis. The short term measures to improve the road and roadside conditions are in terms of controlling the pedestrian encroachment and undesired parking etc. Whereas long term measures are concerned with traffic regulations and control and road capacity improvement measures. TSI values further can be used as inputs in modelling travel time predictions in traffic congestions incorporating traffic volume and composition as other attributes. The traffic congestion model M-TCM developed here on multi-linear regression base finds application in computation of the congestion conditions on a route. TCI, the output of the model provides the base for traffic quality performance measurement, so as traffic engineer can initiate necessary steps to reduce the TCI values by employing appropriate traffic engineering measures.

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