Congestion Quantification Measures and their Applicability to Indian Traffic Conditions

S. Vasantha Kumar and R.Sivanandan

Abstract--- *The problem of traffic congestion is plaguing most of the metropolitan cities around the world and India is no exception to this. Before addressing this concern through appropriate measures such as infrastructure expansion, Transportation System Management (TSM) measures, it is necessary to comprehend the nature and extent of the problem. This involves the quantification of traffic congestion by using certain performance measures. Congestion quantification, besides its application in prioritization of improvement measures to reduce congestion, is also useful in evaluating the current system performance, providing alternate route choices in Intelligent Transportation System (ITS) applications, vehicle emission studies and wide range of planning and policy evaluations.*

This paper presents a brief review of various approaches to quantify congestion and associated performance measures based on comprehensive literature search. Applicability of these measures to Indian traffic conditions, which has uniqueness in both roadway and traffic characteristics, has also been examined in the context of constraints in data collection, measurement feasibility, technological advances like Global Positioning Systems (GPS) and cost effectiveness. The feasibility of the use of GPS fitted public transport buses as vehicle probes for quantifying the congestion was studied by carrying out a pilot study in one of the bus transit routes in Chennai, India. The data collection involved use of GPS units in personal vehicles such as two-wheeler, auto and car, as well as public transport bus. The results are promising and offer scope for further research by developing mathematical models which can predict the congestion levels of various types of vehicles using public transit buses as probes.

I. Introduction

THE problem of traffic congestion and ways to tackle needs to be addressed urgently in major urban areas of India. The exponential growth of personal vehicles, combined with increase in trips and trip lengths are the major reasons for traffic congestion in India. In Chennai, the total personal vehicle population has increased from 10 lakhs in 1999 to almost 32 lakhs in 2011. This accounts for about 220 percent rise in the last 12 years. The increase of personal vehicles on urban roads not only causes traffic congestion, but also leads to safety issues. A study by Wilbur Smith Associates (1) found that, the anticipated average journey speed on major corridors in cities with population more than 80 lakhs (category-1a) will be 9 kmph and in cities with population 40-80 lakhs (category-1b) will be 10 kmph in the year 2021. In 2031, the situation will be even worse with anticipated speeds of 6 and 7 kmph, respectively. The master plan for Chennai (2) for the year 2026 is aiming for a modal split of 70:30 (Public transit: Personal vehicles) against the modal split of 35:65 in 2009. The decreasing use of public transport further exacerbates the congestion situation.

The solution options for reducing congestion are infrastructure expansion, Transportation System Management (TSM) measures, Congestion Pricing and technology applications like ITS. Before suggesting any of the above measures to reduce congestion, it is essential to first study the current system performance. Also, since congestion is a dynamic phenomenon with variation in space and time domain, it is necessary to study the duration, extent and intensity of traffic congestion in space-time domain in an individual facility or area-wide urban network system using the available performance measure(s). This process of measuring or estimating congestion by one or many of the performance measures is called congestion quantification. The quantification of traffic congestion is useful in many areas of transportation engineering such as the traditional capacity improvement, alternatives analysis, wide range of planning and policy evaluations, optimization of traffic control strategies, providing alternate route choices in ITS applications and for air quality and energy models. Thus, it becomes necessary to have accurate measures of congestion for analytical purposes, such as evaluation of transportation systems and prioritization of improvement measures, and at the same time for use by the policy makers and the public (*15*).

The methods to quantify congestion can be grouped into highway capacity manual (HCM) measures, queuing-related measures, and travel time-based measures. Selection of a particular method primarily depends on the facility being studied, constraints in data collection and purpose of congestion quantification. For example, if one wants to know the level of service (LOS) for a given facility, HCM based approach would be more appropriate than the other two approaches. If the purpose is to compare the congestion level across facilities or the same facility over different time periods in a format which is more understandable for the traveling public or the policy makers, then travel time based measures would be more relevant. If the data collection involves the travel time from active or passive probe vehicles, then travel time based approach would be more relevant as they involve travel time, speed and delay which can be easily computed

S. Vasantha Kumar, Ph.D Research Scholar, Department of Civil Engineering., IIT Madras, Chennai. E-mail: vasanth_research@yahoo.co.in
R. Sivanandan, Professor, Department of Civil Engineering, IIT Madras, Chennai. E-mail: rsiva@iitm.ac.in

from probe vehicles. If the data collection involves the measurement of volume/flow, speed and occupancy through loop detectors or video based techniques, then the HCM based method or queuing related approach would be more feasible.

This paper presents a review of congestion quantification studies. The performance measures found in various literature for congestion quantification were compiled and the necessary inputs for calculating them are reported. Suitability of these measures to Indian traffic conditions have also been explored. The suitability of these measures under Indian traffic conditions are examined in terms of data collection or measurement feasibility, technological advances like Global Positioning Systems (GPS) and Geographical Information Systems (GIS) and cost effectiveness. Unlike in developed countries, in India and in other developing countries, the use of automatic traffic data collection techniques is in nascent stage. Also, the unique nature of lack of lane-disciplined traffic in India restricts the applicability of certain performance measures which are lane based (eg., congested roadway expressed in lane-miles and lane-mile duration index) for congestion quantification.In recent years, the public transport buses in most of the metropolitan cities of India are gradually being equipped with GPS instruments for providing the bus arrival time information at bus stops. The real-time monitoring of movement of buses on urban streets could act as a good and cheap source of traffic information and could be considered for determining certain performance measures which are travel-time based. Hence, the study of suitability of the performance measures under Indian traffic conditions which can address our unique nature of traffic and data collection constraints attains importance and the present study is an attempt in this direction.

II. Overview Of Methods to Quantify Congestion

The methods to quantify congestion can be grouped into Highway Capacity Manual (HCM) measures, queuing-related measures, and travel time-based measures. Each of these methods is briefly explained below.

A. Highway Capacity Manual (HCM) based Method

The Highway Capacity Manual (HCM) (*3*) contains concepts, guidelines, and computational procedures for computing the capacity and quality of service of various highway facilities, including freeways, highways, arterial roads, roundabouts, signalized and unsignalized intersections, etc. The HCM based method mainly uses the volume to capacity (V/C) ratio and level of service (LOS) as performance measures to measure/quantify congestion. The usual classification of LOS is from A through F, with A describingthe free-flow operations and F the breakdown in vehicular flow stage. Congested conditions often fall into LOS F range, where demand exceeds capacity of the roadway. Volume-to-capacity ratios could be compared to LOS to reach conclusions about congested conditions.

The use of V/C ratio is one of the traditional ways to quantify congestion because of the relative ease of traffic volume data collection and because surrogate measures such as LOS can be derived from V/C values. While conceptually simple and easy to understand by the professional transportation community, HCM based measures tend to be abstract for the traveling public. They usually require detailed, location-specific input data, which makes them more appropriate for localized analyses and design than for area-wide planning (*4*). Thus, they tend to be most appropriate for individual highway segments or intersections, rather than for corridors or region-wide analysis, although composite or index measures can be calculated based on these measures, such as percent of the roadway network operating at LOS F (*5*). Also, HCM measures are difficult to use for long-range comparisons because concepts such as capacity and speed-flow relationships tend to change over time. Sometimes, estimating capacity even within 10 percent of its actual value can be a difficult task because of many variables which can influence capacity. Also, HCM based measures break down in oversaturated conditions (*6*).

Many HCM based studies have been reported for congestion quantification (*7-11*). Different organizations adopt different classification of V/C ratios for depicting various congestion levels. For example, a V/C ratio of less than 1.0 indicates uncongested level; 1.0-1.3 indicates congested level; V/C ratio of greater than 1.3 indicates severely congested level (*7*). In some studies (*8*), V/C ratio of 0.80 to 0.89 itself indicates moderate level of congestion; 0.90-0.99 indicates heavy congestion; V/C ratio of greater than or equal to 1.0 indicates severe congestion level.

In India, the notable studies on HCM based approach are by Patel and Varia (*9*), Maitra *et al*. (*10*) and Anjaneyulu and Nagaraj (*11*). Patel and Varia (*9*) assumed that congestion is functionally related to the speed-flow variation. Therefore, modeling congestion predominantly depends on the modeling of speed-flow behavior under prevailing roadway, traffic and control conditions. Based on this, they proposed 10 different levels of service 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. A similar study is by Maitra *et al*. (*10*), with more emphasis on volume and operational characteristics while estimating or defining the congestion. Anjaneyulu and Nagaraj (*11*) proposed five LOS categories (A-E) based on the plot between coefficient of variation of speed and the operating volume for all the three classes of roads studied.

B. Methods based on Queuing Measures

The queuing-related measures concentrate on measurement of queue length and lane occupancy as performance measures to quantify congestion. Queue length and duration can be determined by videographic techniques and lane occupancy (percentage of time a traffic lane is occupied by vehicles) can be measured from vehicle detectors. Queuing-related measures are increasingly being used (*12-13*) to quantify roadway congestion because of the increasing availability of vehicle detectors and other sensors. Although queues best reflect the public's perception of congestion, measuring queues remain laborious, site-specific, and time-specific. Because it is usually impractical to measure queues on a broader spatial scale, queuing-related measures tend to be inappropriate for planning and policy-related analyses (*4*). Installation of multiple loop detectors for queue detection in city streets has almost been precluded in view of the environmental cost and the need for systems maintenance (*12*). Development in detection technologies in recent yearshas made it possible to directly measure queue length, such as through the use of a video detection system. Application of such a system is limited by available capital, and physicaland environmental constraints (*12*).

Yi *et al*. (*12*) proposed a modeling approach to queue length estimation at a signalized intersection using a macroscopic model based on the continuum principle together with a general speed-density relationship.

Geroliminis and Skabardonis (*13*) proposed a methodology of identifying queue spillovers in a 1.42-mi-long stretch of Lincoln Avenue, which is a major urban arterial near the Los Angeles International Airport in US. The detector data of every 30 s (vehicle count and occupancy) and signal timing data for the study period was used as the input to spatially and temporally identify the spillovers. The authors concluded that the queue length estimation helps to preempt congestion by predicting congestion locations/times. It can also be integrated in real-time traffic management schemes, either at intersection scale or at larger complex urban systems.

C. Travel Time based Methods

The travel time-based measures to quantify congestion are primarily based on travel time, travel speed, and delay. Since traffic congestion is a dynamic phenomenon with elements of both space and time, travel time based measures are more appropriate as they are flexible enough to describe traffic conditions at various levels of resolution in both space and time. This makes travel time based measures appropriate for handling specific locations as well as entire corridors (*4*). Since most of the travel time based measures are dimensionless, it helps to compare mobility levels on different roadways or among different modes of transportation. It also allows analysts to perform comparisons over long periods of time, e.g., years or decades. The measures associated with the time or speeds are easy to understand and interpret by both the transportation professionalsand the traveling public. Travel time-based measures translate easily into other measures like user costs, and can be used directly to validate planning models such as travel demand forecasting models. Another advantage is that the travel time-based measures are applicable across modes (*14*) and reflect the combined effects of geometric and operational features of the road (*6*). Travel time measures can do a better job at pinpointing locations of congestion and can help in identifying congestion causes (*6*). All these reasons make travel time based measures extremely powerful, versatile, and desirable for congestion quantification. An increasing number of transportation agencies are switching to travel time measures to monitor and manage congestion (*4*). The National Cooperative Highway Research Program project on "Quantifying Congestion" (*15*), has recommended that travel time-based measures be used to estimate congestion. The latest 2011 Urban Mobility report (*16*) gives utmost priority for travel time based procedures to quantify congestion.

Many studies have been reported worldwide which use travel time estimates to quantify congestion. Taylor *et al*. (*17*) developed a GIS-based system for collecting on-road traffic data from an instrumented GPS fitted probe vehicle driven in a traffic stream. The probe vehicle can record travel time, distance covered, location, speed, fuelconsumed, air pollutant emissions, engine performance, operating state variables, and delay and queuing data over time (second-by-second). A case study application of the system is described focusing on studies of congestion levels on two parallel routes in a major arterial corridor in metropolitan Adelaide, South Australia. The performance measures like delay, congestion index, proportion stopped time, acceleration noise and mean velocity gradient were analyzed to study the extent and duration of morning and evening peak hour congestion in the selected corridors.

Quiroga (*4*) developed a GIS-based application to process 2.4 million GPS records on 40,000 km of travel time runs using probe vehicles on a 240-km highway network of Baton Rouge, Louisiana. The various performance measures studied were acceptable travel time, travel rate, delay, total delay, delay rate and relative delay rate.

The studies on travel time based congestion quantification are still in a rudimentary stage in India. One of the earlier attempts in India was by Srinivasan and Shetty (*18*) and a similar recent study was by Lovely (*19*). Srinivasan and Shetty (*18*) proposed six measures of congestion, namely, the average travel speed, average stopped time per km, average stopped time per minute of travel time, average number of slowdowns per km, average number of slowdowns per minute of travel time and speed-based congestion index. The measures were evaluated in 146 roads separately for morning and evening peak hour by employing 2 to 4 test car runs in the metropolitan city of Bangalore, India. The speed-based congestion index values obtained for various road stretches were classified based on ten category levels (Nil, 0-10, 10-20, … , 80-90) and the percentage of the length of roads in km for each category was found separately for morning and evening peak hour. It was found that during both the peaks, nearly 95% of road lengths have congestion below 50% level and average stopped time of 2.5 sec occurred per minute of total travel time. The study employed a moving observer method for manually noting down the travel times and stopped times. .

A total of 32 measures were identified from literature (*4*, *15-29*) which are travel time based and are listed in Table 1. The required input to calculate these measures are also shown in column 2 of the table along with the source(s). The selection criteria for choosing a particular measure primarily depends on the purpose for which congestion quantification is being done. For example, if the objective is transportation planning and policy evaluations, then measures from Sl. No.16 through 32 would be more appropriate as they usually express congestion in terms of vehicle-hours or person hours on an annual basis. They require inputs like trip purpose, volume, vehicle occupancy, congested road length and duration, etc. in addition to actual travel time, speed or delay. Also, for trip reliability studies, measures like buffer index could be considered.

If the objective is to evaluate the current system performance to suggest improvement measures to reduce congestion or if it is required to display the current traffic conditions through web/VMS in a more user friendly format, then measures from Sl. No. 1 to 13 would be more preferable. They involve only the primary inputs like travel time, speed or delay. People can easily understand and interpret these performance measures. The acceleration noise and mean velocity gradient (Sl. No. 14 & 15) could be considered for detailed congestion analysis as it involves the study of speed changes over time.

There is a possibility that the congestion measures from 1 to 15 of Table 1 are correlated. Este *et al*. (*21*) studied this aspect by considering seven parameters, namely, the travel time, speed, congestion index, time moving, acceleration noise, mean velocity gradient and proportion stopped time and calculated the correlation coefficients between the various congestion parameters for morning peak flows. It was found that, out of the seven congestion parameters that were investigated, there are only two fundamentally different indicators. Acceleration noise is one, while all the other six parameters are highly correlated. Since the other six parameters are highly correlated, there is no need to calculate more than one of the six, and the observer is free to select the parameter that is the easiest and most convenient to observe.

Table1: List of Travel Time Based Congestion Measures

Sl.No.	Performance measure	Required input	Source (See references)
1.	Congestion index or Relative delay rate	Travel time	19, 20, 21, 22, 23
2.	Congestion index (based on speed) or Degree of congestion	Speed	18, 19
3.	Travel rate	Travel time	4, 15, 24, 25
4.	Delay rate	Travel time	4, 15, 23, 24, 25
5.	Travel rate ratio	Travel time	24
6.	Delay ratio	Travel time	15, 24, 25
7.	Time moving	Travel time	21
8.	Proportion Stopped Time (PST)	Travel time	17, 21, 22
9.	Travel time rate or Travel rate index	Travel time	25, 26
10.	Travel time index	Travel time	16, 25, 26, 27, 28
11.	Delay or Travel delay	Travel time	4, 16, 17, 22, 25
12.	Percentage delay	Travel time	29
13.	Travel time ratio	Travel time	29
14.	Acceleration Noise (AN)	Travel time and speed	17, 21
15.	Mean Velocity Gradient (MVG)	Travel time and speed	17, 21
16.	Total delay	Travel time, volume, vehicle occupancy	4, 15, 25, 27
17.	Buffer Index (BI)	95th percentile travel time	25, 27, 28
18.	Misery index	Travel time	25, 28
19.	Congested travel	Congested road length, volume	15, 25, 27
20.	Congested roadway	Congested road length	15, 25, 27
21.	Accessibility	Travel time, trip purpose	15, 25, 27
22.	Speed reduction congestion index	Mean travel speed of vehicles	15, 23, 27
23.	Congestion severity index	Delay, volume	15, 25
24.	Lane mile duration index	Congested road length, duration	15, 25
25.	Incident related travel delay	Delay, Recurring to incident delay factor ratio	16
26.	Annual person delay	Delay, vehicle occupancy	16
27.	Person speed	Passenger volume, speed	15
28.	Corridor mobility index	Speed of person movement	15
29.	Delay per traveler or per person	Travel time	27, 28
30.	Planning time index	95th percentile travel time	27
31.	Percent of congested travel	Volume	16, 27, 28
32.	Percent variation	Travel time , standard deviation	28

III. SUITABILITY OF PERFORMANCE MEASURES UNDER INDIAN TRAFFIC CONDITIONS

In India, the traffic comprises wide variety of vehicle classes of varying static and kinematic characteristics; also, lane discipline is poor on urban roads. This raises certain issues on the applicability of certain performance measures which are expressed in lane-based or vehicle-based units. This aspect needs further examination.

In terms of traffic data collection for input to performance measure calculations, currently, automatic traffic data collection system applications in India are in a nascent stage. The roads and nature of traffic here raises issues in installation and maintenance ofthe loop detectors. Recent advances in image processing technology may have potential to realize automatic extraction of flow/volume for heterogeneous traffic conditions. As an alternative to laborious data collection, simulation of traffic conditions can also be potentially adopted to measure congestion. However, appropriate simulation models for heterogeneous traffic will be needed for this purpose.

When compared to other two approaches, the travel time based method offers many advantages for congestion quantification. The disadvantage with travel time based congestion measures could be the budgetary limitations which can impose restrictions on the number and coverage of travel time studies using active probe vehicles. However, the recent technological advances are assisting transportation officials in providing the necessary tools to make travel time data collection more affordable and reliable. Examples of those technological advances include electronic transponders for automatic vehicle identification (AVI), Global Positioning Systems (GPS) and Geographic Information Systems (GIS). According to Este *et al*. (*21*), GPS offers an accurate and cost-effective mechanism for collecting real-time stream of data about road system performance which can then be processed to derive congestion measures for monitoring the performance of the road system, for integration into ATIS, and for planning and management of the road network.

In recent years, an increasing number of buses, taxis, couriers, commercial and government vehicles, and even private cars are being fitted with GPS. This constitutes a valuable resource that can be tapped to provide real-time data ontraffic conditions (*21*). In India, equipping private vehicles with GPS may be a difficult task due to privacy issues and lack of public participation. However, the public transit vehicles in major metropolitan cities of India are gradually being equipped with GPS devices. The Metropolitan Transport Corporation (MTC) of Chennai has GPS in 600 buses out of the total fleet size of 3,400 (THE HINDU, March 03, 2009). Process is underway to install the GPS system in another 1,000 buses. The public transit buses travel alongside other vehicles and quite often both experience same traffic conditions, intersection control or incidents or special events.The use of public transit as probes for congestion quantification offers advantages like frequent trips during peak hours, wide range network coverage, etc. However, the travel time characteristics of public transit buses are influenced by the transit characteristics like frequent acceleration, deceleration and stops due to bus stops, besides the differences in physical characteristics.Also, the sample size of public transit buses may be an issue when compared to the overall vehicle population. Even then, studies have been carried out to relate bus travel time to steam travel time (*30*, *31*). But measuring congestion using only bus data is relatively a new area which has not been explored before and offers scope forresearch. Thus, in countries like India, where other reliable automated traffic data collection system is rarely available, GPS data from public transit buses may become an option for estimating the travel time based congestion measures such as congestion index, etc. When compared to running personal vehicles as test vehicles which involves huge cost, the use of public transit as probes is a cheaper and effective source of traffic information.Also, for assessing congestion levelsin real time at different times of the day, the GPS data from public transit buses could be a potential source.

IV. A Pilot Study To Evaluate the Feasibility of the Use of Public Transit Buses as Probes

The feasibility of the use of GPS fitted public transport buses as vehicle probes for quantifying the congestion was studied by carrying out a pilot study in one of the bus transit routes in Chennai, India. The bus route selected was route number 5C, which connects the Parrys in north and Taramani in south with a route length of about of 15 km. This route is representative of an urban road in India as it comprises road links of varying geometric and traffic characteristics. Data collection was carried out at different times of the day over a week using GPS units, which were fixed in the public transit buses and by manually carrying GPS devices in three types of personal vehicles - two-wheeler, auto and car; 14 trips were made for each mode. The personal vehicle trip was started at the same time and location as that of the public transit bus and followed the same route with a speed representative of other vehicles. In order to facilitate the comparison of congestion index (C.I) of bus and that of personal vehicle, the entire study stretch of 15 km was divided into uniform 500 m subsections and the data extraction involved extraction of travel time of bus probes and personal vehiclesin each of these sections. Relating bus C.I to personal vehicle C.I becomes more meaningful if we consider the unique characteristics of transit buses. For example, the bus exhibits certain characteristics, such as frequent stops at bus stops and deceleration and acceleration when approaching and departing from bus stops, besides vehicular characteristics. In the present study, this has been taken into account by considering the dwell time at 21 bus stops along the route including the acceleration and deceleration times at each of those bus stops. Since all modes of vehicles are sharing the same roadway without any exclusive bus lanes, the only characteristic that differentiates the bus probes from the remaining vehicles is the dwell time at bus stops. Hence, the dwell time with associated acceleration and deceleration times were removed from the actual section travel times. The removed times were replaced with travel times interpolated based on the starting speeds (time when deceleration started) and ending speeds (time when acceleration ended) at bus stops, assuming that the bus did not stop at bus stops.

Congestion Index (C.I.) was computed for each 500m section for each of the 84 trips (14 trips×3 modes and corresponding public transit bus), both for public transit buses and personal vehicles. The below equation (*19, 20, 21, 22, 23*) was used.

$$Congestion\ Index\ (C.I) = \frac{Actual\ travel\ time - Free\ flow\ travel\ time}{Free\ flow\ travel\ time}$$

The C.I value near zero indicates very low levels of congestion, while an index greater than 2 shows congested condition (*21*). A sample result for two-wheeler is shown in Figs.1a and 1b. Fig. 1a shows the variation in C.I for bus and two-wheeler over distance (by section). Fig.1b relates the C.I.s of bus and two-wheeler for various sections.As expected, the public transit congestion index is greater when compared to that of two-wheeler due to the difference in average speed of bus and two-wheeler. It can be seen from Fig.1a that both the modes show a similar trend (increasing and decreasing) in C.I variation (in 500m section), which indicates that the public transit can potentially serve as a probe for ascertaining the traffic congestion of other vehicles in the stream. In order to statistically confirm this, the correlation analysis was carried out using Pearson's correlation coefficient calculated between the bus C.I and personal vehicle C.I. The result of correlation analysis is shown in Fig.2. It can be seen from Fig.2 that, the correlation coefficient is positive for all the 42 trips. The correlation coefficient will be positive only if the variables tend to go up and down together. It shows that if the traffic is higher in a particular section, both transit probe and other vehicles will get slowed down. Similarly, if free flow condition exists, both the modes travel fast. Statistical hypothesis tests were conducted to verify that the correlation coefficients were, in majority of the cases, significantly different from zero. The results of correlation analysis thus indicate that the buses could be used as probes for ascertaining the congestion levels experienced by other personal vehicles such as two-wheeler, auto and car. The outcome of correlation analysis and the visual inspect of scatter plot diagram (Fig.1b) indicates that a linear relationship could be built between bus C.I (independent variable) and the two-wheeler C.I (dependent variable).The regression model fitted for the data shown in Fig.1b has the form $y = 0.795x - 0.574$, where y is the two-wheeler C.I (dependent variable) and x is the bus C.I (independent variable), with R-square estimated as 0.669. Similar to two-wheeler, regression models can be fitted for other remaining trips and modes as well. Using the regression equation as shown in Fig.1b, one can predict the C.I of other personal vehicles using only the bus C.I. Further evaluation and enhancement of such models are underway. The section-wise bus C.I can easily be computed in real-time using the GPS data from public transit buses.Thus, for countries like India, where the sophisticated automated data collection systems are in nascent stage, the GPS data from public transit buses may potentially be considered to infer about the stream traffic congestion using travel time based measures such as C.I.

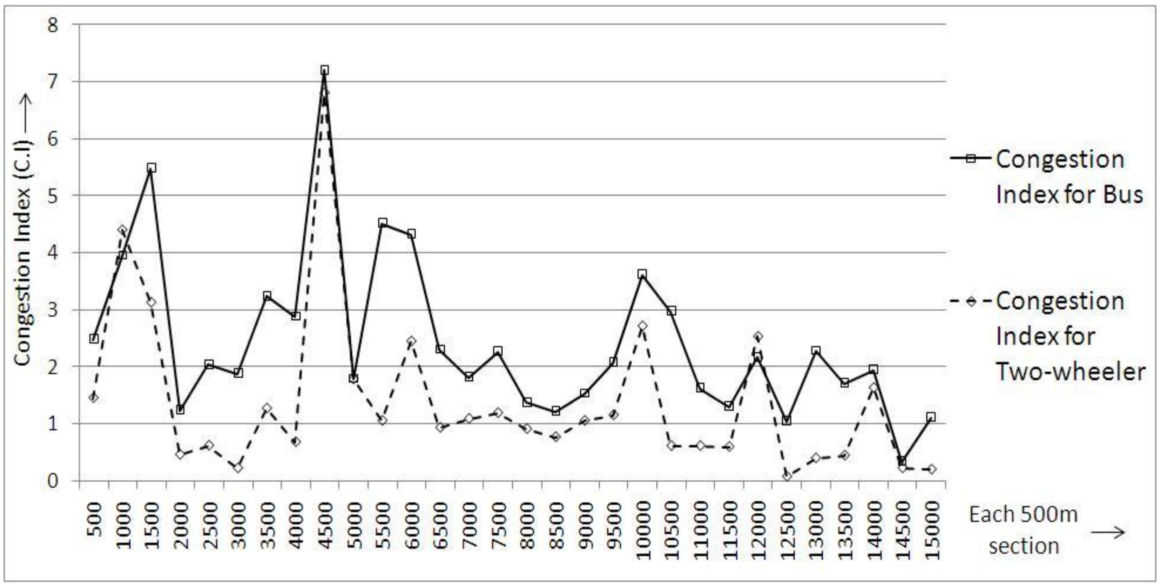

Figure 1a: Variation in C.I over Distance (Section-Wise) for a Sample Two-Wheeler Trip

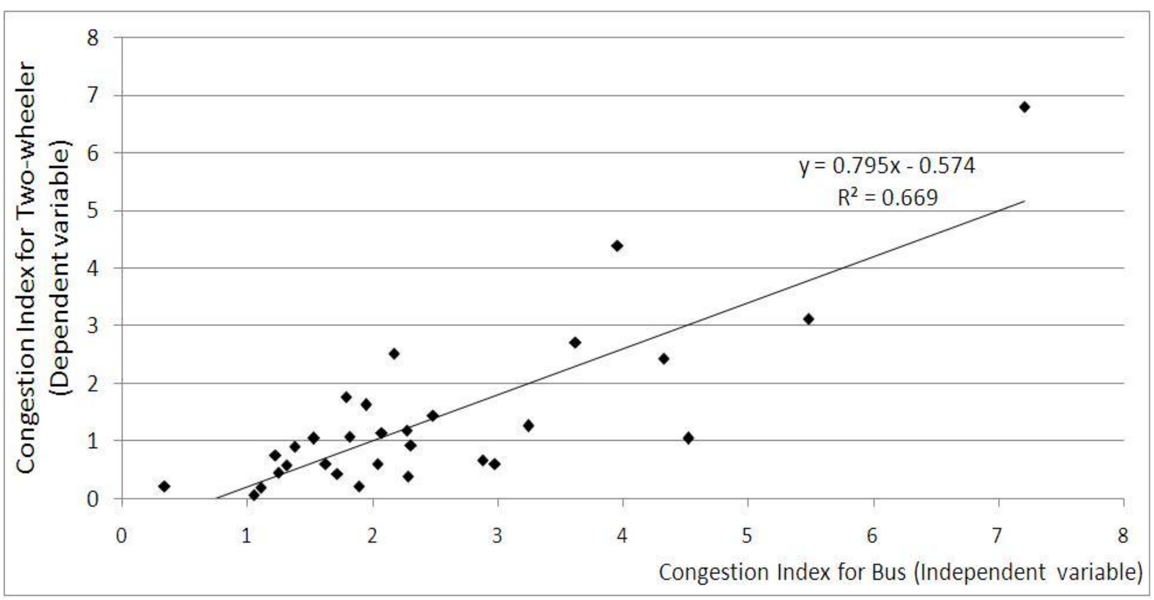

Figure 1b: Plot of C.I between Bus and Two-Wheeler for a Sample Two-Wheeler Trip

ISBN 978-93-82338-01-7 | © 2012 Bonfring

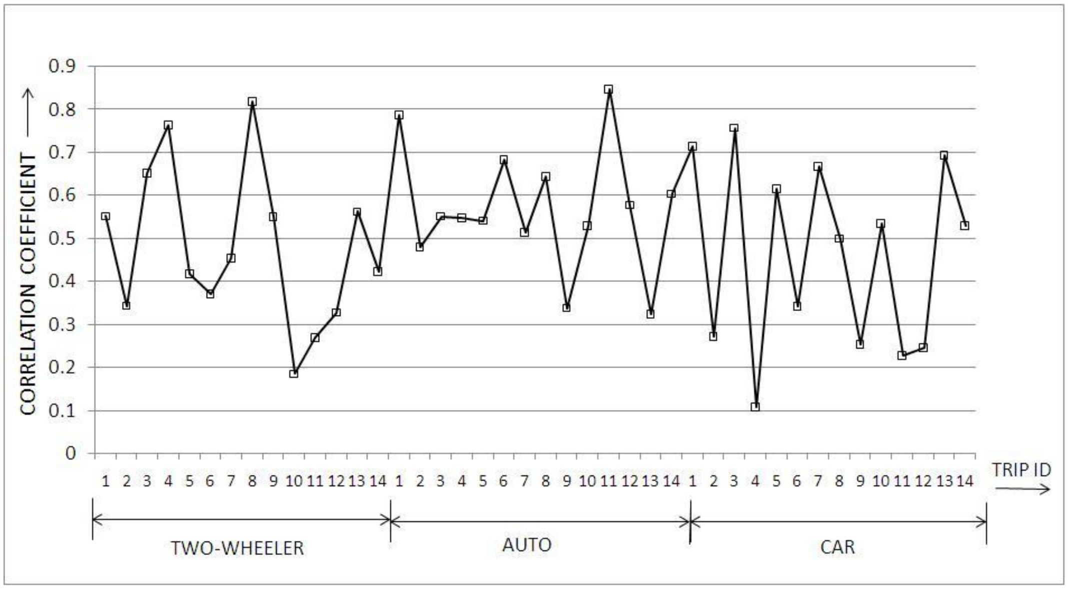

Figure 2: Trip-Wise Correlation Coefficient Calculated between Bus C.I and Personal Vehicles C.I.

V. CONCLUDING REMARKS

This paper presented a brief review of various approaches to quantify congestion based on comprehensive literature search. The selection criteria for choosing a particular measure primarily depends on the purpose for which congestion quantification is being done. It was found that the use of travel time based congestion quantification approach provides more advantages when compared to other approaches like HCM based procedure and queuing based approach. The GPS can give the required data on travel time, speed and delay in real-time for input to travel time based congestion measures. In India, GPS fitted public transit buses could potentially be used as probes for assessing real-time congestion levels by adopting travel time based measures in a cost effective manner. However, issues like acceleration, deceleration near bus stops, stopping time at bus stops and staging for ticketing, besides low sample size when compared to overall population, are the challenges which need to be addressed when considering public transit buses as probes for estimating stream congestion. A pilot study was demonstrated using correlation and regression analysis, on the use of congestion index calculated using GPS data of public transit buses for estimating other personal vehicles congestion index in a typical urban bus route in the metropolitan city of Chennai, India. The results are promising, though further evaluation and enhancement of approach is desirable.

VI. ACKNOWLEDGEMENT

This study was made possible partly due to funds made available through Centre of Excellence in Urban Transport at IIT Madras, sponsored by Ministry of Urban Transport (MoUD), Govt. of India.

REFERENCES

[1] Study on traffic and transportation policies and strategies in urban areas in India - Final Report, Chennai Metropolitan Development Authority, India, 2008.
[2] Second Master Plan for Chennai Metropolitan Area 2026, Chennai Metropolitan Development Authority, Chennai, India, 2008.
[3] Highway Capacity Manual 2010, Transportation Research Board, Washington, D.C.
[4] Quiroga, C.A. (2000) Performance measures and data requirements for congestion management systems. Transportation Research Part C, 8, 287-306.
[5] Grant, M. and C. Fung (2005) Congestion Management Systems: Innovative Practices. Task 1 report. ICF Consulting Inc., Fairfax, VA, USA.
[6] Beverly, N. (2004) Transportation 2025 - Appendix: Congestion Management Plan. State guide plan element 611, State of Rhode Island and Providence, USA.
[7] Congestion Management Process (CMP) - State of the System Report - Fiscal Year 2011, Austin, Texas, USA.
[8] Congestion Management System for the Mid-Hudson Valley Transportation Management Area – 2005, Orange County Transportation Council (OCTC), Goshen, NY, USA.
[9] Patel, S.G. and H.R. Varia (2010) Evaluation of level of service through congestion on urban road links. Proceedings of the 12th World Conference on Transport Research (WCTR), Lisbon, Portugal.
[10] Maitra, B., P. K. Sikdar and S. L. Dhingra (1999) Modelling congestion on urban roads and assessing level of service. Journal of Transportation Engineering, 125(6), 508-514.
[11] Anjaneyulu, M.V.L.R. and B.N. Nagaraj (2009) Modelling congestion on urban roads using speed profile data. Journal of Indian Roads Congress, Paper No.549, 65-74.
[12] Yi, P., C. Xin and Q. Zhao (2001) Implementation and field testing of characteristics-based intersection queue estimation model. Networks and Spatial Economics, 1, 205-222.
[13] Geroliminis, N. and A. Skabardonis (2011) Identification and Analysis of Queue Spillovers in City Street Networks. IEEE transactions on Intelligent Transportation Systems, 12(4), 1107-1115.
[14] Laird, D. (1996) Emerging issues in the use of GPS for travel time data collection. National Traffic Data Acquisition Conference, Albuquerque, New Mexico.
[15] Lomax, T. (1997) Quantifying congestion - Volume 1. NCHRP report 398. Transportation Research Board, Washington D.C.
[16] Schrank, D., T. Lomax and B. Eisele (2011) Urban mobility report. Texas Transportation Institute, The Texas A&M University System, Texas, USA.

[17] Taylor, M.A.P., J.E. Woolley and R. Zito (2000) Integration of the global positioning system and geographical information systems for traffic congestion studies. Transportation Research Part C, 8, 257-285.
[18] Srinivasan, N.S. and P.S. Shetty (1971) Travel time study in a metropolitan city. Journal of the Indian Roads Congress, 34(2), 233-284.
[19] Lovely, L. and N. Madhu (2006) Study on congestion measurement on urban road stretch. Proc. of the NCTT2006 Conference, Trivandrum, India.
[20] Tong, D Traffic information deriving using GPS probe vehicle data integrated with GIS. http://www.gis-t.org/files/ 13auY.pdf, Nov.2005, Last accessed November 23, 2011.
[21] Este, G.M.D., R. Zito and M.A.P. Taylor (1999) Using GPS to measure traffic system performance. Computer-Aided Civil and Infrastructure Engineering, 14, 255–265.
[22] Ali, A.T. and M.M. Venigalla (2006) Global positioning systems data for performance evaluation of HOV and GP lanes on I-66 and I-395/I-95. Proc. of the IEEE Intelligent Transportation Systems Conference, Canada.
[23] Smit, R., A.L. Brown and Y.C. Chan (2008) Do air pollution emissions and fuel consumption models for roadways include the effects of congestion in the roadway traffic flow? Environmental Modelling& Software, 23, 1262–1270.
[24] Vaziri, M., R. Jafarabadyand S.P. Bindra (2007) Modeling highway congestion index for a developing country: the Iran experience. ScientiaIranica, 14(1), 1-10.
[25] Medley, S.B. and M.J. Demetsky (2003) Development of congestion performance measures using ITS information. Report VTRC 03-R1, Virginia Transportation Research Council, Charlottesville, Virginia.
[26] Transportation cost and benefit analysis II – congestion costs. http://www.vtpi.org/tca/tca0505.pdf , Victoria Transport Policy Institute (VTPI), Aug 2011, Last accessed November 23, 2011.
[27] NCHRP report 618-Cost-effective performance measures for travel time delay, variation, and reliability. Transportation Research Board, Washington D.C, 2008.
[28] Lomax, T., S. Turner and R. Margiotta. Monitoring urban roadways in 2000: using archived operations data for reliability and mobility measurement. FHWA-OP-02-029, Texas Transportation Institute, College Station, TX, 2001.
[29] Gaurav, R. A travel time delay approach to quantifying congestion in the Chicago area. Working Paper 96-17, Chicago Area Transportation Study, Illinois.
[30] Kumar, S.V., L.Vanajakshiand S.C. Subramanian (2011) A model based approach to predict stream travel time using public transit as probes. 2011 IEEE Intelligent Vehicles Symposium (IV), Baden-Baden, Germany, 101-106.
[31] Bertini, R.L. and S.Tantiyanugulchai (2004) Transit Buses as Traffic Probes: Empirical Evaluation Using Geo-Location Data, Transportation Research Board, 83rd Annual Meeting (CD-ROM), Washington, D. C.
[32] Welkowitz, J., R.B. Even and J. Cohen (1999) Introductory Statistics for the Behavioral Sciences. John Wiley & Sons.