STUDY ON TRAFFIC CONGESTION PROBLEM IN INDIA AND ABROAD- A REVIEW

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Abstract: *Traffic congestion has been one of major issues that most metropolises are facing. The first step for selecting appropriate mitigation is identification of congestion measures. Congestion - both in perception and in reality - impacts the movement of people. Traffic congestion wastes energy, time and causes pollution. There are two factors due to which congestioneffect; (a) micro-level factors (b) macro-level factors that relate tooverall demand for road use. Congestion is 'triggered' at the 'micro' level (e.g. on the road),and'driven' at the 'macro' level. The micro level factors are, for example, many people want tomove at the same time, too many vehicles for limited road space. On the other side, macro level factors are e.g. land-use patterns, car ownership trends, regional economic dynamics, etc. this paper gives an overview and presents the possible ways to identify and measure metrics forurban arterial congestion. A systematic review is carried out, based on measurement metricssuch as speed, travel time/delay and volume and level of service. The review covers distinctaspects like definition; measurement criteria followed by different countries/organizations. The strengths and weaknesses of these measures are discussed. Further, a short critique ofmeasurement criteria is presented.*

Keywords:*Congestion measurement. data collection methods, land use pattern traffic congestion,*

1. INTRODUCTION

The major issue that most metropolises are facing is Traffic congestionandtherefore, many measures have been taken in order to mitigate congestion. It is believed thatidentification of congestion characteristics is the first step for such efforts since it is anessential guidance for selecting appropriate measures. Congestion impacts the movement of people and freight both in reality and in perception and is deeply tied to the history ofhigh levels of accessibility and mobility. Traffic congestion wastes time and energy, causespollution and stress, decreases productivity and imposes costs on society.

There are two principal categories of causes of congestion, and they are; (a) micro-levelfactors (e.g. relate to traffic on the road) and macro-level factors that relate to overalldemand for road use. Congestion is "triggered" at the "micro" level (e.g. on the road), and"driven" at the "macro" level by factors that contribute to the incidence of congestionand its severity. The micro level factors are, for example, many people and freight wantto move at the same time, too many vehicles for limited road space. Many trips may bedelayed by events that are irregular, but frequent: accidents, vehicle breakdowns,poorly timed traffic signals, special events like mass social gatherings, political rallies,bad weather conditions, etc. which present factors that cause a variety of trafficcongestion problems. On the other side, macro level factors e.g. land-use patterns, employment patterns, income levels, car ownership trends, infrastructure investment, regional economic dynamics, etc. also may lead to congestion.

Measures aimed at reducing congestion can the either demand or supply side oriented. It istherefore important to distinguish both types of measures. Three main factors influence thesupply side of road travel. Firstly, capacity is one of the most important elements ofroad space supply. For example, the total kilometres of roads and the number of lanesdetermine the capacity of the road network. Secondly, the operation of the road networkinfluences supply. Maximising the efficiency of operations, such as optimising signals improves "supply". Thirdly, the supply of the road transport equation is also affected byincidents such as accidents or road works. Importantly, the last two aspects can beinfluenced by traffic management approaches. It is thus the supply-side of the road networkthat can be optimised by traffic management tools. Supply of road space is mainlydetermined by past investment decisions and current operations. Changes in the supplyside of road space thus involve construction of new road space or reductions in existingroad space. Changes in traffic operations are also considered to be supply side measures.

Demand for road space is influenced by a large number of issues. Essentially, demand is createdwhen the need for travel between an origin and a destination arises. Demand therefore stronglydepends on socio-economic and population factors. Another important factor influencingdemand is the relative cost of road travel as well as the availability of alternative meansof transport. Other aspects that influence demand for road travel are availability of parkingand the social perception of car versus public transport travel.

This review paper discusses the existing practices in India and Abroad, the contributions byindividuals and prevailing methodologies for measurement of the congestion along withthe critical review of the methods. Review has also been done with reference to Indianconditions. The critique and the suggested methodology may be useful for similardeveloping countries.

II. STUDIES CARRIED OUT IN INDIA AND ABROAD

IN INDIA

Major problem for Civil engineers in India is Traffic Congestion. Cities are suffering from different level of traffic congestion. The growth of private vehiclesage has increased at a faster rate in most of the cities. In general,car ownership and usage has remained at a much lower level in Indian context. The poorroadway condition, non-uniform roadway features in terms of carriageway and shoulderwidth, encroachment of road, abutting land use and resulting pedestrian activities, poorlane discipline, improper bus stop location anddesign, vehicles of wide ranging characteristicsof technology and operating condition, heterogeneity of traffic, uncontrolled on-streetparking, etc. indicate that the nature and cause of congestion in India might be substantiallydifferentfrom that in the developed countries. Although the roads are becoming at a fast rate,there has been no serious attempt to quantifythe growth of congestion in different citiesin India. The non-availability of funds for additional roadway infrastructure has serioulyconstrained the growth of the supply side.

Pucher et al. (2005) summarize key trends in India's transport system and travel behaviour, analyze the extent and causes of the most India's urban transport crisis, severe problems, and recommend nine policy improvements that would help mitigate the problems. Dewan and Ahmad (2007) conducted a survey for car-pooling in Delhi and willingness of commuters for car-pooling and they observed that car-pooling is one of then solutions to reduce the traffic congestion in Delhi. Sen et al. (2009) discussed the characteristics of the ITS techniques that need to be developed to cater the traffic conditions and congestion in developing regions and presented a brief description of a few efforts being made in this direction. Merugu et al. (2009) discuss the project INSTANT (INfosys-STANford Traffic project), carried out for six months from Oct 6, 2008, to April 10, 2009 and which involved about 14,000 employees of Infosys. The aim of the project is providing incentives to decongestors. The project succeeded in incentivizing many commuters to travel at uncongested times, thereby significantly reducing their commute times. Roy et al. (2011) discuss a novel and interesting way to detect the congestion on the urban arterials in India. They suggest using a Wi-Fi signal emitting device and a receiver across the road to identify the congestion. This method was found to be successful in terms of high accuracy of classifying the road as congested or free flowing. Anusha et al. (2013) studied that two-wheelers constitute a major proportion of urban traffic in developing countries and therefore their effect on the saturation flow at signalized intersections could be substantial. A Meher et al. (2014) concluded that traffic simulation model VISSIM can be used to generate the traffic flow and speed data for conditions that are difficult to obtain from field observations.Ajitha et al. (2015) investigated the issue of estimating traffic density in the absence of automated sensors at the side roads/ramps on Indian roadways.Gowri et al. (2015) developed simulation model that can be used as an appropriate intersection lane control tool for enhancing the efficiency of flow at intersections.SuprabeetDatta et al. (2017) s studied to build up a VISSIM simulation model andalign it to find out volume-to-capacity proportions of turning movements at uncontrolled intersections under Indian mixed traffic conditions.Badhrudeen et al. (2018) studied the phenomenon of platoon dispersion deals with the spreading out of groups of vehicles discharged together from a signal (platoon) as they move along the roadway during normal traffic operations.Gowri et al. (2018) developed avehicle-specific lateral shift duration model by considering different explanatory variables such as direction of lateral shift, available space gaps, speeds of subject vehicle and surrounding vehicles, vehicle types, and clearance. Roshan et al. (2018) studied that GPS data can not only be used to predict the locations of bottlenecks but also provide insightful information about the type of infrastructure, which is useful for highway operations and management.

STUDIES CARRIED OUT ABROAD

Dewees (1978) use a simulation program to estimate the external time costs that an additional vehicle using a congested city street imposes on other motorists on that street. This study demonstrated the usefulness of a traffic simulation program for estimating congestion costs. The paper addresses data needs and examines the use of global positioning system (GPS) technology for the collection of travel time and speed data. Turner (1992) examined indicators of congestion and suggested that measures to quantify the level of congestion should (i) deliver comparable results for various systems with similar congestion level, (ii)accurately reflect the quality of service for any type of system, and (iii) be simple, well defined and easily understood and interpreted among various users and audiences. Thurgood (1995) developed an index called Freeway Congestion Index, which simultaneously captures the extent and duration of congestion on freeways. Levinson and Lomax (1996) discussed desired attributes of a congestion index. Traffic congestion is travel time or delay in excess of that normally incurred under light or free-flow travel conditions (Lomax et al., 1997).Boarnet et al. (1998) identified three issues that must be addressed in measuring congestion. It should (i) reflect the full range highway performance, (ii) be based on widely available data, and (iii) allow comparison across metropolitan areas. Traffic congestion is a condition of traffic delay (when the flow of traffic is slowed below reasonable speeds) because the number of vehicles trying to use the road exceeds the traffic network capacity to handle those

(Weisbrod et al., 2001). Congestion may be 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) (Bovy and Salomon, 2002). Medley and Demetsky (2003) studied how to define the performance measure(s) that could be used to show congestion levels on critical corridors throughout Virginia and to develop a method to select and calculate performance measures to quantify congestion in a transportation system. Total delay and the buffer index were used in the investigation. The methodology is applied for Hampton Roads region of Virginia. Congestion can be defined as the situation when traffic is moving at speeds below the designed capacity of a roadway (Downs, 2004).

Robert and Theodore (2002) discussed various approaches for quantifying congestion andhow these different measures affect the perception of the problems. In a study done for the state of New Jersey, thresholds of the volume-capacity ratio on any given roadway were adopted to identify where congestion was occurring. The severity of this congestion was thenanalyzed by using both distance-based and time-based measures to describe the magnitude of the problems. Stathopoulos and Karlaftisis(2002) studied how to estimate the duration of congestion on a given road section and the probability that, given its onset, congestion will end during the following time period. The results indicated that the Log logistic functional form best describes congestion duration.Choi et al. (2007) conducted a study by applying Travel Time Index (TTI) to show the level of traffic congestion. It was observed that TTI index describes the traffic congestion in both time and space with minimum of data collection effort. Aworemi et al. (2009) examined the causes/effects (road condition, accidents etc.) and possible ameliorative measures of road trafficcongestion in some selected areas of Lagos State. Hongsakham et al. (2008) proposed method for estimating degrees of roadtraffic congestion by using Cell Dwell Time (CDT) information available fromcellular networks and classified into degrees of congestion. Dowling et al. (2004) defined methodology for estimating and predicting the total annual traffic congestion attributableto recurrent and non-recurrent congestion. The methodology is applicable to freeways,conventional highways, and urban streets. Ishida et al. (2003) develop the recording system ofthe driver’s judgment on congestion/jam by using PC to find major factors affecting thecongestion/jam recognition of drivers as well as passengers, and lastly to develop congestion/jam judgment model. A methodology and its application to measure total, recurrent, andnon-recurrent (incident related) delay on urban freeways are described using two real-lifefreeway corridors in Los Angeles, California, and one in the San Francisco, California, BayArea (Skabardonis et al., 2003). The authors observed that incident-related delay wasfound to be 13-30% of the total congestion delay during peak periods. Owusu et al. (2006) demonstrated that efficient vehiclemonitoring can be achieved by integrating Global Positioning System (GPS) derived trafficdata such as vehicle speed and direction of traffic flow into a Geographical Information System(GIS) environment. The system developed has been used to show the second-to-second positional changes in speed and directions of vehicles travelling in Kumasi, the second largest city in Ghana. The aim of the study performed by Ishizaka et al. (2005) is to discuss the feasibility of a system to collect traffic information using probe vehicles in a developingcity (Bangkok) in terms of cost efficiency. Study estimated the minimum number of probe vehicles that can ensure sufficient data collecting information from which reliable average travel time can be calculated. The Transport Systems Centre (TSC) has developed an integrated Global Positioning System (GPS)(Taylor et al., 2000). This paper presents areview of issues, procedures, and examples of application of geographic information system (GIS) technology to the development of congestion management systems (CMSs).The paper examines transportation network performance measures and discusses the benefit of using travel time as a robust, easy to understand performance measure.StathopoulosandKarlaftis (2002) tried to probabilistically model the duration of traffic congestion usinglog-logistic function. Cottrell (1991) developed logistic regression models with explanatory variables, AADT/capacity, K-factor (i.e., the ratio of the 30th highest hourly volume of theyear to the AADT) to predict the occurrence of congestion. Simulation program is used to estimate the external time costs that an additional vehicle using a congested city street imposes on other motorists on that street. The traffic flow on two street networks in Toronto is simulated for the morning rush hour anda mid-day period. This study demonstrated the usefulness of a traffic simulation program for estimating congestion costs and identifies some problems inherent in previous empirical approaches to this problem.MilicaSelmic (2014) studied that the BOCR approach has four merits, as follows: (1) benefits, (2) opportunities, (3) costs, and (4) risks; the developed model considers the problem of trafficvolumereduction in the city. The model is very flexible and easily can be modified and/or improved for some other cities.

Lam and Tam (1997) investigate why the standard modelling and evaluation procedures currently used by the Hong Kong Government are inadequate for assessing the traffic congestion measures. Empirical evidence is given together with discussion on modelling and evaluation issues raised by the existence of suppressed/induced traffic.Pattara-atikom et al. (2006) investigates way to estimate degrees of road traffic congestion based on GPS measurements from main roads in urban areas of Bangkok, Thailand. The study used human perception to obtain classification thresholds and evaluated the performance of the proposed method et al. (2007) classify the traffic states and define types of recurrent congestion according to their evolvement. An approach of identifying traffic control area and congestion source using spatial-temporal speed figure is introduced et al. (2008) focus on experimental observations and theoretical analysis of urban freeway congestion due to complex features of traffic flow, shock wave and state transition. Study observed that the theory of shock wave speed could be used to help establishing traffic control strategies and to control queue length. Sun et al. (2009) studied the relations between traffic flow parameters of trafficbottleneck and phase transitions in profiles of traffic flow fundamental parameters.Zhengyu et al. (2009) studied the spatiotemporal characteristics of urban trafficcongestion, and identified the frequent congested sections in the network ofShanghai city using floating car data. Zhang and Gang(2009) studied the system objective function of minimum network congestion – valuesand the quantitative analysis model of traffic congestion state for the Sioux Fallsnetwork. Wei et al. (2017) investigated a microscopic spatial-temporal method to capture the vehicle movement trajectories at an isolated intersection in China.

III. IDENTIFICATION OF THE CONGESTION MEASUREMENT METRICS

Congestion can generally be defined as excess demand for road travel. Supply of road travel infrastructure is not sufficient to meet demand levels to a given level of service. Traffic congestion increases delays to users. Consequently, travel speeds fall and delays are explained. This general definition of congestion implies that it can be measured in various ways. Average speed, flow/density, delay and travel time variability can all be used to assess the level of congestion.

SPEED

The prevailing traffic speed at any section of a roadway affects the quality of trafficat the time. Whereas excessive speeds affect the severity of road traffic accidents,crawling speeds in the urban environment are also indicative of congestion. Nowadays,efficient vehicle monitoring can be achieved by integrating Global Positioning System(GPS) derived traffic data such as vehicle speed and direction of traffic flow into aGeographical Information System (GIS) environment.

TRAVEL TIME AND DELAY

Congestion is a travel time or delay in excess of the normally incurred under light or free flow travel conditions (Lomax et al., 1997). Unacceptable congestion is traveltime or delay in excess of an agreed-upon norm. The agreed-upon norm may varyby type of transportation facility, travel mode, geographic location, and time of theday. The authors of the study conducted using the U.S. Census data to analysetheunacceptable congestion, concluded that the unacceptable congestion is when lessthan half of the population can commute to work in less than 20 minutes or if morethan 10% of the population can commute to work in more than 60 minutes. Congestion is the presence of delays alonga physical pathway due to presence of other users (Kockelman, 2004).

VOLUME

In Cape Cod, Massachusetts, a traffic congestion indicator is used to track average annual dailybridge crossings over the Sagamore and Bourne bridges. This very simple measurewas chosen for this island community since it is appropriate, easy to measure, and sincehistoric data are available to monitor longterm trends. Congestion usually relates to anexcess of vehicles on a portion of roadway at a particular time resulting in speeds that areslower sometimes much slower than normal or "free flow" speeds (Cambridge Systematicand .I, 2005).

LEVEL OF SERVICE (LOS)

Michigan defines freeway congestion in terms of LOS F, when the volume/capacity ratio isgreater than or equal to one.

Demand/Capacity Related

Congestion prevents traffic from moving freely, quickly and/or predictably (OECD, 2006).When vehicular volume on a transportation facility (street or highway) exceeds the capacityof that facility, the result is a state of congestion (Vuchic and Kikuchi, 1994). Traffic congestionoccurs when travel demand exceeds the existing road system capacity (Rosenbloom, 1978).Congestion is a condition in which the number of vehicles attempting to use a roadway at anytime exceeds the ability of the roadway to carry the load at generally acceptable service levels(Rothenberg, 1985). Congestion is an imbalance between traffic flow and capacity that causes increased travel time, cost and modification of behaviour. Congestion is a condition that arises because more people wish to travel at a given time than the transportation system can accommodate: a simple case of demand exceeding supply (Miller and Li, 1994).

Congestion is the impedance vehicles impose on each other, due to the speed-flow relationship, inconditions where the use of a transport system approaches its capacity (ECMT, 1999).

COST RELATED

Congestion is undesirable as it reduces accessibility and increases costs associated with travel. The level of access is determined by various factors including travel time and reliability. As congestion affects travel time and reliability, it reduces accessibility. Traffic congestion refers to the incremental costs resulting from interference among road users(VTPI, 2005).

OTHERS

In the State of Oregon, the 1991 Transportation Planning Rule (TPR, 1991) uses VKT (VehicleKilometresTravelled) as a primary metric, with a goal of reducing VKT by 20% per capitain metropolitan areas by 2025. Congestion may be 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) (Bovy and Salomon, 2002).

IV. CONGESTION MEASUREMENT METHODOLOGIES AND INCONSISTENCIES

Congestion measurement methodology should have the following characteristics: (a) It shouldbe simple to understand and unambiguous; (b) It should have the ability to describe theexisting traffic conditions and predict the future changes; (c) It should have an abilityto apply statistical techniques, replicability of the results with a minimum of data collection;(d) The methodology should have applicability to various modes, facilities and time periods.

Speed

The literature has suggested several speed measures besides average travel speed. The average travel rate, in minutes per mile, is the reciprocal of average travel speed. Peakperiod nominal speeds are a weighted average of speeds on freeways and principal arterialstreets, which allow comparison of the freeway and principal arterial street network betweenurban areas. The ratio of peak period to off-peak period speed suggested as direct measures ofcongestion.

CRITIQUE

Congestion is a function of a reduction in speeds, which is the direct cause of loss oftime and leads to increased vehicle operating costs, fuel consumption, and emissions of air pollutants and Green House Gases (GHGs). Therefore, the setting of a threshold that is directly related to travel speeds is most appropriate. This is in contrast to the traditional planning use of LOS, which compares volumes with capacity and does not explicitly account for speed. A speed-based threshold account for more of the impacts of congestion than would a threshold based on capacity. The use of a range of speed for entire study area reflects the lack of consensus among urban areas as to the appropriate threshold, which reflects local conditions. Speed reduction index measure may be difficult for public to understand because result is a number with no units. Result is relative to free flow speed,which is difficult for motorists to comprehend.

TRAVEL TIME

The use of travel time studies (Lomax et al.,1997) and related measures to describe system performance and congestion permeated the traffic engineering literature as early as the late 1920s. The early studies concentrated on determining average travel speeds in congested downtown areas and attempted to locate the magnitude and sources of travel delay.

Time-based congestion measures provide a different perception on congestion, one in keeping with the common perception of the problem. Time-based congestion measures also provide guidance on identifying major issues, enabling policy makers to better address problems within the state and solutions that are most likely to have the greatest impact. Travel time index has the advantage of expressing traffic congestion in terms of both space and time. It is easy for public to understand the main concept of this index.

The time-based measures of congestion provided a stronger basis for more generalized conclusions. Travel time index requires separation of recurring and incident delay. Measurement of non-recurring data can be difficult. Travel Rate Index doesnot comprise the finer traffic events; it is not responsive to exceptional conditions related to climatic events, accidents or construction activity interferences. Travel Rate Index measure can be difficult for public to understand.

LEVEL OF SERVICE

Traditionally, the use of level of service (LOS) has been one of the most popularmeasures of traffic congestion. The LOS concept as adopted in the HCM (1985)represents a range of operating conditions. Volume to capacity ratio can provide agood measure of the volume compared ton capacity of the roadway under existing and future conditions. Therefore, volume-tocapacity can be used as a measure of future performance through basic calculations using available data. Where accurate futureland use data is available, growth can be estimated based on anticipated development activity versus anticipated growth rates. Volume to capacity ratios could be compared to LOS to reach conclusions about congested conditions. Some of the congestion indexes, which works based onlevel of service, are explained below.

The main advantage of LOS measure is that it is comprehensible by most non-technical audiences. This is the representative variable in traffic flow analysis. It is widely used because it is very easy to collect this data in the field.LOS cannot provide a continuous range of values of congestion and these methods provide no distinction between different levels of congestion once congested conditions are reached. Byrne and Mulhall (1995) criticized level of service analysis a measure of congestion because it only represents location-specific congestion phenomenon and does not reflect overall or regional congestion condition. Hamad and Kikuchi (2002) haveargued that the use of a stepwise LOS measure is sometimes misleading, especially whenthe condition is near a threshold. Lane-Mile Duration Index has a limitation that it can’t reflect the effect of having different highway functions on traffic congestion. Lane-mile duration index results would be poor since not all freeway segments in area collect traffic data.

DELAY MEASURES

Delay has been defined as the additional time experienced by a road user in comparison tothe free flow travel or the acceptable travel time. For delay estimation, researchers have used different threshold values for the beginning of delay. Lindley (1987) used threshold of congestion to begin at a volume to capacity (v/c) ratio of 0.77 (or the speed of55 mph corresponding to v/c ratio of 0.77). Lomax et al. (1997) used certain specified values for different roadway categories based on consensus among technical and nontechnical groups to determine acceptable travel time and threshold for the beginning of congestion. Schrank and Lomax (2005) used

60 mph for freeways and 35 mph for arterial roads as free flow speed for comparison with congested speeds and they used the 85thpercentile speed in the off-peak period as the free flow speed.

Delay rate can be used to estimate the difference between system performance and the expectations for those system elements, which can be used to rank alternative improvements (Lomax et al., 1997). Relative delay rate reflects the condition of flow that travellers' can relate to their travel experience (Hamad and Kikuchi, 2002). Total delay could also allow transportation professionals to estimate how improvements within transportation system affect a particular corridor or the entire system. Total delay shows the effect of congestion in terms of the amount of lost travel time. The use of ratio measures is limited for a particular road type or facility and the value cannot be used effectively for a geographic area.

Relative delay rate measure may be difficult for public to understand because result is anumber with no units. Congested travel or congested roadway length does not represent the differentmagnitude of congestion.

V. DATA COLLECTION METHODS

Data collection techniques can be broadly classified into two categories, one-probe vehicles (mobile vehicles with data collection equipment), and others that are making use of fixed sensors. The traffic congestion studies data can be collected by both methods, point's data like traffic volume count, speed etc., using fixed sensors and travel time, journey speed etc., using probe vehicles data like floating car method.

FIXED SENSOR BASED TECHNIQUES

These techniques include sensors such as inductive loop detectors, magnetic sensors ,etc. that are deployed on road to collect the required data. Some of the fixed sensor techniques are described below.

DUAL LOOP DETECTOR BASED TECHNIQUES

Pairs of inductive loop detectors placed at various locations on the road can be used to identify vehicles on the basis of axle spacing (Benjamin and Cassidy, 2002).This type of data used to measure travel time of vehicles between the detector stations. This data can be used to inference/estimate the traffic congestion.

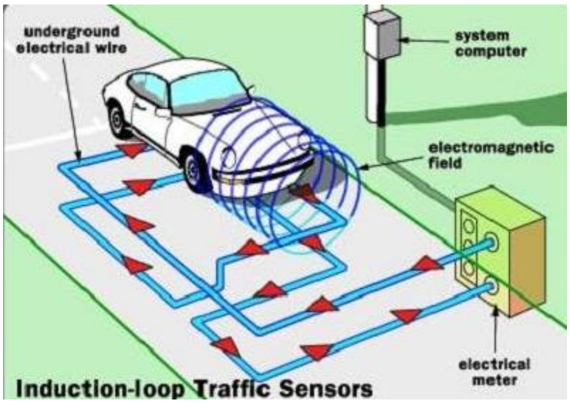

Fig.1 Inductive Loop Traffic Sensor

Widespread application of the technique in congestion detection can be prohibitive in terms of infrastructure cost, as dual loop detectors need to be constructed at regular intervals along the road. This technique is costly and the algorithm in Benjamin and Cassidy (2002) assumes that consecutive vehicles often maintain their relative order within a platoon for long distances. In India, the axle spacing for truck and buses are same, hence classification of the vehicle are not accurate. This lane-based system assumption is unrealistic in Indian traffic scenarios where overtaking, buses and auto-rickshaws stopping to pick up or drop off passengers is common phenomena.

MAGNETIC SENSOR BASED TECHNOLOGIES

Cheung et al. (2004) has suggested magnetic sensor as a low-cost alternative of inductive loops. It primarily performs vehicle identification and classification using a single magnetic sensor. Vehicle identification is further used to detect congestion by extracting information like speed and length of the vehicle.

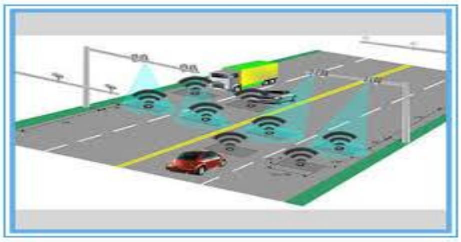

Fig.2 Magnetic Based Sensors

Experiments have been performed on a road with intersection that follows a lane system. This assumption makes this method unfit for Indian traffic as discussed above. Absence of a lane based system implies that vehicles neednot approach the sensor in a way which will assure their detection. Studies show (Cheunget al., 2004) that the motorcycle detection is not reliable. This is a concern because alarge percentage of Indian traffic consists of two-wheelers.

IMAGE SENSOR BASED TECHNIQUES

Some of the studies (Palubinskas et al., 2008;Long Chen et al., 2008) make use of image sensors like CCTV, deployed on the roadside and measure congestion level by image processing techniques, where slower the images change with time, higher is the level of congestion. Similar techniques (Hinz et al.,2007) have been used to process satellite images.

Fig.3 CCTV based Sensor

These are more costly systems than loop detector techniques and also require high maintenance cost, which makes it prohibitive to deploy these in India. Proper positioning and distribution of cameras to capture images of disorderly traffic will be a challenging factor. Frame level change detection algorithms need to be modified for Indian roads so that image change due to extraneous factors like people crossing road through cars stuck at congestion should be filtered out and not incorrectly interpreted as free flowing traffic.

PROBE VEHICLE BASED TECHNIQUES

Probe vehicles are vehicles that are part of traffic and equipped with various sensors Mohan Rao A. et al. like GPS receiver, accelerometer, Distance Measuring instruments (DMI), etc. tomeasure various parameters such as speed with which traffic is moving, road surface condition, etc. Probe vehicle based techniques are classified below into two categories, based on: i) prediction techniques, and ii)localization techniques.

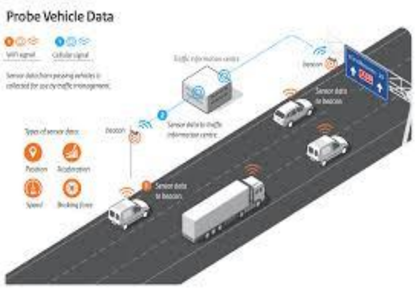

Fig. 4 Probe Based Sensors

CONGESTION PREDICTION

The data collected by this technique will be used for characterizing traffic by segmenting the road, delimited by traffic signals. A segment is part of road for which vehicles exhibit similar speed because they are subjected to same fundamental conditions like the same traffic signal, road length, width and number of lanes. Average, temporal and spatial speeds, calculated from GPS data, are used for characterizing traffic as free flowing or congested.

Segments are bounded by signalizedintersections. In India, even within such a segment, traffic conditions will vary as there will be many intermediate intersections, unsignalized, where drivers will follow random protocols to decide who will go first.

The techniques discussed above form representative set of the broad categories of data collection techniques used for traffic sensing. As pointed out, each of them has some associated drawbacks that preventit from being applicable as it is on Indian roads. The probe vehicle technique might be used in India after proper evaluation andthe data collected by this technique should be validated on sample basis by conventional method used in Indian. Rao and Rao (2009)evaluated a methodology for applying the GPSfor measurement of travel time and speedand validated the results with conventional methods and also carried out the statisticalchecks, the results obtained by GPS are satisfactory and can be used for measurement of traffic congestion studies.

SUMMARY AND OUTLOOK

A range of features have been suggested for a measure of congestion. The measures to quantify the level of congestion should, (i) Deliver comparable results with similar congestion level, (ii) Accurately reflect thequality of service (iii) Be simple, well-defined and easily understood and interpreted among various users. Considering the different desirable attributes for a congestion measure suggested bythe afore-mentioned researchers, congestion is a function of a reduction in speeds, which is the direct cause of loss of time and leads to increased vehicle operating costs, fuel consumption, and emissions of air pollutants and GreenHouse Gases (GHGs). Therefore, the setting of a threshold that is directly related to travel speeds is most appropriate. This is in contrast to the traditional planning use of LOS, which compares volumes with capacity and does not explicitly account for speed. A speed-based threshold account for more of the impacts of congestion than would a threshold based on capacity. Congestion measurement criteria based on speed can be adopted, because traffic speed is highly sensitive parameter and directly related to the vehicle operating cost; safety of the road users.

This parameter can be easily measured by various low cost technologies which are highly suitable for Indian conditions.

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