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A Case Study on Road Traffic Congestion Level

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ABSTRACT: Traffic congestion is one of the most visible, worldwide, and immediate transport problems plaguing not only India's but also most of the cities of the world on a daily basis. It affects all modes of transportation especially roads and all socioeconomic groups. Rapid population growth, increasing urbanization, inadequate/unplanned transport infrastructure, poor public transport systems and the rising number of personnel vehicles are some of the primary causes of congestion. This article reviews the findings of studies based on road traffic congestion. Various traffic congestion measurement metrics have been discussed. These matrices categorized into three parts (1) Travel time based, (2) speed based and (3) level of service-based. Also, congestion data collection techniques employed in different studies have been discussed. The findings of the study indicate that improved traffic management and control, better public transport services, increases in funding for transport infrastructure, use of modern technology and overall coordination of transport and land-use policies are important parameters to reduce congestion.

KEYWORDS: Traffic congestion, Traffic flow, Congestion measures, Data collection techniques

I. INTRODUCTION

Traffic congestion has become a major issue with the metropolis facing the most. Due to urbanization and the high use of roadway vehicles the problem of traffic congestion is increasing day by day. Some private are companies have an important role in being congestion in large cities because they provide easy services of two and four-wheeler vehicles.

Being traffic congestion on urban or nonurban areas wastage time and energy, increase pollution and stress, reduces production, and thus increase the demand for costs on society as well as the country for spending. The problem of traffic congestion is an open challenge for metropolitan cities as well as medium and small cities. According to TomTom (2020), India is the most affected country by traffic congestion. 4 of the 10 most crowded cities in the world are in India, namely Bengaluru (71%), Mumbai (65%), Pune (59%), and Delhi (56%). According to the Boston Consulting Group report-2018, daily commuters during peak traffic hours on an average, travelers spend 1.5 hours or more in Delhi, Mumbai, Bengaluru, and Kolkata. Traffic congestion measured (Stipancic et al., 2017) by using the congestion index (CI) during peak hours shows that congestion is directly correlated with accident frequency. World Road Statistics (2018) released a report on road accidents and deaths due to road accidents comprising of 199 countries. In the report, India got 1st rank in the number of road accident deaths. It is believed that identifying the characteristics of the congested portion of the road is the initial step for such efforts as it is the necessary guidance for the selection of appropriate measures. Various researchers and research organizations have provided several types of definitions of traffic congestion but they are all based on some traffic parameters such volume and capacity (or density), travel time (or delay), and speed. However, the uses of these definitions are dependent on collected data, and literature consists of several types of data collection techniques. therefore, we can say literature does not exist a unique definition of congestion. (Anthony, 2004). We have been finding the criteria for the congestion measure from a study of Aftabuzzaman (2007). They suggest a congestion measure should have such criteria clarity, simplicity, continuity, and comparability.

The objective of this paper is to discuss different kinds of congestion measures considering quantitative and qualitative indicators. A systematic review has been done on various congestion measurement methodologies at the national and international levels and illustrates different types of data collection techniques. It will help in selecting an appropriate congestion measure as well as applying suitable data collection methodology for practitioners, planners, and policy decision-makers.



II. MEASURE OF TRAFFIC CONGESTION

To tackle the problem of traffic congestion, various measures have been developed for the identification and quantification of traffic congestion by various researchers. These measures can be helpful for finding the degree of traffic congestion and the performance of the roadway. We are categorizing these measures into three parts: Travel time based, speed-based, and level of service based

Travel time based: Travel time is the time taken to cross a section of a road by a vehicle, this time used as a parameter in traffic congestion studies. Urban Link's performance evaluation was conducted based on travel time. Some measures related to travel time are listed below.

Delay	<p>Del quantify Delay is used to quantify traffic congestion. Delay is defined as extra travel time to taken driving a vehicle against their expectations. Lomax et al. (1997) represented delay as the difference between free-flow travel time (FFTT) and average travel time (ATT) i.e. Thus delay can be calculated by using equation (1).</p> $\text{Delay} = \text{ATT} - \text{FFTT}$
Planning time index (PTI)	<p>PTI is the ratio relation between the free-flow travel time and the 95th percentile travel time (95%TT) (Karuppanagounder and Muneera, 2017). As travel time increases, PTI also increases. Thus, PTI should behave the minimum value for better traffic operation. $\text{PTI} = \frac{95\%TT}{\text{FFTT}}$</p>
Congestion index (CI)	<p>CI measure is the ratio relation between the delay and FFTT. Here delay is the difference between ATT and FFTT. For better traffic operation, ATT for the commuters should be minimum (Karuppanagounder and Muneera, 2017). The congestion index for a link of roads using travel time can be defined as</p> $\text{CI} = \frac{\text{Delay}}{\text{FFTT}}$
Travel time index (TTI)	<p>TTI index is the ratio relation between peak period travel time (PPTT) and FFTT (Lomax and Schrank, 2005). This measure has been used in both recurring and incident traffic congestion conditions (Rao and Rao, 2012).</p> $\text{TTI} = \frac{\text{PPTT}}{\text{FFTT}}$
Travel time index (TTI)	<p>TTI is the ratio relation between ATT and FFTT (Karuppanagounder and Muneera, 2017). For better traffic performance, the TTI should be minimum.</p> $\text{TTI} = \frac{\text{ATT}}{\text{FFTT}}$
Buffer time index (BTI)	<p>The additional percentage of a passenger's time must be on time so that 95 percent of the time is represented by the buffer time index (Nakat et al., 2014)</p> $\text{BTI} = \frac{95\%TT - \text{ATT}}{\text{ATT}} \times 100\% \tag{6}$
<p>Speed based: Speed is the most commonly used measure of performance for roadway and traffic congestion. Speed can be calculated in several ways, first, based on average travel time combined with the length of the corridor understudy. Average travel speed can be calculated by Average travel speed = Length of the corridor / Average travel time (7)</p> <p>Second, the average speed of the stream is the weighted average of recorded spot speeds of vehicles using radar guns over the count period.</p>	
Speed Reduction Index (SRI)	<p>The speed reduction index is the rate of vehicle speed reduction due to congestion. This rate allows comparing the degree of traffic congestion for different types of transport services by using a constant as a scale to distinguish between different congestion classes at different levels. Thus it usable to particular routes of the urban road network or individual segments of the roadway for peak or off-peak period. (Kukadapwar and Parbat, 2015). It can be calculated by using the equation</p>



	$SRI = \frac{\text{Non-peak flow speed} - \text{Peak flow speed}}{\text{Non Peak flow speed}}$
Very-lowspeed Index (VLSI)	<p>The very low-speed index is the ratio relation between the time-traveling at a much slower speed and the total travel time. It has been used (Kukadapwar and Parbat, 2015) in traffic congestion evaluation on the urban roadway. Thus, a very low-speed index can be calculated by using the following equation</p> $VLSI = \frac{\text{Time spent in delay}}{\text{Total travel time}}$
<p>Level of Service (LOS) based: LOS has been used as a qualitative measurement that explains the operating conditions of the traffic stream and its perception by the driver and passengers. LOS is used for the identification of traffic performance as a threshold. Generally, LOS is categorized into six levels from A to F. (Manual, 1985). In which the free-flow speed is represented by LOS A and congestion by LOS F (i.e. stop and go flow). LOS may be represented in the various levels, where operating speed is plotted against the volume/capacity ratio for urban conditions</p>	
Congestion Severity Index (CSI)	<p>CSI was used as a measure of urban area freeway delay, which calculates delays travel per million vehicle kilometers. The CSI uses 1985 HCM calculation and local freeway traffic volume distribution to estimate recurring delays and an incidence database to estimate each hour of a typical day. An analysis has been done by Lindley (1987), using this index presented a threshold for congestion (v/c ratio of 0.77 or greater) on a different section of a freeway</p>

III. LITERATURE SURVEY ON VARIOUS APPROACHES FOR CONGESTION STUDY

Joseph and Nagakumar (2014) investigated the capacity and LOS of roads in Bangalore city. Required data like traffic volume, speed, and road geometry were calculated through field studies. It was found that mid blocks were congested during peak hours. The level of service F found for the entire stretch. A quantification of congestion on the urban mid-block sections for Ahmedabad City by including both operational and volume characteristics of traffic movement was done by Patel and Gundaliya (2016). It was shown through this study that defining LOS quantitatively could be a better option. The effect of the width of a carriageway on the level of congestion was also determined. It was concluded that by increasing one lane or widening the carriageway, congestion can be reduced up to 30–50%. The fuzzy inference approach was proposed for measuring the degree of congestion with greater accuracy and low error margin on the major arterial road networks (Kukadapwar and Parbat, 2015). The developed model was demonstrated by using the real-time traffic data of road networks in Nagpur city of India. **Patel and Mukherjee (2015)** investigated the assessment of congestion in road networks rather than link flow congestion at Ranchi city, of Jharkhand State, India with the help of Traffic Contestability Value. It was shown that if the TCV value was lower, then congestion was higher in the spatial zone and vice versa. In the study of Inner Ring Road, Delhi, Rao and Rao (2016) established the congestion thresholds on urban arterials to identify the traffic congestion in terms of speed using floating car data. The free speed measured on these corridors was 57 km / h. Stream speed observed under normal conditions was between 27km/h to 33km/h and the speed of the congested stream was between 18 km / h to 22 km / h. From this study, they observed that in congested conditions 50 percentile of the vehicles were running below the speed of 19 km / h. Thus, the congestion speed can be defined as 19 km / h for this corridor. Jain and Jain (2017) proposed a congestion index for estimating congestion on Delhi urban roads using categorized vehicular traffic data such as traffic volume and spot speed collected by manual counting and radar gun respectively in counting periods of 15 minutes, and travel time collected by the moving car method. Using different methodologies on Travel Time Index (TTI) developed by Taxes Transportation Institute (Systematics, 2005) to determine the factors affecting congestion. Henry and Koshy (2016) used the travel time index to estimate the congestion at a road segment between two places, Kumaranalloor and Gandhi Nagar in Kottayam, Kerala, these locations are the most congested roads segments in the city. By analyzing the hourly variance of congestion, it has been observed that vehicles take 81% to 133% more time to cross the segment. A comparative study of the performance evaluation on the urban link under heterogeneous traffic conditions using the travel time-based indices such as delay, travel time index, congestion index, and planning time index was reported (Karuppanagounder and Muneera, 2017). It was estimated that the performance indicators have higher values when the value of travel time was high on that link.



IV. CONGESTION DATA COLLECTION TECHNIQUES

Data collection methods have been classified into two classes, quantitative and qualitative data. For traffic congestion studies reported in literature one or the other of these techniques were used by researchers. Various quantitative data collection techniques have been discussed in Table 2.

Table 2: Quantitative data collection techniques

Trajectory data	Cross-sectional data	Floating car data
Data based on trajectory provide space-time profiles of all traffic vehicular in a selected location of road segment (Treiber et al., 2013) In this method, the selected segment of traffic can be viewed directly above a tall building by cameras or an airplane. Extracting the data over time from video footage using various software to track the position of each vehicle. Traffic density, lane changes can be measured using this data collection method. A novel traffic congestion estimation approach on roads in the open-world scene observed from TV cameras placed on poles or buildings was proposed by Li et al. (2008). Palubinkas et al. (2008) presented an approach to estimate congestion on temporal data collected by optical digital camera images. That approach is based on vehicle detection on the road segment by change detection between two images with a short time interval. Hinz et al. (2007) gave a theoretical overview for upcoming dualchannel radar satellite missions to surveillance of road network from space and illustrates the potentials and limitations by real data. Camera-based techniques consist of complex and errorprone methodologies, these methodologies demand automated and robust algorithms to track the vehicles, and thus these techniques are costly as a student for data collection. Also, the camera-based method gives information at a few hundred meters away from a road segment.	Single-vehicle data or microscopic data: Microscopic data is collected on the specific road section, data can be captured from radar or light barriers by using pneumatic tubes to lying across on the road. Commonly, induction loops are deployed beneath the road surface for microscopic data collection. A single-loop detector may be used to automatically measure at a fixed point on a road section, passing the time of vehicle, traffic volume, and speed when vehicle length is known. The double-loop detector is made up of two (or more) induction loops separated by a fixed segment of road, for example, 1m. Thus, this technique can provide traffic volume, speed, etc. In this technique, we need two inductive loop detectors mounted at many places of the road that is used to classify in the vehicle category depend on axle spacing. (Coifman and Cassidy, 2002). This method of data is expansive and provides travel time of vehicles between detector stations. Wireless magnetic sensor networks for traffic measurements on freeways and intersections provide an attractive, lowcost alternative to inductive loops (Cheung et al., 2005). It is used to obtain the number of vehicles, speed, and occupancy. These sensors are used to classifications of the category of vehicles based on the nonaxle spacing of vehicles that cannot be derived from standard loop data. Aggregated data or macroscopic data: The macroscopic data can be obtained by averaging the aggregate microscopic single-vehicle data over fixed time intervals. The time interval varies between the 20s to 5min, the most common interval being 60s. Ranjan et al., 2020 proposed another way of	Floating car data provide information about a single-vehicle only. These vehicles are specially equipped. In contrast to trajectory data, floating data is captured inside a vehicle. In this method, we can collect georeference coordinates by GPSreceivers that are then "map-matched" to a road on the traffic map. And can determine the travel time and speed from two GPS points in road space. (Taylor, 1992). Other types of sensors (such as radar) deployed on the probe vehicle to record the travel distance and speed of the leading vehicle (Stipanovic et al., 2017; Stipanovic et al., 2019). In this way, augmented floating car data is referred to as extended floating-car data. with the low speed of many equipped vehicles like taxis, van, bus, and trucks of commercial transport agencies or companies are present on roads, so we are not able to describe the entire traffic by using floating car data. Fortunately, when floating car data information becomes relevant: in free-flow speed and congested conditions difference does not matter then this bias vanishes.



	<p>collecting macroscopic data. Seoul Transportation Operation and Information Service (TOPIS) is an online open-source web service in South Korea. It is going to use as an efficient and inexpensive data acquisition method across the city by taking a snapshot of traffic congestion maps. Similarly, using several types of traffic maps in different countries like Google map, Bing map, and Baidu map, can be determined city-wide congestion levels in real-time.</p>	
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V. DISCUSSION

Congestion occurs due to four basic reasons for instance environment, mechanical, human, and infrastructure. Quantitative and qualitative both types of congestion indices have been discussed, suggested by the afore-mentioned researchers. Various congestion data collection methods have been explained which will be useful in the selection of a suitable technique for Indian conditions. Congestion measurement criteria can be adopted based on available budget by adopting speed based or LOS based matrices. Ridesharing emerges an important role with high efficiency in the use of existing assets such as personal vehicles. Recently the role of this increase most of the popular cities. Ridesharing is a new point-to-point transport model, and has seven features: (1) dynamic pricing, (2) dynamic routing, (3) smart dispatching, (4) customer network effect, (5) demand pooling, (6) feedback collection, and management system and (7) flexible supply base. From ridesharing, we can find four advantages that can automatically reduce traffic congestion by 17%-31% and optimize infrastructure investment (1) Accelerating public transportation, (2) Providing alternatives to car ownership, (3) Supplementing incomes, (4) Optimising infrastructure timing and location. Delhi will be launching a mobile application based on a new high-tech system linked to smart cameras deployed at traffic signals to help ease the chaotic roads (not required to manage traffic physically by Traffic cops). Signals will change to red or green in real-time based on traffic volume and not at fixed intervals. The system is being adapted based on studies of international countries' best practices in cities such as Sydney, Singapore, and Amsterdam. A similar system based on real-time traffic is functional at Closure Home, Coimbatore, Tamil Nadu, India.

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