Traffic Congestion Metrics: A Review

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Abstract

With the increasing population, traffic congestion has become one of the major issues in India. Traffic congestion causes two major issues. First, it increases fuel consumption and emissions, which leads to pollution, and secondly, it increases road accidents which lead to loss of precious human life and damages property. To reduce congestion, identification of congestion measuring metrics, proper land-use patterns and traffic management are three major factors. This paper reviews different congestion metrics used to measure traffic congestion and traffic management measure used to reduce congestion. A systematic review is carried out, and the strength and weaknesses of these measures are discussed.

Keywords: - *Traffic Congestion, Traffic management, Congestion measurement*

INTRODUCTION

Traffic congestion to a layman involves motionless or slowly moving vehicle lines on a freeway or city street, lane closure due to road construction or an accident, or some form of traffic backup. On the other hand, the transportation professional thinks of congestion in terms of flow rates, capacity, volumes, speeds and delay.

Traffic congestion occurs when traffic capacity does not meet traffic demand at sufficient speed, traffic controls are misused, or an event occurs on the road, such as an accident or vehicle breakdown. Congestion may occur at any time of the day.

Traffic congestion is a relative phenomenon linked to the difference between the roadway system performance that users expect and how the system performs. Urban traffic congestion must be understood in the broader context of city dynamics and agglomeration benefits. Traffic congestion in urban areas is often the outcome of successful urban economic development, employment, housing and cultural policies that make people want to live and work relatively close to each other and attract firms to benefit from the gains in productivity thus derived.

Traffic congestion can be classified into two types, i.e. recurrent and non-recurrent, and can be distributed over a network or isolated. There is recurrent congestion when traffic on a highway reaches its capacity at a given location at a consistent and repetitive time of day. Non-recurrent congestion is caused by frequent or unexpected events that temporarily rise, requiring

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or reducing roadway capacity. These incidents include collisions, vehicles with disabilities, road-building and inclement weather.

The increasing congestion on many roadways is a major concern to travellers and transportation managers. Traffic congestion causes longer travel times, higher fuel consumption, and increased emissions.

Traffic congestion can be divided into two stages, namely, (i) Micro-level and (ii) Macro-level (Rao A. M., 2012). The micro-level stage consists of all the problems related to on-road traffic like accidents, vehicle breakdowns, poorly timed traffic signals, special events like mass social gatherings, political rallies, bad weather conditions, etc. and the macro-level stage consist of problems like land-use pattern, road and transportation network, car ownership trend, etc.

Traffic congestion can be quantified using congestion metrics like speed, delay, volume-capacity (v/c) ratio, Level of Service (LOS), etc. Quantification of traffic congestion is done so that improvement mitigations can be compared with existing or base scenarios. Improvement mitigations can be either traffic management schemes like proper lane behaviour, signal redesign providing of bus-bay, non-motorised lane wherever required, etc. or suitable land-use pattern like providing an appropriate capacity of the road, parking space sight distance, etc.

LITERATURE REVIEW

This section comprises some of the literature used for measuring and quantifying congestion and improvement mitigations to reduce traffic congestion.

Quiroga, 2000 examined transportation network performance measures and discussed the benefit of using travel time as a robust and easy to understand performance measure. Travel time and delay were identified as two major performance measures to quantify the congestion in his study. Segment-wise analysis was done with the help of GIS to quantify the congestion along with different road segments and facilities.

Medley and Demetsky, 2003 developed a method to monitor congestion using performance measures. Two performance measures have been chosen for investigation: maximum delay and buffer index to determine road congestion rates in the Virginia district of Hampton Roads. Total delay was chosen as a performance measure because it relates to travel time, and the data needed to calculate this measure is easy to collect.

Total delay = (Actual Travel Time – Acceptable Travel Time) * Volume

The buffer index was chosen as a performance measure because it relates to the reliability of an individual vehicle trip, useful to both the public and transportation professionals. The travel rates used in this calculation can be derived from average speed measurements and route length. These measures helped transportation professionals determine the impact of congestion on one vehicle travelling on a roadway segment during a specific period. Also, the buffer index could help alert motorists about the anticipated changes in travel time on specific roadway segments so that travel could be planned accordingly. The buffer index reflects the quality of single-vehicle travel rates.

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Buffer index (%) = [(95th percentile travel rate – Average travel rate)/Average travel rate]*100% where all rates are in minutes per mile.

Toledo and Carlos A.M., 2011 proposed congestion indicators like Excess delay (ExD), Travel time index (TTI), Relative speed reduction (RSR) (weighted average and networks as a link), Queue indicator, which was used and the simulation was carried out using VISSIM (PTV 2009). Regression analyses have been used to identify indicators that better describe delay and pollutant emissions. When considering NOX emissions, none of the indicators worked satisfactorily, and when considering multiple areas, RSR performed best, followed by ExD and TTI when single networks were considered. The LOS, delay and emissions can be obtained by VISSIM (PTV 2009) for giving results and conclusions.

Omer and Khalik studied the congestion indicators: Level of service (LOS) and Volume to capacity (V/C), also known as the Demand to supply ratio. The current study is limited to the highway capacity volume (HCM 2000). They have used microscopic flow models as well as macroscopic flow models. GIS technology was used to analyse the data collected over all the stretches. The author stated that GIS is a powerful tool for analysis as a congestion performance measurement. The authors proposed some measures to reduce congestion which are stated below:-

Reducing trip generation demand on the road network at peak hours:

Reducing at-grade junctions on-street network:

Prioritising bus lanes at signalised intersections for movement before other traffic services by allocating lanes for HOV -

To use ITS by putting movable median barriers to add capacity during peak hours, optimising signal timing etc.

Jingfei et al., 2013 developed an evaluation index system for urban road intersections. Traffic congestion is established by applying Analytic Hierarchy Process (AHP). The traffic status of intersections was evaluated and decided by the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method. Design rationality, facilities perfection and management science are major aspects considered to form an index.

Alho et al., 2014 developed a state-of-the-art modelling framework to improve congestion by changing the configuration/enforcement of urban logistics loading/unloading of bays. Integrating simulation models to existing models and optimising strategies that takes into account double-parking derived vehicle obstruction. Congestion indicators selected are, number of obstructing vehicles, number of vehicles affected by the obstructions, the sum of delays (total and disaggregated by vehicle type-freight and non-freight) and average speed impacts (average speed pre and post changes in the system- non-freight only). Secondary indicators regarding the economy and environmental factors are also derived from the primary indicators.

Vieira et al., 2014 studied the impact of introducing pre-signals in traffic intersections using micro-simulation. They proposed that signal optimisation was the best and economical method

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for traffic management rather than infrastructure changes. Their study used the parameters such as average waiting time per vehicle in 1 minute and a decrease of the queues average size for evaluation.

Brennan Jr. et al.,2015 proposed a scalable Time Inflation performance measure that accounts for speed variations along a corridor that affect free-flow speeds and travel times. The time inflation performance measure is based on a measured SMS obtained from probe vehicle data and compares it with a variable congestion speed threshold.

A. M. Rao and K. R. Rao, 2015 considered a ring road in Delhi's National Capital territory. Using micro-simulation software VISSIM, they have calibrated the whole ring road to measure the performance of different scenarios to find out the best techniques to reduce traffic congestion. Calibrated modelled in VISSIM was checked based on: vehicle speed, travel time, traffic volume, visual Observation collected from the site.

Five different scenarios were considered, which are as follows:

Base case (Do Nothing)scenario

Traffic management (i.e. one-way routes, one-way path, signal command, etc.)

Elevated road (75% of the study area was elevated, and the public transport stops were provided below the flyovers)

Shifting of the bus stop (The location of the bus stops moved to appropriate nearby locations towards the intersection, the congestion created by the buses can be reduced to a certain level)

Dedicated bus lane scenario

The evaluation of performance measures was done based on: Traffic volumes, the average speed of all modes, network performance, individual link performance, travel delay, travel time. It was observed that scenario 2 has the best effect as the speed of the study area increased drastically (i.e. 37.89%), and travel time and travel delay was reduced by 22.1% and 59.14%, respectively.

Mascia et al., 2016 investigated the efficiency of traffic management tools in reducing traffic congestion and associated pollution, including traffic signal control and en-route navigation through variable message signs (VMS). Speed and delay were the parameters used for performance evaluation. Evaluations were taken from both environmental and traffic points of view.

S. Marve and M. Bhorkar, 2016 identified reasons for congestion and suggested few solutions that can be incorporated to reduce congestion in the Hingna area of Nagpur, Maharashtra. A manual method of data collection was used, and from that, it was identified that narrow streets, on-street parking and improper lane management are the main reasons that cause congestion in the Hingna area. Limitations on traffic congestion can be upgraded by embarking on various strategies such as expanding road capacity, improved road infrastructure, restrictions on routes for Rickshaw, financial penalties for traffic lawbreakers and the application of Flyover in the future.

A. M. Rao and K. R. Rao, 2016 identified that congestion could be defined based on: travel time and delay, volume, level of service (LOS), demand/capacity ratio and speed. Further, they explained that for computing congestion based on speed, free-speed and stream speed and congestion speed of road network are required. Stream speed is the speed of a vehicle when the flow of traffic increases compared to the flow of traffic

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corresponding to free flow. The traffic stream includes a combination of driver and vehicle behaviour, and both are non-uniform. Congestion speed occurs near the bottleneck sections or where traffic flow is more than flow corresponding to stream speed. The authors considered a ring road in Delhi's National Capital territory and found that the free-flow speed obtained on this corridor was 57 km/h which was reduced in-stream speed flow from 27 km/h to 33 km/h. Further, when congestion stream speed was observed, it was found that the speed decreases from 18 km/h to 22 km/h and 50 percentile of the vehicles are running below 19 km/h. They further stated that detailed studies are needed to establish speed stability as a congestion metric under varied traffic, road infrastructure and land-use characteristics. This would help to accept speed or identify a different metric as one of the reliable congestion indices.

Feifei et al., 2016 aimed to analyse traffic congestion in urban road networks. Their study selected the speed performance index for evaluation of congestion and divided the traffic state into four categories: heavy congestion, mild congestion, smooth and very smooth. Many vehicle speed data are detected from urban road traffic systems, and based on these data, the Beijing Traffic Management Bureau (BTMB) presented the speed performance index as the urban road traffic state assessment indicator. The index value (ranging from 0 to 100) reflects the ratio between vehicle speed and maximum permissible speed.

T. Itoa and R. Kaneyasub, 2017 proposed a driver model that forecasted traffic congestion based on changes in driving behaviour and did not rely on traffic flow monitoring infrastructure. It was hypothesised that changes are visible in driver behaviour according to changes in the travel phase, which are: the free travel phase, the meta-stability phase, and the traffic congestion phase and stated that congestion could be detected in a meta-stability phase when traffic flow starts increasing, based on speed and throttle opening and steering angle.

CONCLUSION

Here, the authors have presented a review of all metrics that are used to quantify traffic congestion. It is observable that the traffic congestion metrics such as speed, delay, travel time, volume, volume capacity (v/c) ratio, buffer index and level of service (LOS) are used to measure and quantify traffic congestion. Further, they suggested that instead of significant infrastructural changes like extra-widening of road or construction of Flyover, small traffic management changes like proper lane behaviour, providing bus-bay, non-motorised vehicle lane, segregating parking space, signal redesign are more helpful in reducing traffic congestion quickly and economically.

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