A Review of Traffic Congestion Metrics

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Abstract

With India's growing population, traffic congestion has become a major issue. Traffic congestion causes two major issues: first, it increases fuel consumption and emissions, which causes pollution, and second, it increases road accidents, which causes the loss of precious human life and property damage. Identification of congestion measuring metrics, proper land-use patterns, and traffic management are three major factors in reducing congestion. This paper provides an overview of various congestion metrics used to measure traffic congestion and traffic management measures used to reduce congestion. A systematic review is conducted, and the benefits and drawbacks of these measures are discussed.

Keywords*: - Congestion, Traffic Management, and Congestion Metrics*

INTRODUCTION

To the untrained eye, traffic congestion is defined as a line of stationary or slowly moving vehicles on a freeway or city street, lane closure due to road construction or an accident, or any other sort of traffic backup. The transportation expert, on the other hand, considers congestion in terms of flow rates, capacity, volumes, speeds, and delays.

When traffic capacity does not match demand at a sufficient speed, traffic controls are overused, or an event on the road occurs, such as an accident or car breakdown, traffic congestion occurs. Congestion can happen at any hour of the day or night.

Congestion is simply a relative phenomenon caused by the disparity between what consumers expect from a roadway system and how the system actually performs. Traffic congestion in cities must be viewed from the perspective of city dynamics and the benefits of agglomeration. Traffic congestion in cities is frequently the result of effective urban economic development, employment, housing, and cultural policies that encourage people to live and work close to one another, attracting businesses to benefit from increased productivity.

Congestion is divided into two types: recurrent and non-recurrent, and it can occur across a network or in isolated spots. When the quantity of traffic on a highway meets its capacity at a certain area at a consistent and recurring time of day, there is recurrent congestion. Non-recurrent congestion is produced by a series of unusual or frequent events that temporarily increase the demand for or reduce the capacity of a highway. Collisions, vehicles with disabilities, road construction, and adverse weather are examples of these situations.

Travellers and transportation managers are concerned about the increased congestion on numerous highways. Longer travel times, higher fuel usage, and higher emissions are consequences of traffic congestion.

There are two stages to traffic congestion: micro-level and (ii) macro-level (Rao A. M., 2012). All difficulties relating to on-road traffic, such as accidents, vehicle breakdowns, badly timed traffic signals, special events such as mass social gatherings, political demonstrations, terrible weather conditions, and so on, are included in the micro-level stage. Land-use patterns, road and transportation networks, car ownership trends, and other issues are addressed at the macro-level.

Congestion metrics such as speed, Delay, volume-capacity (v/c) ratio, Level of Service (LOS), and others can be used to quantify traffic congestion. Traffic congestion is quantified so that improvement mitigations can be compared to current or baseline conditions. Improvement mitigations can take the form of traffic management schemes such as proper lane behaviour, signal redesign, bus-bay provision, non-motorized lane provision, and so on, or proper land-use patterns such as providing adequate road capacity, and parking spot sight distance, and so on.

LITERATURE REVIEW

Some of the literature utilized for measuring and quantifying traffic congestion, as well as improving mitigations to lessen traffic congestion, are included in this area.

Quiroga, 2000 looked at transportation network performance metrics and outlined the advantages of utilizing trip time as a reliable and simple metric. In his analysis, he selected travel time and delayed as two primary performance criteria for quantifying congestion. To quantify the congestion along distinct route segments and facilities, a segment-by-segment analysis was carried out using GIS.

Medley and Demetsky (2003) devised a strategy for monitoring traffic congestion based on performance indicators. To assess traffic congestion rates in the Virginia region of Hampton Roads, two performance indicators have been chosen for investigation: maximum Delay and buffer index. Total Delay was chosen as a performance metric because it is related to journey time, and the data required to calculate it is simple to gather.
Total Delay = (Actual Travel Time – Acceptable Travel Time) * Volume

The buffer index was chosen as a performance metric because it relates to the dependability of a single-vehicle trip, which is helpful to both the general public and transportation professionals.

Average speed readings and route length were utilized to calculate the travel rates in this calculation. These metrics aided transportation planners in determining the impact of traffic congestion on a single car moving down a specific stretch of road at a specific time. The buffer index could also be beneficial in informing motorists about expected changes in journey time on certain roadway segments, allowing them to plan their trips accordingly. The quality of single-vehicle travel rates is reflected in the buffer index.

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

(RSR) (weighted average and networks as a link) and Queue indicator were proposed by Toledo and Carlos A.M., 2011 and were utilized in the simulation, which was carried out using VISSIM (PTV 2009). In order to find markers that better reflect delay and pollutant emissions, regression analysis was performed. When it came to NOX emissions, none of the indicators performed well, and when several areas were evaluated, RSR came out on top, followed by ExD, and TTI came out on top when single networks were considered. VISSIM (PTV 2009) can be used to gather

LOS, Delay, and emissions in order to provide results and conclusions.

Level of service (LOS) and Volume to capacity (V/C), also known as Demand to Supply Ratio, were investigated by Omer and Khalik. The current research is limited to the volume of highway capacity (HCM 2000). They used both microscopic and macroscopic flow models in their research.

The data obtained throughout all of the spans were analyzed using GIS technology. According to the author, GIS has been found to be a useful tool for analyzing and measuring congestion performance. The authors proposed the following steps to alleviate traffic congestion: -
During peak hours, reducing trip generation demand on the road network.

Reducing the number of at-grade intersections on the street network.

Allocating lanes for HOV to give priority to bus lanes at signalized junctions for passage before other traffic services.

To employ ITS to boost capacity during peak hours by installing moveable median barriers, optimizing signal timing, and so on.

Jingfei et al. (2013) developed a technique for evaluating urban road crossings. The Analytic Hierarchy Process (AHP) was used to determine traffic congestion, after which the traffic status of junctions was reviewed and selected using the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) approach. Design logic, facility perfection, and management science are all key factors taken into account when creating an index.

Alho et al., 2014 created a cutting-edge modelling framework to reduce traffic congestion by altering the structure and enforcement of urban logistics loading/unloading bays. Integrating simulation models with existing models and optimizing strategies that account for vehicle obstruction caused by double-parking. The number of obstructing vehicles, the 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 were chosen as congestion indicators (average speed pre and post changes in the system- non-freight only). Secondary indicators for the economy and the environment are also derived from the main indicators.

Vieira et al., 2014 used micro-simulation to investigate the impact of implementing pre-signals in traffic crossings. They claimed that signal optimization, rather than infrastructural upgrades, was the most effective and cost-effective strategy for traffic management. For evaluation, they evaluated parameters such as average waiting time per car in one minute and a decrease in average queue size.

Brennan Jr. et al., 2015 introduced a scalable Time Inflation performance metric that takes into consideration speed changes throughout a corridor that influence free-flow speeds and trip durations. The time inflation performance metric compares a measured SMS derived from probe vehicle data to a configurable congested speed threshold.

A. M. Rao and K. R. Rao (2015) considered a ring road in Delhi's National Capital Territory and calibrated the entire ring road using micro-simulation software VISSIM to measure the performance of several scenarios in order to determine the optimum scenarios for reducing traffic congestion. Vehicle speed, journey time, traffic volume, and visual observations obtained from the site were used to calibrate the VISSIM model.

The following are five alternative situations that were considered:
Base case (Do Nothing) scenario Controlling traffic (i.e. way routes, one way path, signal command, etc.)

The road is raised (75 percent of the study area was elevated, and the public transport stops were provided below the flyovers)

Bus stop relocation (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
Traffic volumes, average speed of all modes, network performance, individual link performance, travel delay, and travel time were used to evaluate performance measures. Scenario 2 was shown to have the most impact, as the research area's speed increased dramatically (37.89 percent), while travel time and Delay were cut by 22.1 percent and 59.14 percent, respectively.

Mascia et al., 2016 looked into the effectiveness of traffic management methods, including traffic signal control and en-route navigation via variable message signs, in reducing traffic congestion and pollution (VMS). The performance evaluation metrics were speed and latency. Both environmental and transportation considerations were considered in the evaluations.

In the Hingna area of Nagpur, Maharashtra, S. Marve and M. Bhorkar (2016) identified reasons for congestion and recommended a few remedies that may be implemented to minimize congestion. The data was collected manually, and it was discovered that small streets, on-street parking, and poor lane management are the main sources of congestion in the Hingna area. Limiting traffic congestion can be improved by implementing several techniques such as increasing road capacity, improving the road infrastructure, restricting Rickshaw routes, imposing financial penalties for traffic violators, and, in the future, implementing Flyover.

Congestion can be defined in terms of travel time and Delay, volume, level of service (LOS), demand/capacity ratio, and speed, according to A. M. Rao and K. R. Rao (2016). They went on to say that in order to compute congestion based on speed, not only free-speed but also stream speed and congestion speed of the road network are needed. Stream speed is the speed of a vehicle when the flow of traffic rises in comparison to the free-flowing flow of traffic. The traffic stream is made up of a mix of driver and vehicle behaviour, both of which are non-uniform. Congestion occurs in bottleneck sections or where traffic flow is greater than the flow corresponding to stream speed. The authors looked at a ring road in Delhi's National Capital Territory and discovered that the free-flow speed on this corridor was 57 km/h, which was decreased to 27 km/h to 33 km/h in-stream speed flow. When the speed of the congested stream was measured, it was discovered that it drops from 18 km/h to 22 km/h, with the 50 percentile of vehicles travelling at or below 19 km/h. They went on to say that more research is needed to determine the stability of speed as a congestion metric under a variety of traffic, road infrastructure, and land-use conditions. This would make it easier to accept speed or identify an alternative statistic as a legitimate congestion indicator.

The goal of Feifei et al., 2016 was to investigate traffic congestion in metropolitan road networks. Their research used the speed performance index to assess traffic congestion and classified it into four categories: heavy congestion, mild congestion, smooth, and very smooth traffic. The Beijing Traffic Management Bureau (BTMB) presented the speed performance index as the urban road traffic state assessment indicator based on a large number of vehicle speed data gathered from urban road traffic systems. The ratio between vehicle speed and maximum allowable speed is reflected by the index value (which ranges from 0 to 100).

Itoa, T., and R. Kaneyasub et al. (2017) suggested a driver model that estimates traffic congestion based on changes in driving behaviour without the use of traffic flow monitoring infrastructure. It was proposed that changes in driver behaviour are visible in response to changes in travel phases, which include the free travel phase, meta-stability phase, and traffic congestion phase, and that congestion can be detected in the meta-stability phase when traffic flow begins to increase, based on speed, throttle opening, and steering angle.

CONCLUSION

The authors have presented a review of all metrics used to quantify traffic congestion in this paper. To assess and quantify traffic congestion, traffic congestion metrics such as speed, Delay, trip time, volume, volume capacity (v/c) ratio, buffer index, and level of service (LOS) are utilized. They also suggested that small traffic management changes such as proper lane behaviour, providing bus-bay, non-motorized vehicle lanes, segregating parking spaces, and signal redesign are more helpful in reducing traffic congestion quickly and economically than large infrastructure changes such as extra-widening of roads or construction of fly-overs.

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