Study of Level of Service (LOS) Criteria for Measuring Traffic Congestion- A Critical Review

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Abstract: Heterogenous traffic conditions has become one of the major issue that need to be resolved in developing countries like India and traffic congestion made it difficult to adopt Level of Service (LOS) criteria as given in Highway Capacity Manual (HCM). It is believed that is the first step for selecting appropriate mitigation measures is the identification of congestion. Traffic Congestion- both in perception and in reality - influences the movement of vehicle and people. Traffic congestion wastes time, energy and causes pollution. Basically, there are two major factors responsible for traffic congestion. The first one is micro-level factors and the other is macro-level factors that relate to overall demand for road use. Congestion is 'triggered' at the 'micro' level (e.g. on the road), and 'driven' at the 'macro' level. i.e. micro level factors are, for example, many people want to move at the same time, too many vehicles for limited road space [1]. On the other side, macro level factors are e.g. land-use patterns, car ownership trends, regional economic dynamics, etc. The present study gives an overview and presents the possible ways to define LOS in the context of urban mixed traffic. A systematic review is carried out, based on measurement metrics such as speed, travel time/delay and volume and level of service. The review covers distinct aspects like definition; measurement criteria followed by different countries/organizations. The strengths and weaknesses of these measures are discussed. Further, a short critique of measurement criteria is presented. Most of the aspects covered are general and applicable in any country.

IndexTerms **– Level of Service, traffic volume, Speed**

I. INTRODUCTION

The population of urban area is increasing rapidly due to the shifting of people from rural to urban area, which increases vehicular traffic on urban streets. It causes the problem of congestion in an urban area. Road traffic congestion poses a challenge for all large and growing urban area. Congestion affects the traffic movement, reduce the capacity of urban roads and causes effects such as air and noise pollution. Besides these, it also causes economic impacts by travel time reduction, excess fuel consumption, loss of productivity, high energy consumption and increase in accident rates. Hence, facilities are to be planned and designed to provide a better Level of Service to the road users.

Level of Service

A qualitative measure used to relate the quality of motor vehicle traffic service. LOS is used to analyze roadways and intersections by categorizing traffic flow and assigning quality levels of traffic based on performance measure like vehicle speed, density, congestion, etc. [1] HCM, 2010 definition of Level-of-Service was further improvised as "a quantitative stratification of a performance measure or measures that represent the quality of service [2]." Quality of service defines how well a transportation facility or a service operates from the traveler's perspective.

The Highway Capacity Manual (HCM 2000) designates six levels of service for each type of facility, from A to F, with LOS "A" representing the best-operating conditions and LOS "F" the worst [3]. Factors affecting LOS are traffic interruptions which include a number of stops per km, speed and delay variations, driving comfort, speed and travel time consumed in traveling the entire stretch & Freedom to maneuver to maintain the desired operating speeds [4]. All HCM Classification of Level of Service are presented in Figure 1.

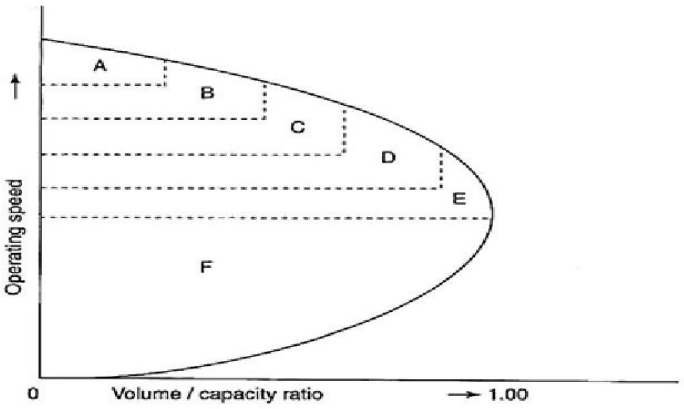

Figure 1: HCM Classification of Level of Service

Traditionally, level-of-service analyses of road traffic facilities have been conducted using analytical methods and procedures. Descriptions of these methods are commonly found in highway capacity manuals, the most widely used example is probably the US Highway Capacity Manual (HCM) (Transportation Research Board, 2000). Analytical highway capacity manual methods provide simple and straightforward procedures to assess the performance of road traffic facilities. However, the methods are, in many cases, not suitable to analyze traffic dynamics and impacts of high degrees of saturation such as queue spillback to upstream facilities [2]. Today, the seemingly ever-increasing traffic volumes have led to congestion on the roads in large parts of the urbanized world. Intelligent Transportation Systems (ITS), e.g. systems for motorway control and advanced vehicle actuated traffic signal systems, have been introduced to manage the traffic demands. The dynamics of the traffic flow is often crucial for the performance of ITS. Increasing traffic demands and the introduction of ITS-are two of the driving factors behind the rising usage of traffic simulation for level-of-service analysis. Traffic simulation gives a possibility to analyze new technologies such as IT and road traffic facilities under various degrees of saturation. Traffic simulation is also used as a tool to generate speed-flow relationships for analytical highway capacity manual methods, see e.g. the work of Briton and Weiser (2006) [2].

2. Traffic simulation based level-of-service analysis [2]

A traffic simulation study consists of the following tasks:

1. Formulation of the aims and scope of the study,
2. Collection of data,
3. Construction of the simulation model,
4. verification of the model,
5. Calibration of the model,
6. Validation of model,
7. substitutes analysis
8. credentials.

There are generally three type of macro level indices which are getting widely used for the purpose of defining LOS. The benefits and drawbacks of all three Macro level congestion indices are given in Table 1.

Factors to be considered while evaluating the LOS

1. Traffic interceptions or restrictions, with due consideration to the number of stops/km, delays involved and the speed changes important to keep the pace in the traffic stream.
2. Speed and travel time are considered to be one of the most important factors which also includes the operation speed and in general travel time consumed in traveling over a section of roadway.
3. The comfort of driver and convenience reflecting the roadway and traffic conditions in so far as they affect the comfort of the driver.
4. Opportunity to maneuver to maintain the desired operating speeds.
5. An economy with due consideration of the effective cost of the vehicle.

It is challenging to consider all the above factors/variables, hence, HCM basically emphases on the ratio of volume to capacity and the travel speed. As with respect to travel speed, the HCM recommends the use of the operating speed on that type of highway carrying uninterrupted flow such as in rural areas [4]. In case of municipal areas, the HCM suggests the use of average travel speed.

Congestion measurement

Worldwide, normally three congestion indices are used which are travel-time and delay, volume and LOS and speed. The merits, drawbacks of each of the indices are given in Table 1.

Table 1. Comparison of Macro-level congestion indices [2]

Macro-level Indices	Benefits	Drawbacks
Travel-time and delay	1. Time-based congestion measures provide guidance on identifying major issues, enabling policy makers to beer address problems within the state and solutions that are most likely to have the greatest impact. 2. Travel-time-index has the benefit of expressing traffic congestion in terms of both space and time. 3. It is quite easy to understand the main concept of this index for public.	1. The time-based measures of congestion provided a stronger basis for more generalized conclusions. 2. Travel time measures do not comprise the finer traffic events; it is not responsive to exceptional conditions related to climatic events, accidents or construction activity interferences. 3. Total delay could also allow transportation professionals to estimate how improvements within a transportation system a particular corridor or the entire system. 4. 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. 5. Congested travel or congested roadway length does not represent the different magnitude of congestion. 6. Travel time index requires separation of recurring and incident delay. Measurement of non-recurring data can be difficult. 7. 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.
Volume and LOS	1. The main advantage of LOS measure is that it is comprehensible by most non-technical audiences. 2. This is the representative variable in traffic flow analysis. 3. It is widely used because it is very easy to collect this data in the field.	1. 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. 2. Lane-Mile Duration Index has a limitation that it can't reflect the effect of having different highway functions on traffic congestion.
Speed	1. Travel speed is closely related measure that can be used to illustrate the reduction in mobility people experience during congestion. 2. Travel speed experienced under Congested conditions can be compared to those found in free flow operating conditions to assess the magnitude of congestion. 3. The duration of congestion can also be determined by measuring the reduced travel speeds over a period of time. 4. Travel speed is relatively easily obtained from model forecast data, and may also be directly observed through field surveys. 5. 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 Green House Gases (GHGs). 6. Therefore, the seing of a threshold that is directly related to travel Speeds is most appropriate.	1. 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. 2. Result is relative to free flow speed, which is difficult for motorists to comprehend.

Review of Literature

Biswas et al. [7] Studied for the identification of alternative performance measures for defining the level of service for urban mixed traffic in Kolkata. For the study, the authors took a six-lane road of urban metropolis of Kolkata. For the analysis, the authors used sixteen hours of traffic volume data and data related to speed was collected by videography method. The authors suggested that Percentage Speed Reduction (PSR) from Free Flow Speed (FFS) identified as an alternative performance measure for LOS assessment in Kolkata. The proposed model was validated using a Kolmogorov-Smirnov (K-S) test. The authors finally classify the road segments into six different levels of services.

Maitra et al. [8] proposed a methodology for finding out the congestion which includes the volume and the operational characteristics of the traffic. For the study, the authors took three different roads in Mumbai. Based on the data collected, the estimated level of congestion and the service volumes were compared to show the effeca t of number of traffic lanes onthe level of congestion and the service volumes. The authors observed that the traffic lanes and the carriageway width distinctly affect the level of congestion at different traffic volumes.

Marwah and Singh [9] attempted to estimate the level of service for urban heterogeneous traffic conditions on the Kanpur roads. The parameters considered by the authors to define the LOS were journey speed of cars and motorized two-wheelers concentration and the road occupancy. Based on the data, a traffic simulation model was developed. Based on the simulation results of the benchmark road and the traffic composition, the LOS were classified into four groups (LOS I, II, III, and IV). The simulation study results clearly demonstrate the capability of the model to simulate the heterogeneous traffic flow conditions of the Urban streets.

Bhuyan and Rao [10] studied the level of service criteria of urban streets in the Indian context. The authors conducted their study in the city of Mumbai and their results were calibrated with the two major corridors in the Kolkata city. For their study, average travel speeds were collected and Hierarchical Agglomerative Clustering (HAC) was applied to define the range of speed of the urban streets and the LOS categories. By the application of this methodology, the authors found out that the urban street speed ranges of LOS categories valid in the Indian context were different from the values which are specified in HCM (2000). The authors concluded that the differences were due to the heterogeneous nature of the flow of traffic along with changing geometric characteristics of the road sections.

Singh and Goyal [11] analyzed the prevailing conditions of the traffic on the roads of Punjab university campus. The traffic volume data were collected using videography technique at the selected points and the existing level of service was calculated. Due to the mixed nature of the traffic, the authors observed that the problem of congestion arises during peak hours. Based on the collected data, the hourly traffic composition and the daily traffic variations on weekdays and weekends were analyzed for determining the capacity and level of service. The level of service calculated for both the roads opposite to boy's hostel and P.U. the market was found to be in category C.

Wei et al. [12] studied the methods of assessment of the level of service of the pedestrian in a town of China by analyzing the relationship between the pedestrians, quality of the road, subjective perceptions, and the physical facilities as well as the operation of the traffic flow. On the basis of collected data and using the statistical software SPSS, the authors established a relationship between the variables for estimation of primary factor which influences the pedestrian level of service and then developed the step-wise regression model along with the level of service of the pedestrian categories on the basis of main factors. The authors observed that the factors which significantly affected the LOS were the bicycle volume, the vehicle volume, driveway access frequency, pedestrian volume and the distance between the sidewalk and the vehicle lane.

Henry and Koshy [13] measured congestion in terms of Travel time index(TTI), which represents the ratio of actual travel time of the traffic in the existing condition to the free flow travel time. For the study, the authors took road stretch between two stations, Kumaranalloor to Gandhi Nagar in Kottayam, Kerala. This study examined the some of the major factors such as traffic volume, dwell time of buses, crossing movements of pedestrians, turning movements of vehicles travelling against free flow of traffic. Based on this model, the congestion occurring during different hours was analysed. The model also helped in the proper planning of traffic movement, by suggesting alternative routes and alternative measures to divert the traffic based on the congestion during different hours of the day, by keeping a balance between the Travel Time Index of different roads.

Levinson and Lomax [14] developed a Congestion Index that shows the differences in actual to the desired travel times for different types of road stretches. The proposed index provides a continuous scale for evaluating the amount of congestion incurred. The authors derived a Delay Rate Index (DRI) concept based on LOS. The proposed Congestion Index concept provides more details on the magnitudes and ranges of congestion in severely congested operating conditions than the traditional LOS concept.

Bharti et al. [15] conducted a study which describes the application of the concept of travel time reliability on heterogenous traffic roads. The travel time data was observed on an urban arterial in New Delhi during morning and evening peak periods and were analyzed and evaluated with various reliability and congestion measures. A relationship of the reliability measures such as Planning Time Index (PTI) with congestion measures like TTI was also shown. Travel time curves were plotted for each 15-minute time interval. Reliability and congestion measures were also evaluated during morning peak and evening peak.

Jain et al. [16] proposed the idea of estimating the congestion on urban arterial and sub-arterial roads of a route in Delhi city having heterogeneous traffic conditions by segmenting the route into different segments and then determining the origin-destination based traffic flow behavior of the segment. The expected travel time in making a trip is modeled against sectional traffic characteristics (flow and speed) at origin and destination points of road segments, and roadway and segment traffic characteristics such as diversion routes were also tried in accounting for travel time. Predicted travel time is then used along with free flow time to determine the

state of congestion on the segments using a congestion index (CI). A model for the prediction of travel time on a given segment was prepared using multiple linear regressions.

Sharma and Raval [17] made an attempt to estimate the level of service for heterogeneous traffic in urban corridors by analysing the space mean speed and v/c ratio with a consideration of the perception of road users. For the study, the authors took a sub-arterial road of Ahmedabad city. The characteristics of the different vehicles on the urban roads were studied to quantify the speed variations, quality of the travel etc. The ranges of the v/c and the space mean speed were determined from the speed-flow relationship of the selected stretch and a revised LOS was suggested and the results were compared with the values given in Indo-HCM. The variations were observed for LOS A. By considering the v/c ratio, the LOS A was found to be less than 0.24, but as per Indo HCM it is less than 0.15. The authors then observed the variations in the LOS A using the space mean speed also and it was found that the criteria suggested by the Indo HCM for LOS A to E was higher than the LOS suggested by the authors for the Ahmedabad city.

Sahini and Bhuyan [18] carried a study to define the Pedestrian Level of Service (PLOS) of urban off-streets having heterogeneous traffic flow conditions. For the study, the authors collected inventory details and speed data from two important cities Bhubaneswar and Rourkela of Odisha state. The collected data which were based upon flow rate, speed and volume to capacity ratio (v/c) and average pedestrian space, six categories of PLOS were estimated ranging from (A-F). The authors observed that the PLOS ranges estimated were lower than that mentioned in the HCM (2010) because of the heterogeneous traffic flow and a low volume of the pedestrian movements in the state.

Patel and Joshi [19] conducted an empirical investigation on the behaviour of the heterogeneous traffic stream speed and the flow rate on a controlled arterial in Surat city of Gujrat. Field traffic surveys were conducted to collect the traffic volume data. The data related to speed was collected manually as well as using videography technique. Based on the 5 min data extracted from the field survey, a multi regime speed-flow relationship was developed and the unobserved data were simulated by the artificial neural network model. The threshold limits of the LOS based on the volume to capacity ratio were established by the cluster analysis approach. For LOS A the limit for the v/c was found to be less than 0.125, but as per Indo HCM it is less than 0.15.

Joseph and Nagakumar [20] attempted to study the various parameters to find the capacity and the level of service of urban road. For the study, six mid-blocks in Koramangala area of Bangalore were taken. Traffic volume counts, speed and delay studies were conducted during the peak and the nonpeak hours and the average time of the journey were calculated. Road inventory survey was also conducted to determine the various geometric parameters of the road. Capacity was calculated on the basis of spot speed studies and the level of service was also found out based on the average speed among each mid-block. Based on the collected data, the hourly traffic composition and the daily traffic variations on weekdays and weekends were analysed. The authors observed that the 50% of the traffic composition consists of two wheelers and three wheelers. Volume to capacity ratio of each midblock exceeds the value 1 during peak traffic. The most congested traffic was found on the section starting from NGV- Sony Singal-Tanishq and the level of service of the entire stretch at peak and non-peak hour was found to be in the category F.

Anjaneyulu and Nagaraj [21] made an attempt to study the relationship of congestion with speed variations. Detailed speed data were collected on the selected road stretch using electronic distance measuring instrument which was installed in a test vehicle, along with a laptop computer. The authors adopted chase car technique and data related to traffic volume was collected for five minutes that acts as an input for the database. Coefficient of Variation (CV) of Speed was chosen as the indicator of congestion. The CV due to traffic volume together with the Mean Velocity (MV) was used to identify the start, growth, and critical zones of congestion. Estimated level of congestion was then used as a measure of Level of Service (LOS) and based on the congestion the authors proposed five levels of service designated by the letters A to E.

Conclusion

A detailed number of features have been discussed in this study in order to measure triffic congestion. The measures to quantify the level of congestion should, (i) Deliver comparable results with similar congestion level, (ii) Accurately reflect the quality 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 by the 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 Green House Gases (GHGs).
The study further reviewed that LOS of Urban Roads is totally different from LOS of Rural Roads. Free flow speed is observed in mid-block sections of an urban street, based on which urban street class is determined. 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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