Determination of Level of Service of Arterial Road in Kohima

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Abstract - *India, a densely populated nation, has the world's second largest road networks. The high population coupled with growth in various infrastructure has led to migration of work force from rural areas to cities across the country. The number of vehicles of varied dimensions increases in every city as the population grows. The traffic operational conditions on a highway become complicated when all of these vehicles of varying sizes travel on the same road without any physical separation and occupy any available space on the roadway. Two wheelers (motorised or bicycles) and other small vehicles penetrates the narrow gaps between two large vehicles, adding to the road's bad condition. In hill roads, the heterogeneous traffic flow with various operational features makes it more unfavourable, causing frequent congestions in the stretch of road. The Level of Service (LOS), a qualitative measure of traffic is categorised based on the operating conditions in the traffic stream. Ascertaining the LOS for urban roads is very crucial as this affects the planning and design of traffic system and its operation, allocation of financial resources for infrastructure building projects to provide for considerably good level of service. This paper focus on to understand the influencing factors of the quality of traffic and methodology to be implemented in determining LOS in urban roads.*

Key words- level of service, urban street, heterogeneous traffic, free flow speed.

1. INTRODUCTION

India, a densely populated nation, has the world's second-largest road network at 58.98 lakh kilometres according to the Ministry of Road Transport and Highways (MORTH), Government of India's annual report 2018-19. With an annual growth rate of about10.7%, the number of motor vehicles registered has increased manifold from approximately 0.3 million in 1951 to 230 million in 2016. The number of vehicles per 100 km of road length has increased significantly from 3,033 in 2010-11 to 4,105 in 2015-16. Maharashtra, Uttar Pradesh, Tamil Nadu, Karnataka and Gujarat accounted for 49% of all vehicles registered in India, while Mizoram, Nagaland, Manipur, Tripura, Arunachal Pradesh, Andaman and Nicobar Islands, Lakshadweep, D&N Haveli, Daman & Diu, and Sikkim together accounted for less than 1%. High vehicular density and traffic congestion are correlated with urban areas. The metropolitan areas, which account for about 11% of the country's population, have 32% of the total automobiles.

The high population coupled with growth in various infrastructure has led migration of work force from the rural areas to the cities across the country. With the growth of people, the number of vehicles of varied dimensions increases every day. When all of these vehicles of varying sizes travel on the same road without any physical separation and occupy any lateral location on the roadway depending on the road space availability, the traffic operational conditions on a highway become complicated. Two wheelers (motorised or bicycles) and other small vehicles penetrates the narrow gaps between two large vehicles, adding to the road's bad condition. Also, the prevailing traffic regulatory system cannot force vehicles to follow lane discipline strictly. The heterogeneous traffic flow with different operational features makes more unfavourable in the hill roads causing frequent congestions in the urban roads. The qualitative measure of traffic is usually in terms of Level of Service (LOS) which is categorised according to the operational conditions in the traffic stream. Ascertaining the LOS for various streets is very much important as this affects the planning and design of the traffic system and its operation, allocation of financial resources for infrastructure building projects to provide a better level of service.

2. LEVEL OF SERVICE IN URBAN AREAS

The level of service in urban areas varies significantly from that of rural areas. The LOS in an urban and suburban arterial roads can be associated with the traffic flow conditions, load-factor at intersections, average vehicle travel speed, peak-hour factor, and service volume to capacity ratio. Due to the significant increase in the number of motor vehicles in cities, peak hours are usually observed during the morning and evening hours, resulting in slower travel speeds, longer trip time period, and increased vehicle queuing. The peak hour factor is defined as the ratio of peak hour volume to the peak rate of flow within the peak hour (for example, 5 minutes, 10 minutes, or 15 minutes). It shows how consistent the traffic flow is during peak hour. LOS of an urban street is based substantially on the average vehicle travel speed for the road section under consideration. The Highway

Capacity Manual (2010) (HCM-2010) defines level of service as "a quantitative stratification of a performance measures that defines the quality of service". From the viewpoint of a traveller, quality of service refers to how good a transportation service or facility operates. Table 1 summarises the characteristics of various levels of service for urban and suburban arterials.

Table - 1: Level of Service for Urban Areas

Level of Service	Operating Characteristics
A	The average overall travel speeds is 50 kmph or more relatively free flowing, with service volume capacity ratio of 0.6 or less, Load factor at intersections about 0.0. Peak hour factor at 7.0 or less
B	This is a stable flow condition. The average overall travel speed drops down to 40 kmph. or more. Slight delay is common. The service volume/ capacity ratio is 0.70 or less. Load factor about 0.11 or less and peak hour factor is 0.80 or less.
C	Reasonably stable flow with acceptable delays. The average travel speed drops down to 30 kmph. or more. The service volume/ capacity ratio is 0.80 or less. Load factor about 0.3 or less and peak hour factor is 0.85 or less.
D	Approaching unstable flow with some delay. The average travel speed drops down to 25 kmph or more. The service volume/ capacity ratio is 0.90 or less. Load factor about 0.7 or less and peak hour factor is 0.9 or less.
E	This is an unstable flow condition with congestion and intolerable delay. The average travel speed drops down to 25 kmph. The service volume are at capacity or near capacity. Load factor at intersection is 1.0 or less and peak hour factor is 0.95 or less.
F	This is forced flow with jammed condition. The average overall travel speed is below 15 kmph Demand volume/Capacity ratios may well exceed 1.0. Intersections overloaded.

Some factors that influence the level of service for an urban street are number of signals a segment has in a kilometer and control delays at the intersections. Other contributing factors, such as increased traffic flow, slow progression, improper signal timing, etc, can significantly reduce the LOS. Urban streets that have more than one signal for each kilometer, that is, streets with medium density to high signal densities are more susceptible to the aforementioned causes, which can result in the observation of low LOS even before noticeable problems arises. An individual signalized intersection, on the other hand, may function at considerably low level, where as, urban street segments that are longer in length and is loaded heavily in the intersections may have a good LOS.

3. LITERATURE REVIEW

The Highway Capacity Manual (HCM 2010) has designated 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. The boundaries for the various levels of service are defined with distinct values, each of which represents a range of operating conditions. The Highway Capacity Manual also has classified the urban streets into number of street classes and speeds into different levels of service categories, applicable in homogenous traffic flow condition. Kiran et al. in [17] stated that the traffic in the developed economies is predominantly composed of passenger cars and can be aptly termed as ‘‘homogeneous’’ traffic, whereas, the traffic in developing countries are composed of vehicle types with a wide variety of static and dynamic characteristics, which occupy the same right of way, resulting in an unsynchronized movement of vehicles. Ashutosh et al. in [4] expressed that the direct implementation of the US-HCM methods in India is not possible because of the heterogeneous traffic conditions and vastly unique driver behaviour found on Indian highways.

Marwah et al. in [20] stated that the level of service is composite of several operating characteristics that are supposed to measure the quality of service as perceived by the user at different flow levels. For heterogeneous traffic condition in India, the authors have attempted to classify LOS categories into four groups (I–IV) based on simulation results on selected roads and traffic compositions. With the advancement of technologies, the global positioning system (GPS) has been successfully applied to data collection and geographic information system (GIS) have extensively used for data compilation. Bhuyan et al. in [7] also have used GPS and various clustering methods such as fuzzy-C means (FCM), hierarchical agglomerative clustering (HAC) to classify urban streets into a number of classes and ATS on segments into number of LOS categories. In these studies, ATS on street segments was used as the MOE, which has been obtained from second-wise speed data collected using GPS receiver. While defining the LOS, Bhuyan et al. in [6] have found that FFS ranges of urban street classes and speed ranges of LOS categories valid in Indian context are different from those values specified in HCM (2000).

Maitra et al. [19] taking congestion as measure of effectiveness for prevailing heterogeneous traffic condition in India divided LOS into nine groups “A” to “I”. Clark [10] in a study on the prevailing traffic conditions of New Zealand suggested for a new LOS category to be termed as F+ or G. Due to the heterogeneous nature of traffic in developing countries, Karuppanagounder et al. in [16] estimated the PCU values for the different types of vehicles of highly heterogeneous traffic and found that apart from vehicular characteristics the PCU value varies significantly with variation in road width and traffic volume. Chandra et al. in [8] stated that the amount of interaction of vehicles is expected to change with the mix characteristics especially, Mahar et al.in [18] stated for different traffic composition on four lane and six lane divided highways wherein the PCU values for vehicle types are shown to vary with traffic volume and proportional share of the vehicle in traffic stream. Al-Kaisy et al. in [2] assessed the effect of heavy vehicles on traffic stream during congestion and found that the passenger car equivalent value suggested by the Highway Capacity Manual are only applicable for free flow conditions. They proposed a passenger car equivalent (PCE) factors for heavy vehicles behaviour during congestion that exhibit logical trends in comparison with the HCM PCE factors for free flow conditions. Chandra et al. in [9] uses the area, as opposed to only the length and speed of a vehicle and found that the PCU for a vehicle type increases with increasing lane width. Nitish et al. in [23] established the fundamental traffic flow relationships namely speed, density and flow to enable the understanding of heterogeneous traffic flow characteristics of two- lane road facility. Anusha et al. in [3] attempted to study and analyse the effects of two-wheeler on saturation flow at signalised intersection, and found significant impact in the capacity analysis. Ebin et al.in [15] pointed out that when the side friction is too high, there is a significant difference between the actual speed and capacity and that predicted by the Indonesian HCM.

Pritam et al.in [22] reported that vehicles that move at or below the limiting speed cause delay to the faster ones resulting in formation of platoons at moderate and heavy flow when passing is restricted. Therefore it is imperative to estimate the limiting speed of slower vehicles correctly to approximate the delay vehicles.

Weather conditions affects the traffic capacity. Alhassan et al. in [1] reported that rainfall affects macroscopic traffic flow parameters. The data generated from a basic highway section along J5 in Johor Bahru, Malayasia was synchronised with 161 rain events over a period of three months. The result revealed a 4.9%, 6.6% and 11.32% reduction in speed for light rain, moderate rain and heavy rain condition respectively. The corresponding capacity reductions in the three rain fall regimes are 1.08% for light rain, 6.27% for moderate rain and 29.25% for heavy rain. They observed no traffic instabilities throughout the observation period and the capacities reported each rain condition were below the no-rain condition capacity. Rainfall has tremendous impact on traffic flow and this have implications for shock wave propagation. Uniyal et al. in [25] reported that traffic congestion is a global as well as local problem. The authors proposed proper traffic management system along with appropriate implementation of traffic rules to mitigate the problems of traffic congestions.

Kiran et al.in [17] stated that most of the studies make use of the methods and concepts developed for homogeneous traffic. Very few studies have attempted to capture and understand the distinctive characteristics of the mixed traffic. Due to heterogeneous nature of traffic, Babit et al. in [5] stated that determination of LOS in urban areas is very much different from the concept applied in rural areas or uninterrupted roads and presented a methodology that can be implemented to determine LOS in urban areas.

4. IDENTIFICATION OF GAPS

From the literature review the following observations were made.

- the urban streets have heterogeneous traffic
- FFS is observed in the midblock portions of the urban street segment where there is no restriction
- The average travel speed is used to determine LOS in urban streets
- Volume to capacity ratio affects the LOS of urban street.
- Urban streets should minimum have LOS C.
- the worst LOS are observed during peak hours

Based on the above observations, the following gaps are identified: -

(i). the level of service of traffic in urban street and highways have been carried out in the metropolitan cities, highways in plain areas, however, very little information on hill roads were found.

(ii). to have a better understanding of traffic behaviour and quality provided to the users it is important to carry out level of service studies in urban hill roads too.

5.0 OBJECTIVES AND METHODOLOGY

The key objectives of the study are;

(i) to conduct traffic volume and speed studies for the defined road section
(ii) to carry out pavement condition survey and overview of road geometrics
(iii)to determine peak hour volume and peak hour factor.
(iv) to determine free flow speed.
(v) to determine capacity of the road, and
(vi) to determine level of service of the road

5.1 METHODOLOGY OF THE STUDY

5.1 To conduct Traffic Volume and Speed Studies for the Defined Road Section

The first step for the study is to define the study area wherein a minimum of 1.5 km stretch will be selected, that will be divided into smaller segments in order to calculate running time and delay time at each segment's end. Collection of traffic data is an essential part of traffic volume study since it provides the raw data for analysis. Counting traffic volume can be achieved in a number of ways, depending on a variety of factors such as manpower, budget, and instrument availability. Two main categories of traffic counting; manual count and automatic count are adopted to count the traffic volume from 6:00 hours to 22:00 hours so as to capture all the peak hours for 7 days.

5.2 To carry out Pavement Condition Survey and Overview of Road Geometrics

A visual inspection on the conditions of the selected road will be carried out to assess the pavement conditions. The study area will be divided into separate sections and visual inspection of the pavement will be done. The survey will provide information on the magnitudes of various types of pavement distress and report what is seen only. Along with this activity, information on the road geometric such as type of pavement, width, shoulder, gradient, kerb, drainage, utility information, signs etc, will be found out.

5.3 To Determine Peak Hour Volume and Peak Hour Factor

The data obtained from the field will then be converted to an equivalent passenger car unit (PCU) by taking into account their relative interference value. A conversion factors suggested PCU values for adoption is given in the table 2.

Table-2: Suggested PCU Values for Undivided and Divided Roads

S. No	Median	Undivided Roads		Divided Roads	
		Range	Median	Range	Median
Motorised Traffic					
1	Two Wheeler (TW)	0.10 - 0.31	0.20	0.10 - 0.45	0.22
2	Auto rickshaw (Auto)	0.33 - 0.65	0.73	0.38 - 2.11	0.90
3	Car (Small and Big Car)	1.00	1.00	1.00	1.00
4	Bus (B)	1.79 - 6.5	3.77	1.99 - 6.00	4.60
5	Mini Bus (MB)	1.36 - 3.11	1.80	1.62 - 4.10	2.07
6	Light Commercial Vehicle (LCV)	2.10 - 3.49	2.30	2.10 - 4.50	2.38
7	Two/Three Axle Truck (TAT)	2.7 - 4.81	3.70	2.70 - 7.50	3.90
8	Multi-Axle truck (MAT)	-	-	3.30 - 7.90	5.90
9	Tractor Trailer Combination	-	4.50	2.51 - 5.89	5.40
Non- Motorised Traffic					
10	Bicycle	0.34 - 0.50	0.39	0.30 - 0.80	0.42
11	Cycle Rickshaw	-	1.80	0.88 - 3.16	2.04

' - ' Implies insufficient sample size

The total traffic volume in terms of passenger car units for each 15-minute duration is determined by multiplying the number of vehicle types by their equivalent factor (as given in table 2). To calculate the total traffic volume in each interval, add the volume of straight-through cars together. After that, one can find out the hour and the 15-minutes interval with the highest volume.

The peak hour volume refers to the maximum traffic volume recorded for a lane or approach under consideration during the hour of the day for that particular intersection. The peak hour factor (PHF) is calculated by dividing the peak hour volume by four times the peak fifteen-minute volume. A PHF of 1 means that the traffic volume is the same every 15 minutes, and therefore the traffic flow is constant over the hour. The lower the PHF value, the more is the variation of traffic flow.

5.4 To Determine Free Flow Speed

The average traffic flow speed when traffic volumes are so minimal that drivers are unaffected by other vehicles on the lane and when traffic control in the intersection is either absent or so far away that it does not affect speed choice is known as free-flow speed (FFS). The free flow speed is found out in the middle section of the highway during the non-peak hours, i.e. under low flow condition (less than 200 veh/hr/lane) or when there is no restriction for the vehicle to reduce speed. A stopwatch can be used to determine the free flow speed. Two lines are marked at a distance of 100 m in the mid block to determine the average speed. The moment a vehicle enters the first line marked on the study area, a stopwatch is started and kept running until such time the same vehicle exits the second line at that instant, stop the stopwatch and record the time elapsed in a proper format. The result is used in finding the running time in the segment as well as the urban street class.

5.5 To determine Capacity of the Road

The aim of a capacity analysis is to determine the highest number of vehicles that a transportation facility can safely accommodate over a given time period. Capacity analysis looks at a facility of the segments under the same traffic, roadway, and control conditions. As a result, segments with varying predominant conditions will have varying capacities. Capacity of the section will be found out from the various combinations of hourly traffic count which is maximum amongst the 7 days during peak hours.

5.6 To Determine Level of Service of the Road

The level of service (LOS) of an urban street is determined based on the average travel speed in the arterial road and urban street classification. The average travel speed is determined by using the length of the road segment and the running time observed in the field. If the facility's capacity is exceeded, the average travel speed may not be a reasonable indicator of the L.O.S. As shown in table 3, the urban street L.O.S is determined by the average travel speed in the arterial road and urban street class.

Table 3. Urban Street LOS

Urban Street Class	I	II	III	IV
Range of free flow speed (FFS)	90 to 70 km/h	70 to 55 km/h	55 to 50 km/h	55 to 40 km/h
Typical FFS	80 km/h	65 km/h	55 km/h	45 km/h
LOS	Average Travel Speed (km/h)			
A	> 72	> 59	> 50	> 41
B	> 56-72	> 46-59	> 39-50	> 32-41
C	> 40-56	> 33-46	> 28-39	> 23-32
D	> 32-40	> 26-33	> 22-28	> 18-23
E	> 26-32	> 21-26	> 17-22	> 14-18
F	≤ 26	≤ 21	≤ 17	≤ 14

6. CONCLUSION

The level of service of an arterial road is determined based on data such as average travel speed, running time, delay time, and urban street class. The traffic data is collected at 15 minutes time interval. The peak hour factor is then calculated by converting the highest 15 minutes to an hourly time. According to the HCM, an urban streets must have a minimum level of service C, which means an average travel speed of 45 - 56 km/h for urban street class-I and 23 - 32 km/h for urban street type IV. This study can form the base for traffic studies for urban hill areas in future for planning and development of the traffic facilities to improve the quality of services.

REFERENCES

[1] Alhassan Hashim, Mohammed, Ben-Edigbe Johnnie, "Extent of highway capacity loss due to rainfall", International Journal of Civil and Environmental Engineering, Vol;6, No 12, 2012.
[2] Al-Kaisy Ahmed, Jung Younghan, Rakha Hesham, "developing passenger car equivalency factors for heavy vehicles during congestion", Journal of transportation engineering, 131(7): 514-523.July 2005.
[3] Anusha C. S, Verma Ashish, Kavitha G.,"Effects of two-wheelers on saturation flow at signalised intersections in developing countries", Journal of transportation engineering, Vol. 139(5): 448-457. May 2013.
[4] Arun Ashutosh, Erramapalli Madhu, Velmurugan Senathipathi, " Selection of a suitable service measure and determination of LOS criteria for Indian multilane interurban highways: A methodological review", Transportation in Developing Economies, Springer, June 2016.
[5] Babit Robin; Sharma, Viranta, & Duggal, Ajay K., "Level of Service Concept in Urban Roads", International Journal of Engineering Science Invention Research & Development; Vol. III, Issue I, July 2016.
[6] Bhuyan P. K, Khrishna Rao K.V., "Defining level of service criteria of urban streets in Indian context",

European Transport\ Transport Europei n.49 (2011): 38-52, 2011.
[7] Bhuyan P.K, Sheshadri Nayak Minakshi, "A review on level of service analysis of urban street", Transport Reviews: A Transnational Transdisciplinary Journal, 33:2, 219-238, 2013.
[8] Chandra S, Sikdar P.K "factors affecting PCU in mixed traffic situations on urban roads", Road and Transport Research, Vol 9. No. 3, September 2000.
[9] Chandra Satish, Kumar Upendra, "The effect of lane width on capacity under mixed traffic conditions in India", Journal of transportation engineering, Vol. 129(2): 155- 160.March 2003.
[10] Clark, I. "Level of Service F: Is it really bad as it gets?" In IPENZ Transportation Group Conference, New Plymouth, November, 2008.
[11] Das Sanhita, Kumar Maurya Akhilesh, "Time headway Analysis for Four-Lane and Two-Lane Roads", Transportation in Developing Economies, Springer, June 2017.
[12] Highway Capacity Manual, Transportation Research Board, 2010, Washington D.C.
[13] Indian Highway Capacity Manual, CSIR- Central Road Research Institute, New Delhi, December 2017.
[14] IRC: 106-1990, "Guidelines for Capacity of roads in Plain areas", 1990. Indian Road Congress.
[15] Nirmal Joseph Ebin, Nagakumar, M. S., "Evaluation of capacity and level of service of urban roads", International Journal of emerging technologies and engineering (IJETE) ISSN:2348- 8050, ICRTIET-2014 Conference proceeding, 30th - 31st August 2014.
[16] Krishnamurthy Karuppanagounder, Thamizh Arasan Venkatachalam, "Effect of road width and traffic volume on vehicular interactions in heterogeneous traffic", Journal of advanced transportation; 48:1- 14, March 2012.
[17] Kiran, Sai, Verma Ashish, "Review of studies on mixed traffic flow: Perspective of developing economies", Transportation in Developing Economies, Springer, February 2017.
[18] Mahar A, Chandra S, Velmurugan S, "Passenger car units at different levels of service for capacity analysis of multilane interurban highway in India".
Journal of transportation engineering, Vol. 140(1): 81-88 .January 2014.
[19] Maitra, B, Sikdar P.K, Dhingra S.L. Modelling congestion on urban roads and assessing level of service. Journal of Transportation Engineering, 1999, Vol 125 (6), ASCE, pp. 508-514.
[20] Marwah, B. R, Singh Bhuvanesh, "Level of Service Classification for Urban Heterogeneous Traffic: A Case Study of Kanpur Metropolis", Transportation Research Circular E-C018: 4th International Symposium on Highway Capacity.
[21] Mathew V. Tom, IIT Bombay, Transportation Engineering System, Chapter 21- "capacity and level of service", February 2014.
[22] Saha Pritam, Roy Nabanita, Kumar Sarkar Ashoke, Pal Manish, "Speed distribution on two-lane rural highways with mixed traffic: A case study in North East India", Journal of Institute of Engineers. India Ser. A 98(1-2):107–113, June 2017.
[23] Sharma Nitish, Shrikant Arkatkar Shriniwas, Kumar Sarkar Ashoke, "Study on heterogeneous traffic flow characteristics of two- lane road". TRANSPORT Vilnius Gediminas Technical University (VGTU) Press Technika Volume 26"2#: 185-196, 2011.
[24] Road Transport year book 2015-16, Ministry of Road Transport and Highways, Government of India. February 2018.
[25] Uniyal Harish, Gandhi Hemlata, "Traffic congestion-causes and solutions: a study of Kota city", International Journal of Trend in Scientific Research and Development (IJTSRD), Vol-2, Issue- 2, Jan-Feb 2018.