LOS ANALYSIS AND CAPACITY ESTIMATION OF IDENTIFIED ROADS

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ABSTRACT

Transport plays a very vital role in the development of a country's economy in determining overall productivity, quality of life of citizens, access to goods and services and the pattern for distribution of economic activity. Transportation development is one of the most visible and important investments made by a government. Efficient transportation is very important for the economic growth of a country and road transport is the only mode that is complete itself. In a country of continental size like India where resources and markets are dispersed across long distances, the provision of efficient, low cost, reliable and safe transport infrastructure and services assumes additional significance. Since the economic liberalisation of the 1990s, infrastructure development has progressed rapidly; today transport system in India comprises distinct modes such as rail, road transport, coastal shipping, civil aviation, inland water transport and pipelines. However, India's relatively low GDP per capita has meant that access to transport has not been uniform. Also railways provide an extremely important way of getting around in India, transporting 18 million citizens every 24-hour experience.

India has a network of National Highways connecting all the major cities and state capitals, forming the economic backbone of the country. It consists of approximately 1,00,475 km National Highways/Expressways, 1,48,256 km of State Highways and 49,83,579 km other roads (MORTH, 2015-16). The national highways constitute hardly 2% of the total road length but carry the 40% of total road traffic. State highways constitute about 4% of total road length and they also carry a substantial proportion of total road traffic. National highways play a very important role in promoting economic growth by providing effective connectivity between different parts of the country and an efficient means to transport freight.

Keywords: National highway, Expressway, heterogeneous, multi-lane highway

1. INTRODUCTION

The transportation research board's (TRB) highway capacity manual (HCM) provides a collection of state-of-the-art technique for estimating the capacity and determining the level of service for transportation facilities, including intersections and roadway as well as facilities for transit, bicycles and pedestrians. HCM was the first document to quantify the concept of capacity of transportation facilities. HCM (1965) edition was the first to define the concept of Level of Service, which has become the foundation for determining the adequacy of transportation facilities from the perspectives of planning, design and operations. Since then HCM has been revised in 1985, 1994, 1997. 2000 and 2010. HCM (2000) presents method for analysing capacity and level of service for a broad range of transportation facilities. HCM (2000) establishes that for multilane highways capacity varies with free-flow speed. It gives the values of capacity as 2200, 2100, 2000 and 1900 PCU/hour/lane for the free-flow speed 100, 90, 80 and 70 km/hour respectively. For highways HCM gives the three performance measures as speed, density and vie ratio. In present study v/c ratio is used as performance measure for calculating the service level of road section.

IMPORTANCE OF RESEARCH ON THE TOPIC

In India presently 5.2 million km length of total road network is available but still India is facing enormous difficulties in providing better vehicular traffic flow and operations. The main source of transportation in India is by road. Due to increase in population and the economic growth, the number of vehicles has increased in cities which are resulting into jammed traffic condition on the roads. Now a day's the traffic conditions on Indian roads are highly heterogonous in nature due to variety of vehicles with different static and dynamic characteristics. The vehicle proportion is much more diverse with many poorly performing vehicles, slow moving vehicles and non-motorised vehicles. For an efficient and increased vehicular traffic it requires better roadway infrastructure with higher capacity. Lane width and shoulder width have a significant impact on the traffic flow. Thus for effective planning analysis and operation there is a need to find the traffic volume and estimate roadway capacity. Under the study, the traffic volume data and speed-flow data are collected. The study is conducted on NH-1 and SH-6 to determine the capacity of the selected stretches of the roads and their present and future level of service. The capacity and LOS of the roads will help in deciding the future improvements of the roads including their widening.

2. OBJECTIVES OF THE STUDY

The study under consideration aims at collecting the traffic volume and speed-flow data of the selected stretches of NH-1 and SH-6. The study has the following main objectives.

To conduct speed-flow studies on the selected road sections to collect speed-flow data.

To analyse the speed-flow data of the selected roads to find out traffic composition, composite PCU value and level of traffic congestion.

To collect the 24 hours traffic volume data from the secondary sources such as NHAI and PWD.

To analyse speed-flow and traffic volume data and determine the capacity of roads.

To determine present and future level of service of the selected roads.

To predict the future widening requirements of the roads.

SCOPE OF STUDY

Under the study, the traffic volume data and speed-flow data are collected. The study is conducted on NH-1 (6 lane divided road) and SH-6 (4 lane divided road) to determine capacity of the road and their present and future level of service. The selected 6-lane section of NH-1 and 4-lane section of SH-6 represents a straight, leveled and rural section of the road located in a plain terrain with good pavement conditions. The 6-lane section has a dual carriageway with 10.5 m wide pavement on either side of the median. The width of the paved shoulder is 1.5m and the width of the median is 4.4 m. The 4-lane section has a dual carriageway with 7.0 m wide pavement on each side of median with paved shoulder of 1.5m cach. The width of median is 2.0 m. The present study though has been analysed for the selected sections of the roads, the results may be generalised and used for the other such roads having similar roadway and traffic conditions.

3. LITERATURE REVIEW

HCM (2000) suggested that a maximum flow rate that can be achieved on a multilane highway is 2200 PCU/hour/lane. The Danish method is also a modification of HCM to suit Danish conditions. The adjustment factors in the Danish method cause a steeper capacity reduction than in HCM 2000 as the conditions become less ideal and therefore, the capacity under ideal conditions on a four-lane highway is 2300 PCU/hour/lane on Denmark highways (Nielsen and Jorgensen, 2008).

Similarly, in Finland and Norway too, HCM 2000 was followed with minor modifications to suit the local conditions and the roadway capacities obtained by the Finnish and Norwegian methods for multi-lane highways is 2000 PCU/hour/lane The structure of the Swedish method is similar to the HCM (1995) and it uses the 1995 HCM adjustment factors for the roadway width, whereas other adjustments factors are mostly omitted. Consequently, the Swedish method yielded higher capacity estimates and the estimated capacity of four-lane divided highways was 4200 PCUs/hour per direction (Luttinen and Innamaa, 2000).

The Australian method for analysis of capacity was basically same as that of HCM method with the basic difference being additional modification has been suggested for specific problems. Under ideal conditions, the average minimum headway of 1.8 seconds was considered and maximum flow of 2000 vehicles per hour per lane was assumed. The succeeding paragraph focuses on the roadway capacity evolved in Asian countries like Indonesia and China for multi-lane highways wherein largely heterogeneous traffic conditions as experienced on Indian highways is witnessed.

Bang et. al. (1997) in their study for establishing Indonesia HCM mentioned that travel speed as the main measure of performance of road segments, since it is easy to understand and to measure, and is an essential input to road user costs in economic analysis. Travel speed is defined in this manual as the space mean speed of light vehicles (LV) over the road segment

as given below: $V = L/TT$

Where, V space mean speed (km/h) of Light Vehicles (LVS)

L-length of segment (km)

1T mean travel time of LVs over the segment (in hours)

Using this analogy, the capacity of multi-lane highways has been estimated as 2300 LVs/hour/lane for Indonesian multi-lane highways. In the case of Chinese conditions, based on the field data collected, VTI highway simulation model was calibrated and validated and this model was used for the determination of Passenger Car Equivalents (PCE) and speed-flow relationships for different terrain types in parallel with multiple regression analysis of empirical speed-flow data. The results showed that the free-flow speeds of vehicles were substantially low and that the roadway capacity was also

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marginally lower (2100 PCEs per lane on four-lane divided carriageways) under Chinese conditions as compared with the values obtained for Indonesian multi-lane highways.

Yang and Zhang (2005) have established based on their extensive field survey of traffic flow on multi-lane highways in Beijing and subsequent empirical model development that the average roadway capacity per hour per lane on four-lane, six-lane and eight-lane divided carriageways is 2104, 1973 and 1848 PCUs, respectively. This is unlike HCM results obtained for many developed countries which prescribe that average capacity per lane on different highways is equal as they assume that highway capacity is constantly proportional to the number of lanes on multi-lane divided carriageways.

CAPACITY AND LOS OF RURAL ROADS

Capacity and level of service are two terms which are closely related with each other. Capacity analysis gives a clear understanding that how much traffic a given transportation system can accommodate in the other hand Level of service gives an idea about how good is the present traffic situation on a given facility. Thus level of service is qualitative measure of given traffic facility, while capacity of highway is a quantitative measure of a facility.

Capacity (HCM 2000)

According to the highway capacity manual(HCM), The capacity of a facility is the maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions.. It is expressed as vehicle per hour or vehicle per day and usually expressed as PCU/hour or PCU/day.

Vehicle capacity is the maximum number of vehicles that can pass a given point during a specified period under prevailing roadway, traffic, and control conditions. This assumes that there is no influence from downstream traffic operation, such as the backing up of traffic into the analysis point.

Person capacity is the maximum number of persons that can pass a given point during a specified period under prevailing conditions. Person capacity is commonly used to evaluate public transit services, high-occupancy vehicle lanes, and pedestrian facilities.

Shukla (2008) studied the mixed traffic flow behaviour on four-lane divided highway for varying conditions of traffic volume and shoulder and developed a simulation model for the observed traffic flow to estimate roadway capacity under these conditions. To understand the traffic flow behaviour on four-lane divided highways under mixed traffic condition, the arrival pattern of vehicles, speed characteristics, lateral placement of vehicles and overtaking behaviour was analysed. Shukla (2008) further reported that the roadway capacity of four lane divided carriageways as 4770 vehicles/hour in each direction is estimated for 'all cars' situation. This exhaustive look at the literature indicates that no substantial work has been carried out for establishing the roadway capacity and DSV for varying carriageway widths on multi-lane highways covering four-lane, six-lane and eight-lane divided carriageways for the heterogeneous traffic mix prevalent on Indian highways with reasonable degree of confidence and hence this research endeavour can be termed as a significant attempt in this direction.

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Recommended values of Design Service Volume

IRC: 64-1990 recommends the following values of Design Service Volumes (Table 2.1). These values corresponds to LOS 'B' and peak hour factor of 8-10% and are based on the assumption that the road is provided with good earthen

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shoulders on both sides. The capacity figures of two lane roads can be increased by 15% when paved and surfaced shoulders of at least 1.5 m width are provided with either side.

"Guideline for capacity of roads in rural areas". Sufficient information about the capacity of multi-lane roads under mixed traffic conditions is not yet available. Tentatively, a value of 35,000 PCUS can be adopted as DSV for four-lane divided carriageway located in plain terrain. This is based upon the assumption that reasonable good earthen shoulders exist on the either side and a minimum 3.0 m wide central median exist. Hard shoulders on dual carriageways can further increase the capacity. A value of 40,000 PCUs can be adopted as DSV for four-lane divided carriageway when designed paved shoulders of 1.5 m width are provided.

Quality and Level of Service (HCM 2000)

Quality of service requires quantitative measures to characterize operational conditions within a traffic stream. Level of service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to manoeuvre, traffic interruptions, and comfort and convenience. Six LOS are defined for each type of facility that has analysis procedures available. Letters designate each level, from A to F. with LOS 'A' representing the best operating conditions and LOS 'F' the worst. Each level of service represents a range of operating conditions and the driver's perception of those conditions. Safety is not included in the measures that establish service levels.

Considering the need for smooth traffic flow, it is not advisable to design the road cross section for traffic volumes equal to the maximum capacity which will become available normally at LOS E. At that LOS, the speeds are rather low and freedom to manoeuvre within traffic stream is very much restricted. Besides even a small increase in traffic at that traffic volume would lead to forced flow situation and breakdown within the traffic stream. On the other hand, adoption of a higher level of service like A and B, although enabling near free-flow conditions would mean lower design service volume necessitating higher number of traffic lanes to carry the higher traffic volumes.

The Capacity flow or the maximum possible flow on a roadway or a traffic lane is attained at a particular optimum speed, the flow decreases at higher as well as lower speed values. Capacity flow is reached when all the vehicles flow as a stream at this optimum speed with no opportunity for overtaking; at this speed the Level of Service is considered to be fairly low when the volume of the road reaches the capacity or the volume to capacity ratio approaches a maximum possible value of 1.0.

Level of service A (volume-0.30 capacity) is marked by free-flow, high freedom to select desired speed and to manoeuvre, excellent comfort and convenience. Volume is about 30% of capacity of road.

Level of service B (volume-0.50 capacity) is indicated by stable flow, reasonable freedom to select desired speed and manoeuvre, volume is about half the capacity. Comfort and convenience is somewhat less than level of service A.

Level of service C (volume=0.70 capacity) represents the zone of stable flow but the operation of vehicle is significantly affected by interruption with other vehicles in the traffic stream. Volume at this level is about 70% of the capacity of the road.

Level of service D (volume-0.90 capacity) represents the limit of stable flow with conditions approaching closed to unstable flow. Level of comfort and convenience is poor. Volume is about 90% of capacity.

Level of service E (volume 1.0 capacity) represents the zone of unstable flow. Traffic volume is at or close to the capacity level of road.

Level of service F (volume capacity) represents the zone of forced or breakdown flow. This occurs when the number of vehicles approaching a point on the road exceeds the number that can pass through it. Queue formation starts taking place behind such locations on the road.

Factors to be considered for evaluation of level of service of a roadway in a comprehensive manner include the operating speed, travel time, traffic interruptions, freedom of manoeuvre, driving comfort, safety, economy etc. However, in order to simplify the level of service concept, two factors considered by Highway Capacity Manual (HCM) are:

i) the ratio of service volume to capacity(v/c) and

ii) the operating and travel speed

Factors affecting capacity and LOS (HCM 2000)

Base Conditions

Base conditions assume good weather, good pavement conditions and users familiar with the facility, and no impediments to traffic flow. Examples of base conditions for uninterrupted-flow facilities and for intersection approaches are given below;

Lane widths of 12 feet

Clearance of 6 feet between the edge of the travel lanes and the nearest obstructions or objects at the roadside and in the median

Free-flow speed of 60 mi/h for multilane highways,

➤ Only passenger cars in the traffic stream (no heavy vehicles)

➤ Level terrain

no-passing zones on two-lane highways and

No impediments to through traffic due to traffic control or turning vehicles.

Base conditions for intersection approaches include the following:

Lane widths of 12 feet

➤ Level grade

No curb parking on the approaches

➤ Only passenger cars in the traffic stream

➤ No local transit buses stopping in the travel lanes

➤ Intersection located in a non-centrally business district area and

- No pedestrians.

In most capacity analyses, prevailing conditions differ from the base conditions and computations of capacity, service flow rate, and level of service must include adjustments. Prevailing conditions are generally categorized as roadway, traffic or control conditions.

Roadway conditions

Roadway conditions include geometric and other elements. In some cases, these influence the capacity of a road; in others, they can affect a performance measure such as speed, but not the capacity or maximum flow rate of the facility. Roadway factors include the following:

Number of lanes.

➤ The type of facility and its development environment

➤ Lane widths

➤ Shoulder widths and lateral clearances

➤ Design speed,

➤ Horizontal and vertical alignments, and

Availability of exclusive turn lanes at intersections.

The horizontal and vertical alignment of a highway depends on the design speed and the topography of the land on which it is constructed. In general, the severity of the terrain reduces capacity and service flow rates. This is significant for two-lane rural highways, where the severity of terrain not only can affect the operating capabilities of individual vehicles in the traffic stream, but also can restrict opportunities for passing slow-moving vehicles.

Traffic conditions

Traffic conditions that influence capacities and service levels include vehicle type and lane or directional distribution.

a) Vehicle Type

The entry of heavy vehicles that is, vehicles other than passenger cars (a category that includes small trucks and vans) into the traffic stream affects the number of vehicles that can be served. Heavy vehicles are vehicles that have more than four tires touching the pavement. Trucks, buses, and recreational vehicles (RVs) are the three groups of heavy vehicles addressed by the methods in this manual. Heavy vehicles adversely affect traffic in two ways:

➤ They are larger than passenger cars and occupy more roadway space and

➤ They have poorer operating capabilities than passenger cars, particularly with respect to acceleration, deceleration, and the ability to maintain speed on upgrades.

The second impact is more critical. The inability of heavy vehicles to keep pace with passenger cars in many situations creates large gaps in the traffic stream, which are difficult to fill by passing manoeuvres. The resulting inefficiencies in the use of roadway space cannot be completely overcome. This effect is particularly harmful on sustained, steep

upgrades, where the difference in operating capabilities is most pronounced, and on two-lane highways, where passing requires use of the opposing travel lane. Heavy vehicles also can affect downgrade operations, particularly when downgrades are steep enough to require operation in a low gear. In these cases, heavy vehicles must operate at speeds slower than passenger cars, forming gaps in the traffic stream. Trucks cover a wide range of vehicles, from lightly loaded vans and panel trucks to the most heavily loaded coal, timber, and gravel haulers. An individual truck's operational characteristics vary based on the weight of its load and its engine performance.

RVs also include a broad range: campers, self-propelled and towed; motor homes; and passenger cars or small trucks towing a variety of recreational equipment, such as boats. snowmobiles, and motorcycle trailers. Although these vehicles might operate considerably better than trucks, the drivers are not professionals, accentuating the negative impact of RVs on the traffic stream.

Intercity buses are relatively uniform in performance. Urban transit buses generally are not as powerful as intercity buses; their most severe impact on traffic results from the discharge and pickup of passengers on the roadway. For the methods in this manual, the performance characteristics of buses are considered to be similar to those of trucks.

b) Directional and Lane Distribution

In addition to the distribution of vehicle types, two other traffic characteristics affect capacity, service flow rates, and level of service: directional distribution and lane distribution. Directional distribution has a dramatic impact on two-lane rural highway operation, which achieves optimal conditions when the amount of traffic is about the same in each direction. Capacity analysis for multilane highways focuses on a single direction of flow. Nevertheless, each direction of the facility usually is designed to accommodate the peak flow rate in the peak direction. Typically, morning peak traffic occurs in one direction and evening peak traffic occurs in the opposite direction. Lanc distribution also is a factor on multilane facilities. Typically, the shoulder lane carries less traffic than other lanes.

Control conditions

For interrupted-flow facilities, the control of the time for movement of specific traffic flows is critical to capacity, service flow rates, and level of service. The most critical type of control is the traffic signal. The type of control in use, signal phasing, allocation of green time, cycle length, and the relationship with adjacent control measures affect operations.

Stop signs and yield signs also affect capacity, but in a less deterministic way. A traffic signal designates times when each movement is permitted; however. a stop sign at a two-way stop controlled intersection only designates the right-of-way to the major street. Motorists traveling on the minor street must stop and then find gaps in the major traffic flow to manoeuvre. The capacity of minor approaches, therefore, depends on traffic conditions on the major street. An all-way stop control forces drivers to stop and enter the intersection in rotation. Capacity and operational characteristics can vary widely, depending on the traffic demands on the various approaches. Other types of controls and regulations can affect capacity, service flow rates, and LOS significantly. Restriction of curb parking can increase the number of lanes available on a street or highway. Turn restrictions can eliminate conflicts at intersections, increasing capacity. Lane use controls can allocate roadwav space to component movements and can create reversible lanes. One-way street routings can eliminate conflicts between left turns and opposing traffic.

4. CONCLUSIONS

The study presented in the dissertation is concluded to evaluate the composition of vehicles, composite PCU values, maximum and average spot speed of vehicles, minimum time-headway, capacity, level of service and widening requirements of NH-1 and SH-6.

The following main conclusions are drawn from this work:

1. Traffic Composition

a) The road section under study consists of about 60% cars, 18% trucks, 5% buses and 13% 2-wheelers on NH-1 while for SH-6, the road section consist of 33% cars, 2% trucks, 2% buses and 50% 2-wheelers.

b) In terms of PCUs, the road section carried about 40% cars, 37% trucks, 10% buses and 4% 2-wheelers on NH-1 while the road section consist of about 40% cars, 7% trucks, 6% buses and 29% of 2-wheelers on SH-6.

c) The slow moving vehicles (consist of cycles, cycle- rickshaws and animal drawn vehicles) were negligible on NH-1. On the other hand, slow moving vehicles were less than 5% on SH-6.

d) The traffic on the road consisted of about 25% of commercial vehicles on NH-1 and 5% of Commercial vehicles on SH-6. Commercial vehicles consist of buses, trucks, truck-trailers, tractor and tractor-trailers.

e) Vulnerable road vehicles on the road consist of pedal cycle, cycle-rickshaw and 2-wheelers are found to be about 13% on NH-1 and 55% on SH-6.

f) The composite PCU value is found to be 1.48 and 0.846 for NH-1 and SH-6 respectively for the given study. A composite PCU value of 1.5 and 0.85 is suggested for NH-1 and SH-6 respectively for conversion of total vehicles into PCUs in a simplified manner.

2. Analysis of Speed-flow and traffic volume data.

a) As far as hourly variation of traffic is concerned on NH-1, it is found to be more or less uniform during period of the study with major percentage of cars followed by trucks and 2-wheelers.

b) As far as hourly variation of traffic is concerned on SH-6, it is found to be more or less uniform during period of the study with major percentage of 2-wheelers followed by cars.

c) Maximum speed of car is found to be about 130 km/h and average speed of cars on the road is found to be 75 km/h on NH-1 and about 80 km/h and 55 kmih respectively on SH-6.

d) Similarly, maximum speed of bus in found to be 90 km/h whereas average speed is 65 km/h on NH-1 and maximum speed for buses is 62 km/h and average speed is 52 km/h on SH-6.

e). The average time beadway between passage of two consecutive vehicles was found to be 1.71 seconds on NH-1 and 1.91 seconds on SH-6.

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