DEVELOPMENT OF INDIAN HIGHWAY CAPACITY MANUAL (INDO-HCM)
(12th Five Year Plan Project)

INTRODUCTION

The most quoted and referred capacity manual in the transportation community worldwide is the United States Highway Capacity Manual (US-HCM) first developed in 1950. Since then, this manual has undergone significant improvements with major restructuring and rewrites in 1965, 1985, 2000 and the recent publication in 2010. For example, the US-HCM 2000 (TRB, 2000) suggested that a maximum flow rate that can be achieved on a multilane highway is 2200 Passenger Car Units (PCU)/hour/lane. The Danish HCM is a modification of US- HCM to suit their conditions. The adjustment factors in the Danish method caused steeper capacity reduction than in US-HCM 2000 as the conditions become less ideal and therefore, the capacity under ideal conditions on a four-lane highway has been estimated as 2300 PCUs / hour/ lane on Danish highways (Nielsen and Jorgensen, 2008). Similarly, in Finland and Norway, US-HCM 2000 (TRB, 2000) has been 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 Australian method for analysis of roadway capacity is basically same as that of US-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 is considered and maximum flow of 2000 vehicles per hour per lane has been assumed. Hence, it is evident that these evolved manuals coexist with roadway design and traffic control practices prevailing in a specified country and cannot be simply transferred to any other country for direct applications.

On the contrary, Indonesian Highway Capacity Manual (I-HCM) evolved the capacity of multi-lane highways as 2300 Light Vehicles (LV)/hour/lane. In the case of Chinese HCM, based on the field data collected, VTI highway simulation model developed under Swedish conditions has been calibrated and validated and this model has been deployed for the determination of Passenger Car Equivalents (PCE). The results showed that the free-flow speeds of vehicles are somewhat low and the roadway capacity was also marginally lower (i.e. 2100 PCEs per lane on four-lane divided carriageways) under Chinese conditions as compared with the values obtained for Indonesian multi-lane highways. Further, 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/lane/direction, respectively. This is unlike HCM results obtained in 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. This article describes the study undertaken by the CSIR-CRRI at the national level to develop the Indian Highway Capacity Manual (henceforth referred to as 'Indo-HCM'). Indo-HCM is being executed by CSIR-CRRI in coordination with some of the reputed academic institutes in the country which includes, Indian Institute of Technology (Roorkee), Indian Institute of Technology (Bombay), Indian Institute of Technology (Guwahati), School of Planning and Architecture (Delhi), Sardar Vallabhai Patel National Institute of Technology, (Surat), Bengal Engineering & Science University, Shibpur, (Howrah) and Anna University (Chennai). This article briefly describes the research endeavour undertaken by the CSIR-CRRI, the goal of the study, study methodology that would be used in various Work Packages (WP), and finally the expected study deliverables.

RESEARCH ENDEAVOUR

The main hypothesis behind conceiving the project is that Indian traffic characteristics are fundamentally different from those in the developed countries and even the driver behaviour is vastly different from even the developing economies like China and Indonesia. Consequently, the development of Indian Highway Capacity Manual (Indo-HCM) has been undertaken on priority in the form of a mission mode project by considering the various categories of Indian roads like Expressways, National Highways (NH), State Highways (SH), Major District (County) Road (MDR), Other District Roads (ODR) and Urban Roads (UR) separately. The principal goal of this research envisages to study the nationwide characteristics of road traffic and to develop a manual for determining the roadway capacity and Level Of Service (LOS) for varying types of inter-urban roads and urban roads separately by including Controlled and Uncontrolled Intersections coupled with addressing the pedestrian facilities existing on the relevant type of roads. To accomplish the stated goal, the study aims at analyzing the characteristics of the heterogeneous traffic flow as shown in Figure 1 to identify appropriate distributions of the

various variables influencing the traffic stream characteristics by examining the traffic flow characteristics through extensive field data collection and analysis. Relevant studies are being conducted on straight / mid-block roadway sections and uncontrolled intersections with adequate coverage of all possible combinations of geometry and operating conditions. Similarly, the capacity and level of service guidelines for the controlled intersections located in the urban areas is studied separately. To improve the applicability of the results nationwide test sections have been selected throughout India.

Figure 1. Heterogonous traffic conditions in India

STUDY METHDOLOGY

Ironically, most of the models developed elsewhere are applicable for homogeneous traffic conditions and hence are not applicable for the heterogeneous traffic prevalent on Indian roads. In India, the first major research effort addressing this issue was undertaken as part of the RUCS-1982 and this was followed by URUCS-1992 and URUCS-2001. For instance, Indian Roads Congress-64 (IRC-64) (1990) suggested a tentative DSV of 40,000 PCUs for the four-lane divided carriageway in plain terrain which is significantly lesser than the values evolved in most of the developing countries and therefore the need was felt for revisiting the DSV values evolved under IRC-64. Consequently, many research studies (Tiwari, et. al., 2000, Velmurugan et. al., 2002, Chandra S. and Kumar U., 2003, Reddy, et. al., 2003, Chandra, 2004, Errampalli,

et. al., 2004, Velmurugan, et. al., 2004, Dey, 2006, Errampalli, et. al., 2009, Velmurugan et. al., 2009, Madhu, 2011) aimed at assessing the roadway capacity for varying carriageway widths including single lane, intermediate lane, two-lane bi-directional and multi-lane divided carriageways (i.e. four lane to eight lane) covering different terrains have been conducted during the last two decades. Unfortunately, these piece meal research efforts have not culminated in the development of Indo - HCM and hence this important research study has been undertaken. The methodology outlined for the development of the Indo-HCM can be regarded as unique as the ongoing research work aims at analyzing the characteristics of the heterogeneous traffic flow so as to identify appropriate distributions for various traffic variables influencing the traffic stream characteristics which can enable to examine the traffic flow characteristics and vehicular interactions occurring on the different typology of road sections. In this study, traditional macroscopic modelling methods as well as microscopic simulation modelling approach have been deployed as the latter is regarded as one of the most effective analytical tools to estimate the roadway capacity of Indian highways (Velmurugan et al., 2010). This is because, these models, once validated, can be used to study the traffic flow characteristics over a wide range of the associated variables which would enable to get more acceptable results and thus could be useful for assessing the effectiveness of traffic management measures. Outputs derived from the appropriate traffic flow simulation models would be used to construct fundamental diagrams of flow thereby making it possible to estimate the capacity of a facility. Further, in order to have uniformity in the analysis method, a standardized methodology was formulated during the 1st National Level Workshop held on 18th - 19th January, 2013 at SVNIT, Surat (SVNIT). The methodology finalized during the workshop is being uniformly adopted by all the academic institutions in India. To accomplish the stated objectives, the entire study has been sub-divided into nine Work Packages (WP) explained in the next section. Also, a 2nd Project Review Workshop is slated to be held at Anna University, Chennai from 28th - 30th March, 2014 to review the yearly progress achieved in each Work Package.

WP-1: Roadway Capacity Estimation of Two Lane, Intermediate and Single Lane Carriageways

The existing normal roadway section in India is categorized as follows:

Undivided roads

(i)   Single Lane roads (3.5m to 3.75m)

(ii)   Intermediate Lane roads (5.5m to 6.0m)

(iii)   Two-lane roads with earthen or paved shoulders (7.0m to 7.5m)

The factors considered while developing the capacity norms for these types of roads are discussed in the succeeding sections. Although the roads in India are categorized based on the lane width as mentioned above, it is noted that invariably the Indian roads have non-standard widths that do not conform to any discrete number of lanes. Hence, the basic concept of lane width would be addressed by considering the existing carriageway width perspective. This applies to the operational features as well, as the vehicles (road users) seldom obey lane markings. Though based on the administrative classification of roads, the inter-urban roads are categorized as NHs, SHs, MDR, ODR and VR and recently, Expressways, the capacities are being studied based on engineering features only. The above referred varying lane widths are considered on the typical inter-urban corridors located preferably in the vicinity of the cities like Delhi, Mumbai, Kolkata, Chennai, Surat, Dehradun and Guwahati to ensure a balanced geographical distribution across the country representing plain, rolling and hilly terrains.

WP-2: Roadway Capacity Estimation of Multi-lane Inter City Highways

In addition to the factors listed under WP-1, factors like lateral clearance, width of median, number of lanes, auxiliary lanes, width and type of shoulders would be considered in the test sections in the vicinity of the cities mentioned earlier. Based on the collected data, adjustment factors would be derived when deemed necessary.

WP-3: Roadway Capacity Estimation of Inter - Urban and Urban Expressways

In addition to the factors listed under WP-2, the capacity of expressway sections will be examined considering the adequacy of ramp provision, weaving sections and merge / diverge sections. Obviously, the test sections on expressways will be selected in accordance with the availability of the same in the vicinity of the cities mentioned earlier. Figure 2 show the typical test section seleceted for the Urban Expressway.

| Delhi-Gurgaon Expressway | Ahemdabad-Vadodara Expressway |

Figure 2 show the typical test section selected for the Urban Expressway.

WP-4: Urban Roadway Capacity Estimation for Arterials / Sub- Arterials / Collectors

For determining the roadway capacity of urban roads classified under Arterial, Sub-Arterial, and Collector Street category, typical test sections located in the cities like Delhi, Mumbai, Kolkata, Chennai, Surat, Dehradun and Guwahati are chosen. In this regard, it is to be noted that the PCU of a vehicle type for a roadway facility is assumed to be unaffected by traffic volume and its composition. Further, the presence of slow moving vehicles in traffic stream would impede the free flow of traffic. Hence, unique attempts have been made in India (both in urban roads and inter-urban road context) to determine dynamic PCU values (Arasan, 2008, Chandra, 2004) for different types of vehicles operating on different categories of road. It is recognized that PCU of a vehicle type changes with all factors influencing the behavior of vehicles in the traffic stream. Therefore, PCU of a vehicle has been proposed to be estimated from field data using the following equation (Chandra, et al, 2004).

$$PCU_i = \frac{V_c / V_i}{A_c / A_i}$$

(1)

Where,

Vc = Speed (or clearing speed for intersection) of a car

Vi = Speed (or clearing speed for intersection) of a vehicle type i

Ac = Projected rectangular area of a car, (length x width)

Ai = Projected rectangular area of vehicle type i on the road (length x width)

In this study, the applicability of the equation (1) to determine PCU for varying types of carriageways are being studied and based on the acceptability of the above formulation for traffic plying on different types of carriageways, the need for refinement would be finalized for both inter-urban and urban roads.The typical test section selected for the Urban arterial was as shown in Figure 3 and Figure 4.

Figure 3: Six Lane divided Urban Arterial Road Section in Delhi

Figure 4: Russel Street Four Lane un divided Urban Arterial Road Section in KolkataRoad Section

WP-5: Capacity Estimation of Controlled Intersections

As intersections are the critical nodal points of any road network, where normally delay is caused to traffic, it is imperative to study the intersections to arrive at the various LOS and capacity norms under different operating conditions. Two broad categories of intersections i.e. uncontrolled and controlled (i.e. signalized) intersections are studied in detail in and around the cities listed earlier.

On Indian urban roads, signalized intersections are present on roads of different widths including the undivided / divided carriageways and therefore, the following factors are being considered:

(i)   Roadway Factors

·   Number of intersecting legs

·   Approach width

- Approach gradient

- Approach curvature

- Safe stopping sight distance

- Intersection sight distance

- Channelization

(ii)   Traffic Factors

- Traffic volume and composition

- Directional (straight and turning) flow of traffic

- Peak and non-peak flow of traffic

- Parking regulation in the vicinity of intersection

- Location of bus stops near the intersection area

- Pedestrian traffic

(iii) Environmental Factors

- Weather

- Other environmental factors influencing the intersection operation

(iv)   Control Conditions

- Speed limit

- Prohibition of overtaking

- Availability of traffic control devices such as signs, islands, markings, etc.

In the case of roundabout, the above detailed analysis is also being conducted separately by considering the parameters envisaged above.

WP-6: Capacity Estimation of Uncontrolled Intersections

As different types of uncontrolled intersections generally exist on all types of Indian inter-urban roads, the various factors listed under WP-5 would be considered except the traffic signal related parameters while collecting the data for roadway capacity of typical uncontrolled intersections. The scope of the work package is confined to the major uncontrolled intersections located on the inter-urban roads catering to the sizable proportion of sub-urban and peri-urban traffic.

WP-7: Capacity Estimation of Pedestrian Facility

LOS is a term used to describe existing operating conditions (or suitability) for a mode of travel in the transportation system. LOS of varying types of roads is primarily based on speed, travel time and intersection delay whereas the calculation of Pedestrian LOS is more complex because it represents the operating condition of pedestrian facilities and level of comfort pedestrians experience in using these facilities. Typical section selected for conudcitng the pedesatrain survey was as shown in Figure 5.

Figure 5. Sidewalk Pedestrian Facility used by the Pedestrians at Mumbai

WP-8: Gap Acceptance Studies

The driver behaviour in some of the typical conflict points would study the crossing vehicle movements at major uncontrolled intersections from the video recordings conducted at vantage positions. Figure 6 show the field of view of camera covering the uncontrolled in intersection for studying the Gap acceptance studies

Figure 6. Field of view of video camera at the selected uncontrolled intersection in Delhi

WP-9: Development of Reliability as a performance measure

Travel Time Reliability (TTR) is increasingly recognized as an important mobility performance measure. Therefore, the objective of this work package is mainly focused on the development of TTR as a surrogate performance measure for expressways and multi lane highways. The arrangement of gantry for fixing camera for the data collections was shown in Figure 7.Figure 7. The arrangement of gantry for fixing the camera for data collection at Delhi

At Delhi   At Chennai

Figure 7. The arrangement of gantry for fixing the camera for data collection

PROJECT DELIVERABLES

The tangible year-wise outputs expected from this mission mode project during the various stages are:

- A State-Of-the Art Report (SOAR) prepared at the end of 2013 highlights the salient aspects of nationwide characteristics of highway traffic, operation and control and also reviews the hierarchical functioning of inter-urban and urban roads.

- Generation and Updating of Traffic Database and Traffic Flow Characteristics for Indian roads envisaged for the Second year (2013-14) is under progress

- Development of Speed-Density-Volume relationships for a wide range of roadway and traffic conditions in India envisaged for the third year (2014-15).

- Procedure for determining the Operational Efficiencies of different categories of Indian roads including intersections with all possible combinations of geometry and operating conditions evaluated adequately is planned for the year 2015-16.

- Guidelines for Roadway Capacity and LOS estimation for different categories of roads and intersections (including pedestrian facility). This includes the revision of existing Indian Roads Congress (IRC) Codes like IRC-64, IRC-106, IRC-103, IRC-SP-30 and also evolving Guidelines for Expressways (New) targeted for 2016-17.

The developed manual is expected to serve as a practical tool for the practicing engineers and planners to mitigate the traffic and infrastructural problems as the models developed in this study would have been calibrated and validated for conditions prevailing on varying road widths including plain, rolling and hilly terrains.

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