HIGHWAY CAPACITY STANDARD IN INDIA – A POLITICAL AGENDA PURSUED

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ABSTRACT

India, like many other developing countries, has heterogeneous traffic, which is a totally different environment from any developed nation. Although many countries in the world still use the US Highway Capacity Manual (HCM) as the standard for their road developments, India does not seem akin to this. India has been pursuing the National Highway Development Project and many others with tentative capacity guidelines, which are ad-hoc and as suited for the project. This paper studies the capacity standards followed in road development programmes in India so far, which have been age-old, modified aptly from time to time to suit the policies of the Government. This paper brings out these facts along with the large amount of research carried out by academic and research institutions in India, carefully considering the peculiarity in traffic mix and road use behaviour. The research study focuses on the effect of this extravagant road development standards followed by ad-hoc policy, one of which has been the unsuccessful PPP funding regime. Cost intensive expressways and multi-lane highways are also required to undergo very careful assessment of demand and level of service to be provided. Thus, realistic and scientifically derived capacity standards are of paramount importance for justified developments without wasting resources for popular political agenda. Such concerns gave rise to a multi-institutional study for development of Indian Highway Capacity Manual (Indo-HCM) during the 12th Five Year Plan under coordination of CRRI, and this should be adopted as the National Standard in due course of time, after review.

KEYWORDS

Highway Capacity, Design Service Volume, HCM, Passenger Car Units

1. INTRODUCTION

Capacity standards for various components of a highway network is of paramount importance in the road development, especially for optimum utilisation of available recourses for developing road infrastructure. This becomes even more important in developing countries, which are in transition, where resources are scarce compared to the transport demand.

India is one of the fastest growing developing countries in the world, and has a massive road development plan underway since last two decades. Road development started after economic liberalization in the 1990s, and various development plans were taken up, which include National Highway Development Project (NHDP) with Golden Quadrilateral and NS-EW Corridors, which started in 1999. Pradhan Mantri Gram Sadak Yojana (PMGSY) started in 2000 along with improving road connectivity to ports and airports and many more. The aim of the then Planning Commission was to improve the network level mobility to reduce the travel time and

fuel cost by improving quality of roads complying to social and environmental safeguards, while promote new technology and ensuring overall safety.

India has now a road network of over 5,472,144 kilometres (3,400,233 miles) as on 31 March 2015 (*1*), the second largest road network in the world. At 1.66 km of roads per square kilometre of land, the quantitative density of India's road network is higher than that of Japan (0.91) and the United States (0.67), and far higher than that of China (0.46), Brazil (0.18) or Russia (0.08). Table 1 shows the total length of India's road network by type of roads as on 31 March 2015.

TABLE 1 Total Length of India's Road Network as on 31 March 2015

Road Classification	Authority responsible	Length (km)	Share of network length
National Highways	Ministry of Road Transport and Highways	97,991	1.79 %
State Highways	Public Works Department of State/Union Territory	167,109	3.05 %
Other PWD roads	Public Works Department of State/Union Territory	1,101,178	20.12 %
Rural roads	Panchayats, JRY and PMGSY	3,337,255	61 %
Urban roads	Local governments and municipalities	467,106	8.54 %
Project roads	Various State/Union territory government departments, and SAIL, NMDC and BRO	301,505	5.50 %
Total	**N/A**	**5,472,144**	**100 %**

Source: Basic Road Statistics of India 2013-14 and 2014-15, Ministry of Road Transport & Highways

Although there is an extensive network of roads in India, qualitatively these are a mix of modern highways and narrow, unpaved roads, which are being improved. As on 31 March 2015, 61.05% of Indian roads were paved (*1*). As of January 2017, India had completed and placed in use over 25,600 kilometres of recently built 4-lane or 6-lane highways connecting many of its major manufacturing centres, commercial and cultural centres (*2*). According to the CIA World Factbook, as of 2015, India had about 96,000 kilometers of national highways and expressways, plus another 147,800 kilometers of state highways (*3*).

Major projects are being implemented under the National Highways Development Project, a government initiative. State Highway Authorities are also implementing major projects - for example, the Yamuna Expressway between Delhi and Agra. With so much of road development projects going on in the country, through initiatives of central and state governments, it is vital to justify the upgradation of a road depending upon the travel demand and capacity need of the road, which is normally based on the projected traffic of 20-30 years. The manuals for four-laning and six laning of highways published by the Indian Roads Congress (IRC) have indicated

certain values of Design Service Volume (DSV) for two-lane undivided and four-lane divided roads to facilitate decisions of highway development projects in the country. The design service volume is taken mostly at Level of Service (LOS) 'B', which is a qualitative measure describing operational conditions within a traffic stream, which at almost 50% of the capacity of the road. However, these values are ad hoc and not based on empirical/scientific studies. Also, often now and then notifications are issued by Ministry of Road Transport & Highways (MoRTH) for adopting much lesser traffic volume criteria for upgradation/widening, to suit the local and political objectives of the government, which is premature and wasteful investment.

During last two to three decades there have been efforts by various educational and research institutions to study the mixed traffic behaviour and related highway capacity norms for India. This paper brings out the findings of these research studies for capacity estimation for Indian roads, and compares the ad-hoc standards followed.

2. RESEARCH CARRIED OUT FOR HIGHWAY CAPACITY ESTIMATION BY VARIOUS INSTITUTIONS

Many developed and developing countries have produced their own highway capacity manual. However, since different counties have their roadway design and traffic control practices based on road traffic mix and road use behaviours, these cannot be adopted for application in India. Accordingly, many logical studies have been undertaken to study the capacity of Indian highways considering the heterogeneity of the traffic.

Initially the capacity standards of the United States were adopted after making some ad hoc adjustments and it was suggested that capacity of a single-lane and two-lane roads in India may be taken as 420 and 1400 PCUs/h respectively (*4*). These capacity values were later discarded by many researchers as these were found to be incorrect, based on their empirical studies.

The first most important and successful highway capacity study in India was made in 1981 when Central Road Research Institute (CRRI), New Delhi initiated a project of Road User Cost Study popularly known as RUCS (6). The major components of the study were a. road user cost survey, which seeks to develop the relationships between the cost component of vehicle operation in relation to road characteristics, based upon data obtained from a large number of vehicles, b. traffic experiments which include determination of free-speed as governed by roadway characteristics; determination of speed-flow relationships for different road types; and determination of accurate fuel consumption data on different vehicles under different road conditions, and c. special studies including the determination of the accident rate and accident cost under different roadway characteristics, the determination of the rate of depreciation of vehicles and the value of time saved by road users and vehicles.

Speed-flow relations for various categories of roads in India, as obtained in RUCS, were used and the capacity was estimated of a single lane, intermediate lane (5.5 m wide carriageway) and two-lane roads as 400, 1200 and 3000 PCUs/h respectively. These values were later included in IRC guidelines also (*5*). The RUCS data were updated in 1991 by collecting fresh traffic flow and speed data on roads in various parts of the country and it was found that the basic desired speeds (BDS) of vehicles had improved considerably during the period 1980–1990 on Indian roads. Thus, the capacity values of single lane, intermediate lane and two-lane roads were revised to 600, 1600 and 2500 PCUs/h respectively(*6*).

An academic study from NIT Kurukshetra found capacity of single lane, intermediate-lane and two-lane roads as 700, 2000 and 2700 PCUs/h respectively (*4*).

Another study at Roorkee University (*4*) collected traffic data on 40 sections of two-lane roads across the country and found a capacity of 2818 PCUs/h. The study found that capacity reduces by almost 12 % for every 0.30 m (1 ft.) reduction in the carriageway width. This study also found the reduction in the range of 10–11%, while RUCS reported a factor of 0.64 when lane width reduces from 3.5 to 2.75 m. IRC: 64 (*5*) suggest a capacity reduction factor of 0.84 with the change in lane width from 3.5 to 3.0 m on two-lane roads. Another study for ten intermediate lane sections concluded that the capacity values between 2000-2300 PCUs /h for a shoulder width of 1.5 to 2 meter. The main contribution of this study was to quantify the influence of shoulder width on capacity of an intermediate lane road. Many such studies were being carried out parallel to these studies by many institutions, like IITs and NITs. These studies included different aspects of traffic flow analysis on two-lane roads, like speed and acceleration characteristics with lateral placement of vehicles and influence of shoulder conditions on capacity of two-lane roads.

An interesting study has been the development of the concept of the dynamic PCU (*7*). The equation used to calculate the PCU factor of a vehicle type was based on space occupied by the vehicle and its speed with respect to that of the passenger car.

$$PCUi = \frac{(Vc|Vi)}{(Ac|Ai)}$$

where, Vc is the speed of car (km/h), Vi is the speed of ith type vehicle (km/h), Ac is the static (projected rectangular) area of a car (m^2), Ai is the static (projected rectangular) area of ith type of vehicle (m^2). The numerator in the above equation is a function of traffic composition and traffic volume on the road, and therefore, PCU for a vehicle type was shown to vary with lane width, traffic volume and its composition, gradient and some other factors.

Research on multilane interurban divided highways is limited to a very few studies in India. One important research study at University of Roorkee (*8*) explored the speed characteristics, placement characteristics, arrival characteristics and overtaking behaviour of vehicles on four-lane divided roads by collecting extensive field data and developed a simulation model which could consider up to five categories of vehicles in different combinations. This study found a capacity of 2100 PCUs/h/ lane for a four lane road.

There are also 1200 km of expressways in India, but the capacity of expressways is still largely unexplored in academic research also. A study in CRRI (*9*) on establishing capacity of expressway considering the traffic flow data on Greater Noida (six lane) expressway and Delhi–Gurgaon (eight lane) expressway, with respect to free flow speed of different types of vehicles and developed speed-flow relationships. It was found that the mean free speed of different types of vehicles were higher on Delhi–Gurgaon expressway than on Greater Noida expressway. The study established the capacity for six-lane and eight-lane expressways respectively to be 2130 and 2625 PCUs/h/lane respectively. Table 2 compiles the capacity values proposed by various research studies carried out at different times for Indian highways over last two decades.

TABLE 2 Recommended Highway Capacities for Various Lane Configurations in Various Studies (in PCUs per hour)

Study	Single lane	Intermediate Lane	Two Lane	4 Lane Road	6 Lane	8 Lane
Before 1981 (Based on US-HDM)	420	-	1400	-	-	-
RUCS Study 1981	400	1200	3000	-	-	-
RUCS Study 1991	600	1600	2500	-	-	-
Research at NIT Kurukshetra, 2003	700	2000	2700	-	-	-
Research at University of Roorkee, 2011	-	-	-	2100 per lane	-	-
Research at CRRI, 2010	-	-	-	-	2130 per lane	2625 per lane
IRC:SP:99-2013						1300 per lane DSV at LOS'B'

3. CAPACITY STANDARDS FOLLOWED IN INDIA FOR HIGHWAY DEVELOPMENTS

In spite of all the effort of the various research studies at academic/research institutions, the standards/criteria followed by the road development programmes by the governments in centre or states are ad-hoc and arbitrary without scientific basis, resulting in many premature capacity expansion for many highways in different parts of the country.

Various IRC codes/manuals have been published, which are widely used for detailed designs of the highway projects in India. However, these codes/manuals are mostly influenced by the United States Highway Capacity Manual (US-HCM) first developed in 1950, which has undergone significant changes with major research in US and around the world in the following six decades and republished in 1965, 1985, 2000 and in 2010. For example, the US-HCM 2000 TRB, 2000 (*11*) suggested that a maximum flow rate that can be achieved on a multilane highway is 2200 Passenger Car Units (PCU)/hour/lane. However, these capacity values are for homogenous traffic and India has its own peculiarity in terms traffic mix and road use behaviour.

A compilation of capacity standards/criteria and DSV followed in India for two lane to six lane highways based on IRC: SP: 73-2015 and IRC: SP: 84-2014 are given in Table 3.

TABLE 3 Design Service Volumes at Different Level of Services

Terrain	Warrants for 2- lane		Design Service volume in PCUs per day			
			2 Lane Highway		4 Lane Highway	
	2-lane with granular shoulder	2- lane with paved shoulder	without paved shoulder	with min. 1.5m wide paved shoulder	LOS 'B'	LOS 'C'
Plain	<8000	>10000	15000	18000	40000	60000
Rolling	<6500	>8000	11000	13000		
Mountainous and Steep	-	-	7000	9000	20000	30000
As per standard	IRC: SP:73-2015				IRC:SP:84-2014	
Notes:	Unless otherwise specified in the concession agreement, 6 laning shall be done when total traffic (including traffic on service road, if any) reaches design service volume to LOC 'C' for 4 lane highway.					

In the IRC codes/manuals, upto four lane roads the DSV has been taken at LOS ’B’ which is 50% of the capacity. However, for 6 laning the criteria/warrant is reaching of LOS ‘C’ in 4-lane highway. Further, there have been recent modifications in this code through separate Government Notifications, which states that any highway cannot have a configuration less than 2 lane with paved shoulder. Thus, the earlier specification of 2 lane with granular shoulder is no longer a configuration for national highways in India.

The latest Notification of the Government of May 2016 has further lowered the capacity expansion warrants for 2-lane roads as given in the Table 4. States that traffic at which the up-gradation two lane with paved shoulder to four lane will trigger, which was earlier 15000 PCUs per day for plain terrain 10000 PCUs per day for rolling terrain and 8000 PCUs per day for hilly terrain is reduced to 10000 PCUs per day for plain terrain, 8500 PCUs per day for rolling terrain and 6000 PCUs per day for hilly terrain.

TABLE 4 Traffic at Which 4-Laning is Triggered from Two Lane Road

Nature of Terrain	Traffic at which upgradation to four lane will trigger (in PCUs per Day) – guideline upto 2015	Traffic at which upgradation to four lane will trigger (in PCUs per Day) – guideline from May 2016
Plain	15000	10000
Roling	11000	8500
Mountaneous/Steep	8000	6000

Source: MoRTH, GoI

These Notifications are not based on any research findings or any scientific basis, and examples of how political agenda drives the road development in India. The justification for such change in the DSV for the highways is given as changing socio-economic conditions in the country and for ensuring safe and comfortable mobility. However, in the absence of any valid scientific assessment for such justifications for the recommended lower DSV warrants, it is likely to lead to overdesigned, extravagant and premature capacity expansion of the network. Many of these projects are delivered in a hurry due to political urgency with very little scrutiny/audit of the plans and designs, which are neither safe nor does they cater to socio-economic need of the society.

For multilane highways and expressways also IRC codes/guidelines were published in 2013 (*10*). The guidelines for 6 laning of highways is given in IRC:SP:87-2013 and for expressways it is given in IRC:SP:99-2013. The expressways unlike 6 lane highways are to be designed at LOS'B' and the DSV is to be taken as 1300 PCUs/lane/hour. Table 5 shows the DSV for expressways of various lane configurations to be adopted as per IRC codes/guidelines. It also mentions that the DSV per day will depend on the peak hour flow rate (i.e. peak hour proportion: PHP) and is specified in Table 4, while the DSV or capacity for multi-lane highways should normally be expressed in per lane basis.

TABLE 5 DSV for Expressways in Plain and Rolling Terrain (in PCUs per day) for LOS 'B'

4 lane	6 lane	8 lane
86,000 for peak hour flow (6%)	1,30,000 for peak hour flow (6%)	1,73,000 for peak hour flow (6%)
65,000 for peak hour flow (8%)	98,000 for peak hour flow (8%)	1,30,000 for peak hour flow (8%)

Over past two decades, there has been a focus on implementation of highway projects through Public Private Partnership (PPP) mode of financing. However, many projects failed in the PPP regime due to wrong assessment of toll revenue resulted from improper traffic forecast and ad-hoc capacity augmentation criteria/warrant followed in their design. One such example is the Delhi-Jaipur expressway, where the adopted design proposed 80 bypasses to be constructed, though the actual need was of 124 bypasses. There have been many sick projects languishing without completion, some with very little work done, which had to be rescued at a huge cost to the exchequer due to public hue and cry for the traffic chaos and unsafe situation created by these over several years. In absence of stringent scrutiny/audit at planning and design stages using only scientific and established warrants/standards, the political manoeuvrings for the projects are likely to lead to infructuous expenses with premature and unsafe developments for unjustified capacity expansion projects.

The Government, after failing to get an encouraging response from the private sector, in view of earlier PPP project experiences of the operators, had decided to shelve its plan to bid out highway projects on a 'build, operate and transfer' (BOT) mode for the time being. The government will now award 5,000 km of road projects under the 'engineering procurement and construction' (EPC) model. Other such models of PPP with heavy burden on Government with little risk of private party, like annuity, hybrid annuity, etc. are also being used to implement

projects. This increases the government's expense on highway development allowing highway developers to collect toll from the public and also collect annuities from the government.

An understanding of risks and their optimal allocation is important for successful completion of projects with private resource. An analysis of contracts shows that the initial development and construction stages involve significant risks, while post-completion risk is only about the traffic. This arises primarily due to inadequate effort on demand projection, adoption of the ad-hoc criteria/warrants for capacity expansion and unrealistic assumptions about market conditions. All these are sufficient indicators that a thorough study and correct assessment of highway performance over the years in terms of capacity provided and financial outcome, is of utmost importance. This can only happen if the research in this direction is encouraged and various research institutions are given the task to update the various road design guidelines based on an extensive research and study of the Indian highways through studies/researches conducted continuously, all over the country.

4. INDIAN HIGHWAY CAPACITY MANUAL (INDO-HCM)

The most recent and significant attempt to establish the capacity of Indian highways based on the extensive study of various categories of Indian roads like Expressways, National Highways (NH), State Highways (SH), Major District Roads (MDR), Other District Roads (ODR) and Urban Roads (UR) separately, was taken up for development of Indo-HCM. The principal goal of this research was to "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"*. The Planning Commission (now Niti Ayog) of the Indian Government has funded the project of Indo-HCM in the 12th Five Year Plan. The five year project was started in April 2012 and the project is handled by a team of several academic and R&D institutions in the country. The Central Roads Research Institute (CRRI) has been the nodal agency for this project with coordinating role and seven academic institutes spread over different parts of the country were the regional coordinators.

Amongst many objectives of the study, development of capacity and level-of-service determination procedure and evolving guidelines for different categories of Indian roads was the primary, including quantification of the impact of various roadway, traffic, climatic and control factors on the capacity and level of service. To accomplish the stated goal, the study aimed at analysing the characteristics of the heterogeneous traffic flow 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 have been 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 has also been studied separately. Nationwide test sections have been selected throughout India, and the following outputs has been achieved through the massive study carried out.

- Roadway Capacity Estimation of Two Lane, Intermediate and Single Lane Carriageways
- Roadway Capacity Estimation of Multi-lane Inter-City Highways

- Roadway Capacity Estimation of Inter - Urban and Urban Expressways
- Urban Roadway Capacity Estimation for Arterials / Sub- Arterials / Collectors
- Capacity Estimation of Controlled Intersections
- Capacity Estimation of Uncontrolled Intersections
- Capacity Estimation of Pedestrian Facilities
- Gap Acceptance Studies
- Development of Reliability as a performance measure

The manual is expected to serve as a useful document for accomplishing the following aspects:

- Decision making tool for road development and management
- Comparison of alternative road infrastructures in terms of LOS
- To forecast LOS as a result of different transportation related policies
- Evaluate and prioritize planning / operational alternatives

A Dissemination Workshop of Indo-HCM (i.e. the findings of the Study) was conducted in March 2017 at CRRI, and later the Final Report and the Manual were submitted to Planning Commission.

Based on the research carried out, a set of guidelines for Roadway Capacity and LOS estimation for different categories of roads and intersections (including pedestrian facility) are developed. This will lead to the revision of existing Indian Roads Congress (IRC) Codes like IRC-64, IRC-106, IRC-103, IRC-SP-30, IRC:SP-73, IRC:SP-84, IRC:SP-87 and evolving new Guidelines for Expressways. The manual is a practical tool for the practicing engineers and planners to mitigate the deficiency road network planning guidelines. The models developed in this Indo-HCM study have been calibrated and validated for conditions prevailing in India on various roads in different regions covering different geometry and terrains conditions.

5. CONCLUSION

Diversity is observed on roads in India with many types of vehicles, terrain and surrounding environment. This had prompted the researchers to indulge in the development of highway capacity estimates for the country's unique traffic mix. However, most of these valuable researches were not able to influence the massive road development programme of the country during last two decades, and ad-hoc norms were being used, which even resulted in failure of highly publicised PPP projects. For the first time a massive effort in the form of the development of Indo-HCM was undertaken by the country's most prestigious academic/research institutions with the financial support of the government, which shows the beginning of a change. In the past, road development programme has been used as a tool primarily dominated by political will and agenda.

The efforts of Indian researchers for developing the Indo-HCM has been humungous, but considering the size of the country and scope of the manual, a time period of 5 years has been too short for its development. Revision of a manual is a continuous process and it is hoped that the Government of India will continue to support this project in future years to update it from time to time based on changing scenario of the traffic on the highways. A continuous approach in

updating the studies for capacity estimation is seen across the world, where change in each aspect of infrastructure development is inevitable.

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