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Study on the capacity of road

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Abstract
Freight transportation improvements are planned and implemented by both the public and private sectors. This has traditionally occurred independently. In general, publicly funded improvement planning follows a lengthy structured process with prescribed involvement by many stakeholders. In contrast, private sector planning has a short response time without external involvement and is driven by market trends. The freight planning process presented in this section focuses on planning performed by the public sector. However, effective planning cannot ignore the latter, since the business aspects of moving freight play an important role in how decisions are made.
The extent to which freight is considered in public planning both at the national and regional metro level varies from being integrated into the prioritization and funding process to not being considered detail. This section presents the state of the practice in public sector planning for freight.
Traffic in India is not an exception to this diverse behaviour. Here a mixed composition of traffic with varying speeds is observed including two wheeler motorized and non-motorized vehicles, slow moving cycle rickshaws, autos as preferred public transport facilities due to urban street networks and fast moving small and big cars, light commercial vehicles, buses and heavy vehicles all are observed without any dedicated lanes to follow unlike road infrastructure facilities of developed countries.
The observation period and study location have been chosen such that to coalesce the influence of roadway and traffic factors into ideal conditions or constant factors in the study, to accentuate interesting influence of slow moving vehicles which tend to put more lane space into use but have small occupancy area themselves. Traffic composition and speed are the traffic data types collected during peak periods on weekdays under dry ideal weather and used to study the other flow characteristics under varying composition of slow moving vehicles on different selected midblock sections. To account the effect of dynamic behavior of passenger car units as the basic unit of measuring highway capacity an experimental and direct empirical approach has been adopted in this work. A set of Passenger Car Units (PCUS) and hence -capacity estimated from the procedure has been compared with those stated as static PCUs in IRC: 106 (1990) and the differences have been reported. It is observed that capacity is decreasing with the increase in the proportion of Slow Moving Vehicles (SMVS) and PCU factors shows an increasing trend with growing populations of SMVS.

Keywords: Freight planning**,** transportation improvements, mid-block section, motorized and non-motorized vehicles, roadway and traffic control facilities.

Introduction
India is a developing country with considerable share of slow moving motorized and non-motorized vehicles along with fast moving traffic observed in almost every region. This mixed modal split reported is an influence of income of road users and infrastructure management on the roads of developed or developing countries, which itself draws the line between standards and methods adopted for traffic planning and management in the respective scenarios. Thus, the attempts are being undertaken by Indian transportation engineers and planners to lead the current and future researches along with available literature to thoroughly understand and concentrate into a standard manual of highway capacity evaluation adhering to mixed traffic conditions for newcomers and field professionals to look upon.
Two-wheelers and cars account for over 85% of the vehicle population in most of the metropolitan cities amongst which two-wheelers alone account for more than 80% of total vehicles in number of metropolitan cities.
Capacity is a central concept in design of roadway and traffic control facilities. Capacity analysis predicts the maximum hourly rate of traversal of vehicles or persons in a lane or road segment in uniform traffic, roadway under controlled conditions.

Average speed of travel and per cent time following are the operational factors at which capacity of a roadway is determined as per US Highway Capacity Manual (HCM) (HCM, 2000) [2]. Indo-HCM (2017) suggests that a relationship between lane capacity and operating speed need to be established through collecting the free speed of vehicles to drive the capacity of urban road segment. These operational factors are influenced by various factors like vehicular characteristics or traffic factors, roadway geometrics and road user behavior which in turn influence the capacity and operating speeds of vehicle roadway. This paper reports certain interesting observations on the considering the influence of slow moving vehicles share on urban streets which influence its maximum likely traversal rate or capacity by estimating dynamic passenger car units. Also, an attempt has been made to understand the traffic stream characteristics of urban streets influenced by the varying share of SMVS (non-motorized vehicles).

The method adopted to study PCUS in this work is an empirical method. Thus, the effect of SMVS (or Non-Motorized Vehicles, NMVs in case of urban arterials) on their own flow characteristics and on the other vehicles composing larger proportion of observed traffic stream on urban arterials is measured using PCUs. Also, a trend is established for reducing capacity with growing proportion of SMVs. Though it has also been observed that share of motorized two wheelers being very high in the study has influenced the expected trend.

Field data collection and processing

Data was collected at sites using a stationary camcorder placed at a suitable and available high rise building nearby to capture a 20-25 m long midblock stretch of road. Since the camera view has a limited coverage area, so the speed measurements in the recorded trap length were assumed similar or equivalent for the entire road stretch. Video was recorded for one hour duration during observed peak hours on weekdays at each site. The videotaping duration within peak hours was reported to have no traffic congestion at the five sites. In addition, the five mid-block sites had no vehicle stoppages like bus stops or rickshaw parking to interrupt or influence the non-homogeneous traffic flow.

Data extraction was done in the laboratory under controlled conditions. The highest, consecutive, twelve, 5-minute counts constituted the peak hour at each site. In the laboratory, the time-frame stamped videotape constituting 25 frames /second was replayed to count the classified.

Method

The planning process consists of several basic steps, which are interrelated and not necessarily sequential: defining the situation, defining the problem, exploring solutions, analyzing performance, evaluating alternatives, choosing the project, and constructing or implementing the selected project. Because of competing needs of the public and private sectors for freight, defining the situation and problem usually requires interaction between these sectors. This can occur through the establishment of a formal relation-ship, usually through a freight advisory group- Members of this group could include staff from the local planning agencies, port authorities, major carriers from rail and trucking companies, package delivery companies, and the region's major shippers. Private sector associations, such as chambers of commerce or economic development agencies, are also important players.

Freight Planning

Provide more extensive information about establishing and using these groups to assist with freight planning activities. If the group is structured appropriately, it can have an active role in all parts of the planning process.

Site Selection

As observed from the test sections taken in literature review, this section discusses the criteria chosen for selecting test sites considering the scope of this study. To avoid the effect of traffic mismanagement (as there are no automated signalized intersections in Varanasi), mid-block sections of two-lane one way, divided urban arterial sections have been considered. The roads taken are negligibly influenced by any side friction factors like parking, merging and diverging traffic, etc. The mixed traffic streams are assumed to be free from any considerable pedestrian interference. The traffic observations are taken during dry weather and sunny weekday time for proper visibility of driver.

These requirements conclude to following characteristics of chosen location for study: Midblock length of straight arterial and sub arterial roads.

Arterial roads free from gradient and curves, and should have similar shoulder and pavement type and width as these contribute to variability of PCUS.

Midblock flow sections: free from on street parking, pedestrian movement, intersections, no ingress or egress of vehicles within the selected trap length. Roads with varying proportions of different vehicle categories.

In this study, five roads with maximum flow or principal arterials, and sub arterials fulfilling the above mentioned criteria have been selected within Varanasi city.

Traffic Composition

All the vehicles were divided into eight categories. The composition of large commercial vehicles on urban roads is, though very minute, but has also been considered separately. About more than 40% vehicles on an average are motorized 2 wheelers in Varanasi which follow non-lane behaviour. The roads were found to display a range of proportions in each vehicle category based on the counts obtained from the video. Motorized Two Wheelers (MTWs) constituted about 35% and larger portion of overall traffic at all the five sites. Slow moving vehicles, *viz*., bicycles and cycle rickshaws composed the overall traffic varying in a range of 15-35% at different sites and standard passenger cars were constituted a small percentage of not more than 10% of overall traffic at each study location during peak hours. Non homogeneous traffic composition was observed at all the sites.

Analysis

An extensive work has been carried out since the emergence of a standard form of US HCM followed by the efforts of Asian researchers which illustrate the non-transferability of US HCM in mixed traffic conditions. Various direct empirical and software based methods of traffic simulation for capacity estimation have evolved over the vast period of research to develop a sustainable technique for meeting increasing traffic demand in future. Thus, these works at national and international level, in the direction of development of a suitable and efficient methodology specific to developing countries have been summarized in this section.

Slow moving vehicles as designated in IRC: 106-1990 are the non-motorized vehicles like cycles, cycle rickshaws, horse and hand driven carts and motorized slow moving heavy vehicles. They are found in high volume with low speeds in mixed traffic conditions as seen in Indian towns and cities. Design speed of urban arterials and sub arterials as per IRC: 86-1983 is 80 km/h and 60 km/h respectively, though the operating speed at desired Level of Service (LOS) may be different from these design speed. Important traffic conditions that affect capacity of a two-lane road are composition of traffic stream, directional distribution of traffic and presence of slow moving vehicles in the stream. Literature suggests some direct and indirect methods of evaluating capacity of highways: headway based, speed based or based on passenger car units. Since this study follows the method of PCUs, the literature containing describing methods by which passenger car equivalents can be evaluated using empirical methods and simulation methods are discussed in following sections.

The maximum hourly rate of traversal of a heterogeneous composition of traffic observed in developing countries, due to its heterogeneity is intended to be measured in equivalent number of passenger car units (PCUS). Van Aerde and Yagar developed a methodology to calculate PCE based on relative rate of speed reduction. This PCE was intended for use in average speed analysis of capacity, which is unique to two lane highways. The factors on which PCUS depend and developed a relation with three PCU factors, one each for speed of any vehicle class v, for time headway for vehicle class v and for lateral clearance for vehicle class v. The model was established using a relation of proportionality of these factors with PCU of respective vehicle category.

The relationship between ratios of speed (as traffic flow characteristics) to projected area (as vehicular characteristics) of vehicle on road with respect to passenger car to define PCU of vehicle type has been provided in the form of... equation-1, popularly known as Chandra's Method of PCU determination.

$$PCUI = (Vc/Vi) / (Ac/Ai)$$

Where, PCU is the passenger car unit of any vehicle 'i'.

'Vc' is the speed of passenger car with reference to which PCU of vehicles of all other categories has been measured.

'Vi' is the speed of any vehicle 'i'.

'Ac' is the area of standard passenger car.

'Ai' is the area of any vehicle 'i'.

Directional distribution and effect of SMVs was also studied in the same work in which nine different road sections of 7 m carriageway were taken. The capacity was observed to reduce with SMVS. A non-linear relationship was observed between the capacity and SVMs while a linear change was found between the capacity and directional uneven split.

The concept of influence area instead of projected area of vehicle in PCU estimation using equation 1 was taken along with considerable per cent of slow or non-motorized vehicles (NMVs), in a case study of Delhi urban area. It inferred reduction in speed of larger vehicles is observed with increasing per cent of slow moving vehicles though same was found to affect negligibly the speed of vehicles smaller in size than passenger cars due to their manoeuvring capabilities. In which service lanes for slow moving vehicles separating their flow from main carriageway was proposed as they were found to reduce the capacity and speed on main carriageway. The relationship between speed of heterogeneous composition of traffic and density is studied assuming some traffic volume in urban arterial sections in the study. it was found that speed of small vehicles is less affected by the traffic composition as compared to heavy or large vehicles.

IRC: 106-1990 suggests that the negative effect of SMVs on capacity can be reduced by dedicated lane usage for slow moving vehicles and enforcing lane discipline. A link node model to represent road network was created in PARAMICS, which also showed the effect of maneuvering by small vehicles increases capacity of roads. The model based on PARAMICS platform in this study was thus used to study speed flow characteristics in an eight lane divided expressway in mixed traffic and deduced that capacity reduced by 15% if vehicles were restricted to follow lane discipline, also the free speed expected to reduce by 7%. Traffic flow on urban roads in Kanpur city, India for a two-lane one-way traffic was studied using simulation model in experienced by different categories of vehicles were decided when the traffic stream contained 65% NMVS. The studied the multi-class speed-flow relationships for a three-lane two-way undivided road in the city of Chennai, India using both linear and Bureau of Public Roads (BPR) models. The class wise direction based models in the study inferred that two-wheelers and cars in the opposite direction strongly influence the speeds of almost all the classes.

As is in both cases is a better approach to simplify the accuracy in use of PCUs evident from the studies from past literature, capacity estimation in mixed traffic depends on average travel speed and flow rate. It is important to study the capacity and PCUS during congested and uncongested conditions, separately. Heavy vehicles impede the sight distance of following vehicles. Thus the proportion of heavy vehicles and also non-motorized traffic affects the average flow rate of traffic stream and reduces capacity of highways. PCUS should be estimated for capacity and speed analysis separately due to their dependence on multiple traffic factors, roadway factors and driver perception.

Estimation of traffic flow parameters

In the laboratory, the traffic video tape was reviewed to obtain speed of traffic flow through the sections length and recorded time frames each traffic movement that acquires to traverse that length. Taking the mean of traffic entity, speeds produced the space mean speed for that particular vehicle category. The PCUS were derived from Chandra's method of PCU determination (Eq.1). Using the PCUS thus obtained classified count of vehicles was converted to traffic stream flow (q) in pcu/hour.

Average stream speed (v) has been calculated using space mean speeds and count of each vehicle category. Density (k) has been calculated using the fundamental speed flow-density relationship (i.e. Q-KV) for each speed-flow data obtained at twelve, consecutive, five minute counts during peak hours for each road section. Basic k-v and q-v plots were obtained from where the maximum flow referred as capacity of road was derived. A plot of q-v relationship shows derived capacity for road section I.

Other road sections were illustrates the Green shield’s linear relationship developed between speed(v)-density(k) obtained from field data. It is seen that coefficient of

determination (R^2) observed for different road sections were satisfactory except for road section IV.t-statistics were also checked at 95% confidence interval and found to be significant in most of the cases.
Variation in following parameters has been observed to measure the effect of varying proportions of SMVS in mixed traffic on two lane roads and reduction in average stream speed with increasing proportion of SMVS. Variation in PCU values of different vehicle categories under high percentage of SMVS.

Effect on average stream speed and capacity
The average stream speed has been obtained for each five minute interval in the observation period at each site by taking the average speed and count of each category of vehicles in that interval. The average speed of bicycles and cycle rickshaws was observed to be around 21 km/h and 9 km/h respectively in this study. This is slower than all the vehicles traversing in mixed traffic conditions and compared to the average speed of standard cars i.e. 36 km/h and other motorized vehicles with good engine efficiency are capable of a good speed of 43-45 km/h during peak flow on urban roads. However, the results from the study of mid-block sections show that the average stream speed is only around 28-30 km/h at all sites under study.
The impact of SMVS on average stream speed and capacity has been reported in the significance level observed was not high -enough and it clearly indicates that the small data in this study can't conclude to one single deterministic relationship between these two parameters, however, the trend can be believed to be reliable as it has been found to be a common trend between average stream speed and percent composition of SMVS observed at each road section in the study. A linearly descending relation between average stream speed with increasing proportion of SMVs has been observed.

Effect on PCU factors and capacity
The SMVS are the non-motorized traffic and heavy vehicles. The vehicles belonging to heavy vehicles category tend to occupy large road space for a long time and obstruct the passage for following vehicles to flow through. As the proportion of heavy vehicles is not considerably observed on urban roads, non-motorized vehicles are the only slow moving vehicles plying on Indian urban arterials. Vehicles like bicycles though tend to have small area and hence capability to use lateral gaps in the non-lane based traffic flow but they have speeds faster than only cycle rickshaws. Cycle rickshaws obstruct the flow of every following vehicle owing to their slow speeds and very little tendency for lateral movements. Thus, SMVs in turn reduce the capacity of roads by obstructing the flow.
Since the effect of SVMs on vehicle like two-wheeler is less due to high maneuverability characteristics, thus majorly it effects on the larger sized vehicles. However, the percentage of larger sized vehicles is less in the present traffic scenario. Therefore, the effect of SVMs was analyzed on the other vehicular categories shows the variation of PCUS of different vehicle types with respect to SVMs percentage. Result depicts that, PCU of vehicles increases significantly with increase in percentage share of SMVS.
Similar plots of PCU variation were obtained at each section showing common trend of variation. However, in few sections (section III and V) a relatively flatter slope in PCU variation of MTW was observed due to its higher maneuverability characteristics and non-replacing percentage criterion of MTW with respect to SVMs in the traffic stream and hence are not obstructed by the SMVs. SMVS thus clearly need a separate dedicated lane for improved traffic management and stream speed. The variation of capacity of all the test sections with the proportion of slow moving vehicles present on them. The trend establishes the fact that with high increment in the proportion of SMVS reduces the capacity of urban roads. Statistical parameters associated with the relationship are just satisfactory but it reflects clearly the negative effects of SMVS on capacity. In addition, it has been observed that SMVS up to 18-20% hardly have any pronounced impact on the capacity and stream flow characteristics of any road, unlike IRC:106-1990 where this proportion of own vehicle category above 5-10% changes the PCU values. Thus, as a result the static PCU factors given in IRC:106-1990 though come within an observed range of values as per share of SMVS, but the exact value from graphs can be used at ease by field engineers. The other traffic flow characteristic trends can be further analysed to help improve traffic and lane management on urban arterials influenced by Slow Moving Vehicles (SMVS).

Conclusions
Proportion of SMVS is an important factor before counting their influence due to slow speed on the traffic stream. Heavy Vehicles (HVS), Non-Motorized Vehicles (NMVS) is main cause of slowing down the average speed of traffic stream as a whole. Though the proportion of HVS is negligible on urban roads as is visible in this study also at each site, SMVS are specifically NMVs on urban arterial roads. Also, the effect of increasing SMVs can be seen with variation of PCU factors for vehicles, especially which are replaced by SMVS during their growth in the traversing traffic stream. Thus, vehicles which are larger in proportion are expected to be influenced more
The effect of Slow Moving Vehicles (SMVS or specifically NMVS in this study) on mixed traffic flow characteristics of urban arterials and their capacity has been analyzed in the present study. The findings of the study can help in understanding and designing traffic facilities in urban regions. From the present study, following key conclusions have been drawn.
The results from the study of mid-block sections show that the average stream speed is dragged down significantly (to minimum of 10km/h), when influenced by the effective composition of SMVs in the traffic stream at all sites under study.
In addition, it has been observed that SMVS up to 18-20% hardly have any pronounced impact on the capacity and stream flow characteristics of any road, unlike IRC:106-1990 where this proportion of own vehicle category above 5-10% changes the PCU values (data obtained in this study does not contains SMVS composition less than 16%). Thus, as a result the static PCU factors given in -IRC:106-1990 though come within an observed range of values as per share of SMVs, but the exact value from graphs can be used at ease by field engineers.
However, average speed is hardly influenced if the maximum composition of traffic is motorized two wheelers (MTWs) due to their efficiency in using the lateral gaps by

lane changing, thus their flow remains unobstructed by the SMVS.

The effect of SMVS on PCU factors is also evident from the study. The influence has been measured for motorized two wheelers and three wheelers and on PCU factors of bicycles. PCU factors show an easing trend with growing proportion of SMVS on all the sections. Reduction in capacity, compared at all sections is evident from the speed-flow relationships.

This study is an attempt to analyze the effect of SVMs on various traffic parameters including stream speed, PCUS and capacity using a limited data set. Although a reliable trend has developed between all parameters, But for extensive analyze of these parameters, similar procedure can be followed using more data at different composition levels for urban mid-block section.

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