Development of PCU factors and capacity norms at mid blocks of rural highways in Visakhapatnam

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Abstract

In India mixed traffic conditions are prevail on roads and highways, different vehicle classes have a wide variation of static and dynamic characteristics. Therefore mixed traffic flow characteristics are very much complex and difficult to estimate the traffic volume and capacity of highway facilities under mixed traffic flow, unless this non-uniformity in static and dynamic characteristics of vehicles is to convert into a common standard vehicle unit called Passenger Car Unit (PCU). Passenger Car Units are developed to find relative effect of alternative modes traveling on the roads. Highway capacity is the maximum number of vehicles that can reasonably be expected to pass a section of road in unit time under prevailing roadway, traffic and control conditions; whereas, service-volume is the maximum number of vehicles that can be accommodated at a specified Level Of Service (LOS). The performance of roadway networks depends on capacity and volume of traffic in the network. Capacity Norms for the highways are necessary for evaluating the deficiencies of the road network, to find out proposed changes in the existing network, designing new facilities by considering future travel demand and the current capacities etc.

Keywords: PCU factors; Specified level of service; Traffic flow; Visakhapatnam; Rural highways.

Introduction

The traffic on Indian roads is heterogeneous or mixed in nature and character. Traffic stream comprises of varieties of slow and fast modes. The slow moving category consists of cycles and bullock carts (Ahmed Al-Kaishy et al., 2005). Fast moving traffic is dominated by two wheeled vehicles like scooters, motor cycles, mopeds, and three wheeled auto-rickshaws. In addition to the above, the traffic consists of cars, commercial vehicles including light commercial vehicles, trucks, minibuses and large city buses (Bhattacharya and Mandal, 1980; Huber, 1982). The unique feature of traffic can be seen in the operating characteristics of varieties of modes of vehicles with respect to static and dynamic operating condition (Carroll and Wiley, 1982). Static characteristics such as sizes differ greatly, e.g. Cycles occupies an area of 0.9 sq.mt, and a large commercial vehicle occupy about 22.78sq.mt (Justo and Tuladhar, 1984). The speeds also differ greatly, bullock carts operate with a mean speed of 8 kmpm and faster vehicles operate with a mean speed of 40 kmpm under normal operating conditions. Accelerating and decelerating properties of the vehicles differ greatly by virtue of their propulsion and operating characteristics. This creates an intricate mix of situation (Bhargab Maitra, 2006).

In Mixed traffic environment, one class of vehicles cannot be considered equal to any other class, as there is considerable difference in their physical and flow characteristics. One way of
representing this non-uniformity in static and dynamic characteristics is to convert all vehicles into common unit and the most accepted unit for this purpose is Passenger Car Unit (PCU).

Methodology

Identification of parameters

The main thrust of the objective is development of PCU factors, Speed-Density curves, Speed-Flow curves and Capacity norms for the rural roads. The important parameters are location details carriageway width and shoulder width, pavement type etc., physical dimensions of the vehicles, classified traffic volume and speeds of the vehicles.

Data collection

Data collection will be planned in two stages.

1. Collection of preliminary data
2. Collection of field data

Collection of preliminary data

- Selection of survey location: Location for the study is identified based on following criteria.
  a) Uniformity of road characteristics in terms of pavement width, shoulder type, etc.
  b) No visual obstructions to traffic because of bus stop, road side developments, etc.
  c) No intersection or side roads in the road stretch so that there is no change in the traffic volume over the entire stretch.
- Fixing stretch length: Minimum road length of any road section should be 400 meters.
- Collection of vehicular dimensions: Different modes traveling on selected roads will be identified. For all the modes, physical dimensions like breadth and length of the vehicles are to be collected.

Collection of field data

- Traffic volume study: Traffic volume survey is carried out on all selected locations for certain duration. Enumerators will be used for collecting data in both directions to record each vehicle type for every time interval of 5 minutes.
- Speed study: Registration plate method will be planned for the same duration corresponding to traffic volume study. Four enumerators will be employed to record entry and exit times of each every vehicle in both directions.

Development of PCU Factors

The variables required for development of PCU factors are traffic volume, space mean speed and projected rectangular area of different types of vehicles traveling in the selected location. By substituting the above variables, Passenger Car Units will be established. PCU factor will be found by using flow and speed, and projected rectangular area of different vehicles. To find speed of each vehicle in the mixed traffic, the following model will be developed.

\[ V_i = C + \frac{\sum a_i^k (n_i V_i^a) + a_i^m}{N} \]

Where

- \( V_i \) = Average speed of vehicle category ‘i’ in kmph.
- \( C \) = Regression constant
- \( a_i \) = Coefficient for category ‘i’
- \( n_i \) = Number of vehicles of categories ‘i’ passing through a specified point in unit time
- \( N \) = Total number of vehicle (mixed) passing through a specified point in unit time.

\( i \) and \( k \) both represents the vehicle group, while \( i \) represents the category for which speed is predicted using compositional effect of \( k \) different categories of vehicles.
The passenger car equivalency of a vehicle type is believed to be directly proportional to the ratio of speeds and inversely proportional to the space requirement of a vehicle with respect to car. Mathematically, it is expressed as

\[ PCU_i = \frac{V_c}{V_i} \frac{A_c}{A_i} \]

Where

\[ V_c = \text{Speed of a car} \]
\[ V_i = \text{Speed of vehicle } i \]
\[ A_c = \text{Projected rectangular area of a car} \]
\[ A_i = \text{Projected rectangular area of vehicle } i \]

By using the above equation PCU factor for each vehicle will be obtained. PCU factors for locations having similar carriageway widths will also be established to know the character of the PCU factors.

**Details of the locations taken for the study**

The study locations are described in Table 1.

<table>
<thead>
<tr>
<th>Road Name</th>
<th>Location</th>
<th>Carriage Way Width (m)</th>
<th>Stretch Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gajuwaka to Atchutapuram</td>
<td>Avasomavaram</td>
<td>7m, with soft shoulder of 2.0m on both sides</td>
<td>410</td>
</tr>
<tr>
<td>Yelamanchili to Atchutapuram</td>
<td>Veduruwada</td>
<td>7m, with soft shoulder of 2.0m on both sides</td>
<td>410</td>
</tr>
<tr>
<td>Anakapalli to Atchutapuram</td>
<td>Timmarajupeta</td>
<td>5.5m, with soft shoulder of 1.0m on both sides</td>
<td>420</td>
</tr>
<tr>
<td>Anakapalli to Pendurthi</td>
<td>Kapusettivanipalem</td>
<td>7m, with hard shoulder of 1.5m on both sides</td>
<td>400</td>
</tr>
</tbody>
</table>

**Collection of vehicular dimensions**

It is necessary to collect vehicular dimensions to know the projected rectangular area of the vehicle, which will be used for the calculation of the PCU factors. There are ten different types’ vehicles traveling on the selected locations (Table 2).

<table>
<thead>
<tr>
<th>Mode</th>
<th>Length (m)</th>
<th>Breadth (m)</th>
<th>Projected Area (sqm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-Wheeler(2W)</td>
<td>1.65</td>
<td>0.70</td>
<td>1.16</td>
</tr>
<tr>
<td>Three-wheeler or Auto (3W)</td>
<td>2.60</td>
<td>1.15</td>
<td>2.99</td>
</tr>
<tr>
<td>Car or Jeep (C)</td>
<td>4.20</td>
<td>1.50</td>
<td>6.30</td>
</tr>
<tr>
<td>Bus (B)</td>
<td>9.20</td>
<td>2.50</td>
<td>23.00</td>
</tr>
<tr>
<td>Light Commercial Vehicle (LCV)</td>
<td>6.60</td>
<td>2.10</td>
<td>13.86</td>
</tr>
<tr>
<td>Lorry(2A)</td>
<td>7.30</td>
<td>2.42</td>
<td>17.67</td>
</tr>
<tr>
<td>Multi Axle (MA)</td>
<td>9.30</td>
<td>2.45</td>
<td>22.79</td>
</tr>
<tr>
<td>Tractor (T)</td>
<td>7.50</td>
<td>2.45</td>
<td>18.38</td>
</tr>
<tr>
<td>Cycle(Cy)</td>
<td>1.80</td>
<td>0.50</td>
<td>0.90</td>
</tr>
<tr>
<td>Bullock Cart (B.C)</td>
<td>4.00</td>
<td>1.80</td>
<td>7.20</td>
</tr>
</tbody>
</table>

**Traffic Volume Survey**

Traffic volume is the number of vehicles crossing a section of road per unit time at a selected period. Traffic volume is used as a quantity measure of flow. This traffic volume study includes classified volume study by recording the volume of various types and class of traffic viz., buses, trucks, passenger cars, light vehicles, multi axle trucks, bullock carts, cycles and pedestrians.

Manual method is employed for collecting classified traffic data by employing a field team. Traffic surveys were carried out on all selected locations for a period of 6.0hrs. The duration at each location is from 01.15P.M to 7.00P.M. Four enumerators were employed for the classified traffic counts in each direction to ensure the accuracy in data collection. Time interval for counting was taken as 5 minutes. Synchronized stop watches were used for data collection.

**Measurement of speed**

Registration plate method, with the help of synchronized watches, was adopted for the measurement of speeds at all the selected locations. The test section was marked by chalk pieces at the entry and exit points and observers are stations at
entrance and exit of test section in both directions. The distance between entry and exit points is kept between 400 to 450 meters according to the site conditions. Synchronised stop watches were used to record the timings and registration number of all vehicles traveling the section. By matching the registration numbers later, space mean speed can be determined. The main advantage of this method is that no sophisticated instruments are needed except synchronized watches.

Preliminary Analysis of data on case study corridor

To understand the character of traffic volume and speed, the collected data is summarized for each hour of the study preliminarily. The details of the preliminary analysis are presented in subsequent articles.

Traffic Volume Data

Classified volume of different modes traveling in the selected stretches for every hour is presented in Fig.1. From Fig.1, it is observed that, traffic volume varies from 500 vehicles per hour to 753 vehicles per hour at Avasomavaram. Similarly, the traffic volume varies from 400 veh / hr to 698 veh / hr at Veduruwada, the traffic volume varies from 460 veh/hr to 721 veh/hr at Timmarajupeta and the traffic volume varies from 800 veh/hr to 896 veh/hr at Kapusettivanipalem. Peak hour volume observed is 753 veh/hr at Avasomavaram on Gajuwaka to Atchutapuram road, 698 veh/hr at Veduruwada on yelamanchili to Atchutapuram road, 721 veh/hr at Timmarajupeta on Anakapalli to Atchutapuram road and 896 veh/hr at Kapusettivanipalem on Anakapalli to Pendurti road. Peak hour volume is observed in between 05.00 P.M to 06.00 P.M. Modal share at all these locations are presented through pie charts in Figs. 1 to 2. It is observed from these figures those two wheelers and three wheelers traffic is predominant at all the locations and the percentage shares of vehicles are also given.

PCU factors

PCU factor is found out at each location using the following information

1. Classified volume count of different categories of vehicles passing through a specified point during a 15 minutes time interval.
2. Velocity of each vehicle type moving on the road during 15 minutes time interval.
3. Physical dimensions of each vehicle category.

For the determination of PCU factors, model was developed for finding speed in mixed traffic using the data collected from traffic volume survey and
registration plate method. Space mean speeds of different vehicles were computed. For each type of vehicle, 15 minute period space mean speeds were averaged. By using different vehicle counts and average speeds measured for every 15 minutes interval, speed equations of the following form were developed.

\[ V_i = C_i + \sum_j a_j^i (n_j V_j) + a_n^i (1/N) \]  
(1)

Where \( C_1, C_9 \) are constant values and \( a_0, a_9, a_{100}, a_{99} \) are regression coefficients.

\( V_{2w}, V_{3w} \ldots \) are speeds of vehicle categories 2w, 3w …

\( n_{2w}, n_{3w} \ldots \) are number of vehicles of categories 2w, 3w … passing through a specified point in unit time, and

\( N = \) Total number of vehicles passing through a specified point in unit time.

It is observed from these tables that R-Square values obtained are varying between 0.77 and 0.96 at Avasomavaram on Gajuwaka to Atchutapuram road, between 0.75 and 0.96 at Veduruwada on yelamanchili to Atchutapuram road, in between 0.76 and 0.95 at Timmarajupeta on Anakapalli to Atchutapuram road, in between 0.75 and 0.97 at Kapusettivanipalem on Anakapalli toPENDURTI road for different speed model. These values indicate reasonably good fit of the existing data. PCU Values on Gajuwaka to Atchutapuram Road are illustrated in Table 3. PCU values of cycles are nearer to the values which are recommended PCU values in the IRC: 64-1990. In Fast vehicles PCU values of Trucks are nearer to recommended PCU values in the IRC: 64-1990. Buses, MAT and Tractors are having higher values than the IRC.

PCU values whereas 2W having lower PCU values than IRC recommended values. PCU Values on Yelamanchili to Atchutapuram are illustrated in Table 4. PCU values of slow moving traffic is very close to the values which are recommended PCU values in the IRC: 64-1990. In Fast vehicles PCU values of Trucks are slightly higher values than recommended PCU values in the IRC: 64-1990 and Buses is having higher values than the IRC values. PCU values of LCV and Tractors are having higher values than the IRC PCU values whereas 2W and Multi axle trucks are lower PCU values than IRC recommended values.

PCU Values on Anakapalli to Atchutapuram are illustrated in Table 5. PCU values of slow moving traffic is very close to the values which are recommended PCU values in the IRC: 64-1990. In Fast vehicles PCU values of Trucks are slightly higher values than recommended PCU values in the IRC: 64-1990 and Buses is having higher values than the IRC values. PCU values of LCV and Tractors are having higher values than the IRC PCU values whereas 2W and Multi axle trucks are lower PCU values than IRC recommended values.
Tractors are having higher values than the IRC PCU values whereas 2W and Multi axle trucks are lower PCU values than IRC recommended values.

PCU Values on Anakapalli to Pendurti are illustrated in Table 6. PCU values of slow moving traffic cycles are equal to the values which are recommended PCU values in the IRC: 64-1990 and Bullock carts having very higher values than IRC recommended PCU values in the IRC:64-1990. In Fast vehicles PCU values of Trucks, Multi axle trucks and Busses are slightly higher values than recommended PCU values in the IRC: 64-1990. PCU values of LCV and Tractors are having higher values than the IRC PCU values whereas 2W are lower PCU values than IRC recommended values.

Conclusions

In this analysis the effect of traffic volume, its composition and stream speed on passenger car equivalents are studied. Method proposed by Chandra is used for developing the PCU factors and the conclusions are:

- For two axle trucks PCU values are found to increase with an increase in compositional share of respective vehicle types in the traffic stream.
- The PCU of two wheelers practically remains unaffected by its compositional share in the traffic stream. Compositional share of 2W at different locations were observed in the range of 31.69% to 34.23% whereas increase in PCU values are 1.1% only and it may be attributed due to high maneuverability.
- In slow moving traffic PCU values of bullock carts are increasing with the decreasing in the compositional share in the stream.

PCU value of Bullock cart is very high when the share is less. Large PCUs of slow moving vehicles even at low density explains that these vehicles consume a disproportionately high capacity of the road where traffic stream includes a variety of modes.

References