Comparison of Passenger Car Units on Plain and Hilly Urban Road

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ABSTRACT

It is quite difficult to estimate the traffic volume and capacity of roadway facilities under the prevailing heterogeneous traffic conditions. So a standard vehicular unit, called the Passenger Car Unit (PCU) has been developed to correlate the congestion caused by different vehicular types with respect to a passenger car. Developed countries formulated several methods for calculating PCUs. These PCU values as developed by developed countries are not suitable for Indian mixed traffic conditions because traffic is more diverse in nature. Highway Capacity Manual (HCM) of USA utilizes PCU factors to estimate the effect of heavy vehicles on traffic stream under mixed traffic conditions. Since the inception of concept a number of methods for the estimation of PCU value for different vehicles categories have been proposed. A number of studies have also been carried out to analyze the effect of different roadway and traffic condition on PCU values. However these studies concentrated on roads in plain terrain only and very limited research has been done till date on the estimation of PCU values on a hilly road. The current study considers a single continuous road stretch of about 3.2 km length in Visakhapatnam city of which 1.9 km is in plain terrain and 1.3 km is in a hilly terrain. PCU values are estimated for both plain and hilly conditions using various methods namely density method, Chandra method and headway method. Comparison of PCU values has been done and finally Chandra method is observed to give more reliable and realistic results in both plain and hilly terrains.

Keywords: Hilly urban road, Passenger Car Units and plain road

1. INTRODUCTION

Transportation contributes to the economic, industrial, social and cultural development of any country. Traffic volume and capacity estimation are essential for any roadway facility as it helps transportation professionals to plan efficiently. However under the prevailing heterogeneous traffic conditions in India, it is quite difficult to estimate the traffic parameters as many new models of vehicles are currently plying on Indian roads. So a standard vehicular unit, called the passenger car unit (PCU) has been developed so as to correlate the congestion caused by different vehicular types with respect to passenger car. Urban roads in India are characterized by mixed traffic conditions,

resulting in complex interaction between various kinds of vehicles (IRC: 106-1990). To cater to this, it is usual to express the capacity of urban roads in terms of Passenger Car Unit (PCU). These are a function of physical dimensions and operational speeds of respective vehicle classes. In urban situations, speed difference among the different vehicle classes is generally low, and as such the PCU factors are predominantly a function of physical dimensions of the various vehicles. The suggested values of PCU by Indian Roads Congress (IRC: 106-1990) are given in Table 1.

2. LITERATURE REVIEW

Indian road traffic is characterized by various typical factors such as poor lane discipline, loose restrictions and use of a wide variety of vehicles in any type of road. Indian Roads congress (IRC-106:1990) suggested PCU values and their usages. The PCU variation with terrain is adjusted as per the capacity of roads. Tiwari *et al*. [1] used *modified density method* to study PCU for heterogeneous traffic on various roads. They studied rural as well as urban traffic locations at highways with different conditions of lanes and shoulder. Botma [2] observed PCU by studying slow moving vehicles and concluded that PCU increases with increase in proportion of slow moving vehicles in the traffic stream. Chandra and Kumar [3] analyzed the effect of quality of shoulder on PCU and found that PCU increases with increase in quality of shoulder. Sikdar and Chandra [4] observed that PCU of a vehicle type decreases with increase in proportion of that particular vehicle type. Mallikarjuna [5] observed that PCU increases with increase in area occupancy and decrease in proportion of traffic. Tiwari et al. [1] found that PCU increases with more number of lanes and easier maneuverability. Arasan and Krishnamoorthy [6] opined that with increase in volume, PCU value of a particular vehicle increases till a certain limit and then decreases since overall traffic speed decreases.

Thus a number of studies have been carried out to analyze the effect of different roadway and traffic conditions on PCU values. However studies concentrating on urban hilly road are very less. The current study aims at discussing various available methods and their suitability in heterogeneous traffic condition for a plain and a hilly urban road.

Table 1 Recommended PCU Factors on Urban Roads (IRC: 106, 1990)

S. No	Vehicle type	Equivalent PCU factors	
		Percentage composition of vehicle type in traffic stream	
		5%	10% and above
1	Fast Vehicles Two Wheeler, Motor cycle,	0.5	0.75

2	Scooter	1.0	1.0
3	Passenger Car, Pickup vans	1.2	2.0
4	Auto Rickshaw	1.4	2.0
5	Light Commercial Vehicle	2.2	3.7
6	Trucks or Bus Tractor Trailer Slow Vehicles	4.0	5.0
7	Cycle	0.4	0.5
8	Cycle Rickshaw	1.5	2.0
9	Tonga (Horse Drawn)	1.5	2.0
10	Hand Cart	2.0	3.0

Various methods namely headway method, density method, Chandra method, multiple regression method, method based on relative delay etc. are widely adopted for estimation of PCU values. Applicability of various methods on Indian roads is still a topic of discussion among transportation professionals. So detail and accurate study on these methods needs to be performed considering Indian mixed traffic conditions. In the current study, three methods are considered to estimate PCU values. They are headway method, density method and Chandra's method.

3. METHOD BASED ON HEADWAY

Heavy vehicles in the traffic stream take up more space. So headways have been used in many studies conducted in western countries for calculating PCU. The PCU is calculated as

$$E_t = \frac{\left(\frac{H_m}{H_b}\right) - P_c}{P_t} \quad (1)$$

where H_m is the average headway for a sample including all vehicle types, H_b is the average headway for a sample of passenger cars only, P_c is the proportion of cars, and P_t is the proportion of trucks.

4. CHANDRA'S METHOD

This method uses two factors: namely, velocity of vehicle type and its projected rectangular area to calculate the PCU value.

$$(PCU)_i = \frac{(V_c/V_i)}{(A_c/A_i)} \tag{2}$$

where V_c and V_i are mean speeds of car and vehicle of type i respectively and A_c and A_i are their respective projected rectangular areas on the road. Though Chandra and Kumar [7] have suggested vehicular dimensions for various categories, they have not been considered for this study as they are quite old. Many new types of vehicles are currently plying on Indian roads and hence the dimensions of vehicles have been considerably changed in recent times. Table 2 gives the details of the type of vehicles and their rectangular plan areas considered in this study.

Table 2 Rectangular projected areas of different vehicles

Type of vehicle	Rectangular plan area (m^2)
Bus/Truck	19.80
Car	5.67
3-Wheeler	3.41
Light Commercial Vehicle	7.41
2-Wheeler	1.49

Density method

In the density method, the PCU of truck (Et) is computed as:

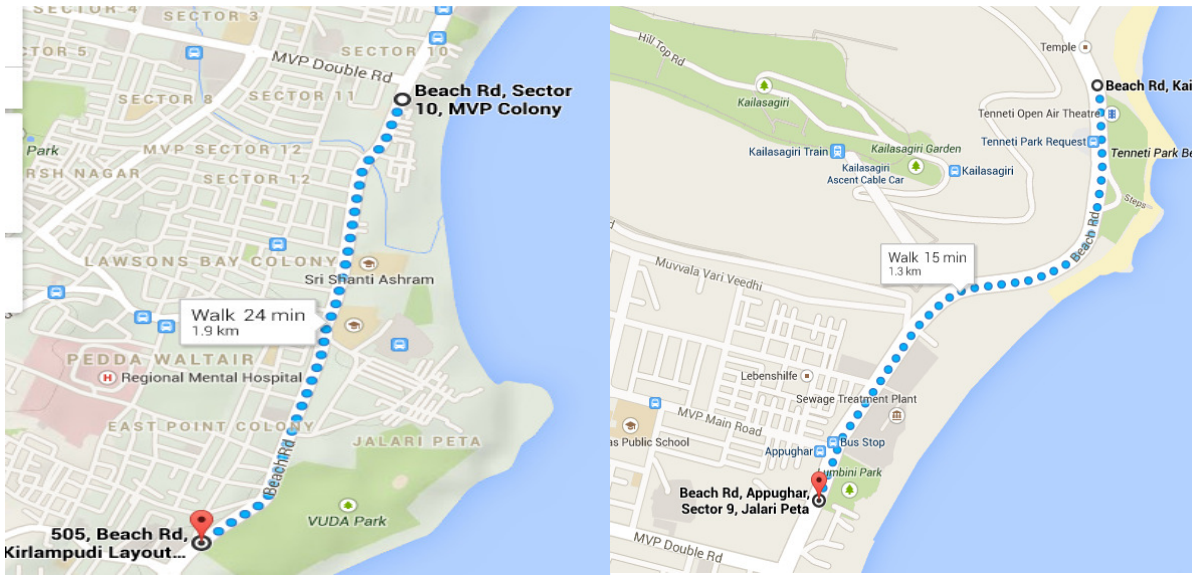
$$E_t = \frac{(k_c/W_l)}{(k_t)/W_l)} \tag{3}$$

where k_c is the density of cars in pure homogeneous conditions(car/km.), W_l is the width of the lane in homogeneous traffic, k_t is the density of the truck in pure homogeneous conditions and E_t is the passenger car unit of the trucks given homogeneous traffic behaviour. In density method where car following and lane discipline behaviour prevails, all traffic entities use an equal W_l.

The current study is important for analyzing capacity of roads/highways in hilly regions of India. The accuracy of data shall be used for road improvements and future road widening schemes.

Data Collection

Visakhapatnam is one of the fast developing cities in India and has taken significant strides in the last two decades and recorded an abnormal increase in industrial activity. With the rapid growth of industries, there has been an exponential growth in the population and the vehicular traffic as well. Traffic data required for the study has been collected on two road sections in Visakhapatnam. One road section is in plain terrain and the other is in a hilly terrain. In the current study, both the road sections have been referred as Section-I and Section-II respectively. The details of the sections is shown in Figure 1.



Road Section 1: Plain Terrain **Road Section 2 : Hilly Terrain**

Figure 1 Road sections selected for the study

Required traffic data such as traffic volume, speeds and headways are collected from the field by manual observations for a period of 2 hours in evening peak time in a typical working day. The study sections have less number of intersections and the vehicles are in stream flow at the sections i.e., there is no effect of bus-stop, school zones, etc. A complete traffic volume study includes the classified volume study by recording the volume of various types and classes of traffic. The method which is adopted in this study for counting of traffic volume is manual method. Manual counters employ a field team to record traffic volume on the prescribed record sheets. For collection of speed data, the time taken by each vehicle to cover the section is noted. At the

entrance and exit points of the sections, observers would note down the times of entrance, exit and also the registration plate number of all vehicles.

5. RESULTS AND DISCUSSION

Traffic composition at sections I and II are found out based on the observed traffic volume of different categories of vehicles. Though bicycles are present during the study time, they are not considered in the current study as the share of the bicycle is less than 1 percent. The observed traffic composition of both the sections is shown in Figure 2.

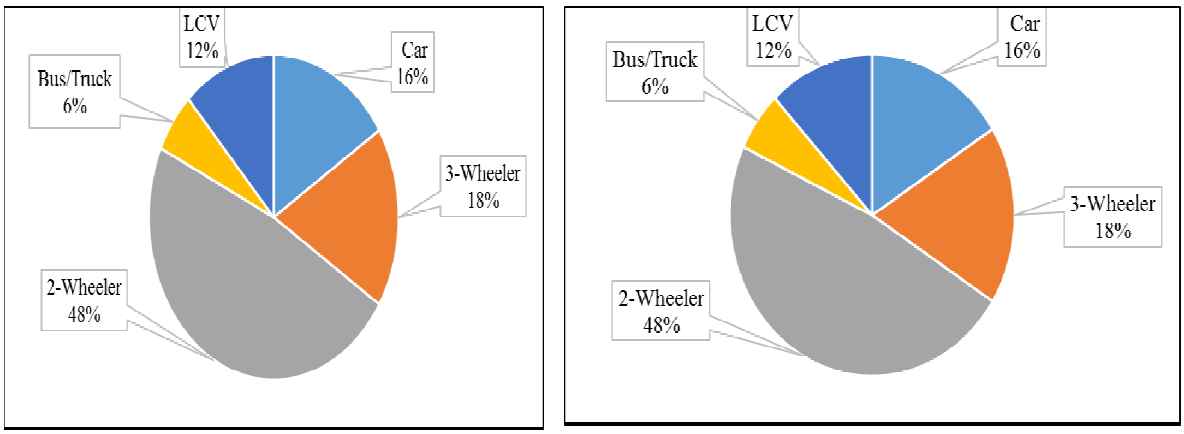


Figure 2 Traffic composition at the study sections

The equations 1, 2 and 3 are used to estimate PCU values in the present study. After the collection of data from manual observations, analysis has been done. Table 3 shows the PCU values obtained by using different methods. The table also shows the variation of PCU values with a change in the terrain i.e. plain and hilly.

Table 3 Estimation of Passenger Car Units

Type of vehicle	Section-II			Section-II		
	Headway Method	Density Method	Chandra Method	Headway Method	Density Method	Chandra Method
Bus/Truck	10.82	2.68	3.64	9.37	2.56	3.65
3-W	2.06	0.72	0.57	1.90	0.56	0.58
LCV	4.01	1.27	1.20	4.32	1.78	1.30
2-W	0.31	0.24	0.20	0.29	0.26	0.20

From Table 3, it can be observed that there is not much change in the PCU values which are obtained using different methods with a change in the terrain. They are almost same for plain and hilly terrains. The PCU values obtained by headway method are very higher than the values suggested by IRC. So this method may not be very useful in estimation of PCU values. However recent studies indicate that headway method yields good results in case of an intersection. The PCU value of Bus/Truck obtained by Chandra's method is slightly higher than that of IRC value whereas the value obtained by density method is nearer to IRC value. The PCU values of other vehicles (3-W, LCV and 2-W) obtained by Chandra's method are very nearer to that of IRC values whereas those values obtained by density method differ slightly. Results obtained from Chandra's method indicate that the method is far more reliable than other methods. Thus Chandra's method can be adopted for estimation of Passenger Car Units in both plain and hilly terrains. As Indian Roads Congress practise code on urban roads is very old, it should be immediately considered for a major revision.

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