



International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization, Volume 2, Special Issue 1, December 2013

Proceedings of International Conference on Energy and Environment-2013 (ICEE 2013)

On 12th to 14th December Organized by

Department of Civil Engineering and Mechanical Engineering of Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India

**DEVELOPMENT OF NEW PCU VALUES AND EFFECT OF
LENGTH OF PASSENGER CARS ON PCU**

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ABSTRACT

In developing countries like India, the road traffic is heterogeneous in nature, consisting of vehicles of wide ranging physical dimensions, weight and power sharing the same lane. Passenger Car Unit (PCU) is the metric used to convert heterogeneous traffic-flow rate or volume into equivalent homogeneous traffic. The PCU factors have direct impact on capacity values and design service volumes of different categories of roads and other facilities. For the design of signalized intersections, PCU values recommended for various categories of vehicles are given in the Indian Roads Congress code IRC-SP41 (1994). There has been substantial development in vehicle technology during the last couple of decades. Therefore, it is necessary to re-assess the PCU values based on field studies.

In this study, an attempt has been made to learn the characteristics of mixed traffic flow at signalized intersections. This work provides the details of an empirical study carried out to determine the PCU values for various types of vehicles, so that a comparison of results with PCU factors recommended by IRC code is possible. Moreover an attempt has been made to find the effect of length of passenger cars on PCU. Data were collected from two signalized intersections and the headway ratio method and regression method were used to estimate the PCU of different types of vehicle. The PCU values obtained in this study are compared with the values established earlier. It is found that the estimated PCU values are different from those being used in India, and they are inversely related to the length of passenger car. Studies reveal that PCU values have a great impact on signal design, emphasizing the need for further studies in this direction.

1. INTRODUCTION

In urban road networks, intersections are the main capacity bottlenecks. The importance of design of the intersection stems from the fact that the efficiency of operation, safety, speed, cost of operation and capacity are directly governed by the design. In the design of a signalized intersection, it is very important

to determine the saturation flow of that intersection. However, saturation flows in passenger cars per hour depend on the type and proportion of various classes of vehicles in the traffic stream. As a result it is necessary to convert heterogeneous traffic into a stream of homogenous traffic using appropriate PCU factors. Passenger car unit (PCU) is the metric used to assess traffic-flow rate or volume on a heterogeneous traffic highway. PCU values devised in developed countries are not suitable for Indian heterogeneous traffic conditions, where traffic was more diverse in nature, and driver do not follow lane discipline.

PCU currently used in the design and analysis of signalized intersections in Kerala as well as in India are based on the values given in the Indian Road Congress code, IRC SP 41. PCU values given in IRC SP 41 are shown in Table 1. Now-a-days, more powerful vehicles are being manufactured, and many of them use automatic transmissions. There is also an increase in power to weight ratios of many models of passenger cars. Also the driver's behaviour, traffic compositions and the roadway characteristics in India are far different from that prevailed at the time of original publication. As a result, there are chances that the PCU factors available in code are not realistically reflecting the effect of present types of vehicles on urban roads. There is no lane marking or lane restriction, no phase in the traffic signal for right turning vehicles, inadequate pedestrian facilities, poor parking facilities, poor road surface condition and so on. Appropriate PCU values are also necessary for capacity analysis as well as traffic engineering research. Also considering various other factors, it is necessary to determine the PCU values on the basis of current roadway and traffic conditions. PCU values of different types of vehicle are determined by keeping a standard passenger car as the basis. But presently a wide variety of passenger cars are available in India. Their overall dimension, power to weight ratio, mileage, etc. are different from each other. Therefore the characteristics of a standard passenger itself need to be defined, for a precise estimation of PCU. Passenger cars now present on Indian roads belong generally to smaller hatchback category and larger sedan category. This emphasizes the need to understand the effect of the passenger car type on the estimation of PCU factors applicable to various types of vehicles.

TABLE 1. PCU VALUES OF DIFFERENT VEHICLES

Type of Vehicle	PCU Values (IRC SP 41)
Car	1
Motor Cycle	0.5
Auto Rickshaw	1
Tempo	1
Truck	4.5
LCV	1.5
Bus	3

2. OBJECTIVES

The main aim of the study is to examine the credibility of PCU values given in IRC SP 41 for the present roadway and traffic condition. In view of the main aim of the study, the following objectives are formulated:

- To develop new PCU values applicable to current roadway and traffic conditions using regression method and time headway technique.
- To compare the PCU values obtained by two methods to know whether they are different.

- To know how the length of passenger car affects the PCU, when hatch backs and sedans are considered as standard passenger cars.

3. LITERATURE REVIEW

Study on Passenger Car Units (PCU) at Signalized Intersections is carried out by studying some past research works in this field. IRC SP 41 Code (1994) is the guide for the design of at-grade intersections in rural and urban areas. The code suggests PCU values and their usages for at grade intersections. Kockelman et al. (2000) analysed the impacts of different light-duty trucks (LDTs) on the capacity of signalized intersections. Debasis Basu et al (2006) explored the Neural Network (NN) approach for capturing the non-linear effects of traffic volume and its composition level on the stream speed. P. Saha et al (2009) carried out an empirical study to determine the PCU of different types of vehicles that reflected the actual traffic conditions of Dhaka Metropolitan City. Hadiuzzaman et al. (2009) reviewed principal methods of measurement of saturation flow and the selection of a proper method to measure this parameter for the traffic condition prevailing in developing countries. Lee et al. (2010) employed the flow rate method to estimate motorcycle PCU values, with the help of a recently developed agent-based simulation model, which was capable of representing the characteristic movement patterns of motorcyclists. Mahendrakumar Metkari et al (2012) reviewed the existing basic methods and their applicability for Indian traffic streams. This paper also identified the gaps in research areas which needed further research. Satyanarayana PVH et al (2012) dealt with the determination of PCU factor at mid block section using space headway method. From the various methods reviewed, time headway method and regression method are selected for this study

4. METHODOLOGY

In this study, two methods have been adopted for finding the PCU values at signalized intersections. One was the time headway method and the other regression method. The detailed procedures of both methods are described below.

A. Time headway method

PCU values of different vehicles are obtained by finding the ratio of adjusted mean headways for vehicle type x following vehicle type x to adjusted mean headways for car following car [9]. The general form of equation is given below.

$$PCU(x-x) = h(x - x) / h(c - c) \quad (1)$$

Where

$h(c - c)$ = Average headway of a car followed by a car
 $h(x - x)$ = Average headway of a type x vehicle followed by a type x vehicle.

B. Multiple Linear Regression Method

In this method, classified vehicle counts are started after 3 sec. of green initiation (startup lost time is about 2-4 sec for the selected intersections). The saturated green time is regressed against the number of each category of vehicles crossing the stop line during the saturated green time, assuming a linear relationship between the variables. The general form of equation is given below.

$$T = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + a_6x_6 \quad (2)$$

Where

T = Saturated green time in seconds
 a_0 = Y intercept
 $a_1, a_2, a_3, a_4, a_5, a_6$ = coefficient of passenger car, motor cycle, auto rickshaw, bus, truck and LCV
 $x_1, x_2, x_3, x_4, x_5, x_6$ = number of vehicles of each category during time T.

5. SITE SELECTION

The criteria for site selection have to accommodate significant flows of the selected vehicles during times of the day when it operated at saturation. Two sites were selected for the study. One was at Pandalam (Pathanamthitta district) and second location was at Kottarakkara (Kollam district). Both are fast growing towns in their respective districts. Data collected from both intersections are given in Table 2.

TABLE 2. DETAILS OF INTERSECTION SELECTED FOR STUDY

Intersection and Approaches	No. of lanes	Width of lane (m)	Green time (sec)	Yellow time (sec)	Percentage composition of vehicles (Car: Motor cycle: Autorickshaw: Bus: Truck: lcv)
Pandalam Intersection					
Kottayam side	1	4.3	32	3	32 : 44 : 15 : 3 : 1 : 5
Pathanamthitta side	1	3.7	18	3	25 : 51 : 14 : 3 : 1 : 6
Kottarakkara side	1	4.5	29	3	34 : 41 : 15 : 1 : 1 : 8
Haripad side	1	3.9	25	3	14 : 51 : 20 : 9 : 1 : 7
Kottarakkara Intersection					
Punalur side	1	4.4	26	3	22 : 47 : 22 : 5 : 1 : 3
Trivandrum side	1	4.7	30	3	36 : 45 : 11 : 4 : 1 : 3
Kollam side	1	4.5	28	3	20 : 44 : 24 : 8 : 1 : 3
Ernakulam side	1	4.6	34	3	41 : 33 : 10 : 8 : 1 : 7

6. DATA COLLECTION

It is important to ensure that the signalized intersections being studied are fully saturated or have adequately saturated portions of the green interval during the time of data collection. Thus morning peak hour was determined in order to ensure the condition. Here, by using a video recorder, events in the observed lane such as beginning of green interval, the passage of the rear axle was used because the first vehicle in the queue frequently stops over the stop line) as well as the vehicle type, the end of saturation flow and the beginning of amber and red interval was noted. Average time headway and number of headways for different categories of vehicle obtained from both intersections are given in Table 3. Table 4 shows the number of each categories of vehicle during saturated green time T at one leg of intersection.

7. DEVELOPMENT OF NEW PCU VALUES

Present roadway and traffic conditions at both intersections were observed and analyzed. Using the present traffic data, new PCU values are developed, adopting time headway method and regression method. In time headway method equations (1) was used for calculating PCU. In regression method collected data were analyzed using SPSS software and excel. PCU of different categories of vehicle were

determined using the collected data. The results obtained in two methods are shown in Table 5 and Table 6.

8. EFFECT OF LENGTH OF PASSENGER CAR ON PCU VALUES

PCU values of different types of vehicle are determined by keeping a standard passenger car as the basis. But presently a wide variety of passenger cars are available in India. In order to find the effect of length

TABLE 3. AVERAGE TIME HEADWAY (SEC) AND NUMBER OF HEADWAYS OF TWO INTERSECTION

Pandalam Intersection				Kottarakkara Intersection			
Passenger cars as a single category				Passenger cars as a single category			
h(c-c)	1.598	N(c-c)	573	h(c-c)	1.619	N(c-c)	619
h(c-b)	1.192	N(c-b)	317	h(c-b)	1.283	N(c-b)	426
h(b-c)	1.124	N(b-c)	341	h(b-c)	1.218	N(b-c)	407
h(b-b)	0.733	N(b-b)	408	h(b-b)	0.707	N(b-b)	625
h(c-a)	1.593	N(c-a)	273	h(c-a)	1.493	N(c-a)	343
h(a-c)	1.279	N(a-c)	216	h(a-c)	1.357	N(a-c)	308
h(a-a)	1.327	N(a-a)	296	h(a-a)	1.355	N(a-a)	327
h(c-bu)	2.435	N(c-bu)	107	h(c-bu)	2.738	N(c-bu)	137
h(bu-c)	2.901	N(bu-c)	94	h(bu-c)	3.04	N(bu-c)	113
h(bu-bu)	3.241	N(bu-bu)	98	h(bu-bu)	3.351	N(bu-bu)	103
h(c-t)	2.641	N(c-t)	68	h(c-t)	2.84	N(c-t)	63
h(t-c)	2.884	N(t-c)	59	h(t-c)	3.1	N(t-c)	75
h(t-t)	3.497	N(t-t)	73	h(t-t)	3.492	N(t-t)	69
h(c-lcv)	1.957	N(c-lcv)	78	h(c-lcv)	1.821	N(c-lcv)	77
h(lcv-c)	1.941	N(lcv-c)	64	h(lcv-c)	1.915	N(lcv-c)	58
h(lcv-lcv)	1.983	N(lcv-cv)	81	h(lcv-cv)	2.05	N(lcv-lcv)	79

of passenger car on PCU values, a study was conducted at both intersections. Instead of grouping all passenger cars as a single category, they are classified into two groups namely hatchbacks and sedans, where sedans are longer in length than hatchbacks. In the first case hatchback cars are considered as the standard passenger car and PCU value of other categories of vehicle are determined. In the second case sedan cars are considered as standard car and PCU value of other vehicles are determined. Time headway method is adopted for the study. The results obtained in two cases are shown in Table 7.

9. RESULT AND DISCUSSION

In developing countries like India, road traffic is heterogeneous in nature. One of the methods used to convert heterogeneous traffic into equivalent homogeneous one is by using PCU factors. In India, PCU values for the design of signalized intersections are adopted from IRC SP 41 code. The main aim of this study was to assess the credibility of PCU given in IRC SP 41 for the present type traffic and roadway condition. PCU values for different categories of vehicle are determined for both intersections separately. New PCU values obtained from site are quite different from the values given in code. It is found that PCU values obtained for motor cycle, auto rickshaw, truck, LCV and bus from both intersections are smaller than the values given in IRC SP 41. By comparing the two methods adopted, it is found that time headway is more accurate than regression method. In regression method width of road has a great role in number of vehicles passing during saturated green time. It is much true in case of mistake in counting the

number of vehicles during saturated green time, it will definitely affect the PCU values. Also error in determining saturated green time affects the result. Output obtained from the study also shows a considerable variation in PCU values at each leg. So time headway method is suggested for further studies. Also an attempt has been made to find the effect of length of passenger cars on PCU. It is found that PCUs of different categories of vehicle are inversely related to length of passenger car. Moreover PCU values obtained by considering hatch back cars as standard are quite higher than values given by sedan cars. PCU obtained by considering passenger cars as a single category lies between above mentioned values. So as a conclusion, it can be said that either for signal design purpose or to determine the saturation flow rate, PCU values applicable to current conditions need to be developed instead of depending on the old PCU values given in code.

TABLE 5. PCU VALUE OBTAINED USING TIME HEADWAY METHOD

Vehicle type	PCU Values		
	IRC SP41	Pandalam	Kottarakkara
Car	1	1	1
Motor Cycle	0.5	0.46	0.45
Auto Rickshaw	1	0.83	0.83
Truck	4.5	2.25	2.23
LCV	1.5	1.3	1.28
Bus	3	2.1	2.14

It is much true in case of heterogeneous traffic condition. Even though the regression method is simple and easy compared to headway method, chance of error is high. If there is any

**TABLE 4. NUMBER OF EACH CATEGORIES OF VEHICLE DURING SATURATED GREEN TIME
Kottarakkara-Kollam Side**

y	x1	x2	x3	x4	x5	x6
15	2	10	1	3	0	0
22	4	8	3	4	0	3
19	4	8	4	2	0	2
21	4	8	5	4	0	0
22	5	6	7	3	1	1
19	3	6	6	3	0	1
15	4	10	1	2	0	0
21	10	5	4	2	0	1
18	5	5	6	2	0	1
15	3	10	0	1	0	3
22	3	6	8	4	1	1
21	5	8	5	2	1	1
22	8	8	8	1	2	1
22	6	12	8	2	0	1
22	4	10	6	2	1	2
17	6	5	4	2	0	0

TABLE 6. PCU VALUE OBTAINED USING REGRESSION METHOD

Intersection Details		PCU values obtained from regression method					
		Car	Motor cycle	Auto rickshaw	Bus	Truck	LCV
Kottarakkara intersection	Ernakulam side	1	0.35	0.86	2.33	2.54	1.45
	Punalur side	1	0.38	0.72	2.4	2.34	1.66
	Trivandrum side	1	0.42	0.88	2.23	1.77	1.29
	Kollam side	1	0.39	0.85	2.16	2.32	1.56
Pandalam intersection	Kottayam side	1	0.47	0.8	2.39	2.48	1.48
	Kottarakkara side	1	0.45	0.86	1.93	2.36	1.16
	Haripad side	1	0.46	0.68	1.78	1.88	1.01

TABLE 7. SUMMARY OF PCU OBTAINED AT BOTH INTERSECTIONS IN TWO CASES

Type of Vehicle	Pandalam		Kottarakkara	
	Only hatch back cars are considered	Only sedan cars are considered	Only hatch back cars are considered	Only sedan cars are considered
Passenger Car	1	1	1	1
Motor Cycle	0.49	0.41	0.46	0.38
Auto Rickshaw	0.88	0.75	0.9	0.74
Bus	2.15	1.8	2.16	1.79
Truck	2.31	1.95	2.28	1.89
Light Commercial Vehicle	1.33	1.11	1.33	1.12

Moreover PCU values obtained by considering hatch back cars as standard are quite higher than values given by sedan cars. PCU obtained by considering passenger cars as a single category lies between above mentioned values. So as a conclusion, it can be said that either for signal design purpose or to determine the saturation flow rate, PCU values applicable to current conditions need to be developed instead of depending on the old PCU values given in code. More over in order to get a better result the percentage of short length and long length in cars in traffic need to be understood. It is suggested that the values obtained in this study can be used as a guideline in the design and analysis of signalized intersections in Kerala as well as in India.

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