

PASSENGER CAR UNIT OF VEHICLES ON MULTILANE URBAN ROADS: - A CASE STUDY OF VADODARA CITY

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Abstract: This paper presents a concept of Dynamic passenger car unit factor, appropriate for the heterogeneous traffic on Indian roads, and shows that the PCU factor for vehicles type is not a static factor as it is usually assumed. By using two methods of computing PCUs, passenger car unit for seven categories of vehicles are found. And compared those PCU factors to each other shows that PCU values are changes with respect to speed, volumes and composition. It can be also said that PCU value is depends on method of derivation. This PCU factors is the ratio of the projected rectangular area of the vehicle type to the speed of vehicle type, with respect to standard car (small car). Some of the factors affecting PCUs value are classified traffic volume of vehicles, average speed, traffic composition and carriageway width. Speed and Volume data are collected at two urban roads of Vadodara city by video camera technique during morning and evening peak hour.

Keywords – Dynamic Passenger car unit, Multilane Urban road, Traffic volume, Heterogeneous Traffic

I. INTRODUCTION

The traffic on Indian roads is heterogeneous in nature and character. Traffic on urban roads in India comprises of varieties of slow and fast modes. The slow moving category consists of cycles and hand carts. Fast moving traffic is dominated by two wheeled vehicles like motor cycles, scooters, mopeds and three wheeled auto-rickshaws. In addition to the above, the traffic consists of cars, commercial vehicles including light commercial vehicles, trucks and large city buses. Different types of vehicles with varying dynamic and static characteristics share the same road space without much segregation and control of speed. The different types of vehicle and their size and speed of that vehicle create a number of problems for traffic operations. In this paper, an attempt has been made to calculate the passenger car unit PCU of wide varieties of vehicles under mixed traffic conditions on two different multilane urban roads of Vadodara city. The Indian Roads Congress (IRC) code specifies the PCU values for different vehicle types for car, truck, trailer tractors, hand carts, motor cycle, rickshaws, bullock carts, etc. However, these PCU values are static and only depend on traffic composition on highways. This paper is focused on the study of the effect of variation in nature of traffic volume, road width and size of the vehicles, on PCU value of vehicles.

The mixed traffic stream consists of wide range of vehicle types with varying dynamic characteristics. Vehicles occupy different spaces on the road, travel at different speeds, and start at different accelerations. Without any physical segregation the operating condition on roads become more complex when all these vehicles of different sizes travel on the same road space. Hence traffic volumes containing a mix of vehicle types are converted into an equivalent flow of passenger cars using passenger car unit.

Table 1.1: Recommended PCU factors for various types of vehicles on urban roads as per IRC 106-1990

SR. NO.	Vehicle Type	Equivalent PCU factors	
		Percentage composition of vehicle type in traffic stream	
	Fast vehicles	5%	10% and above
1	Two wheelers –motor cycle, scooter, etc.	0.5	0.75
2	Passenger car, pick-up van	1.0	1.0
3	Auto-rickshaw	1.2	2.0
4	Light commercial vehicle	1.4	2.0
5	Truck or Bus	2.2	3.7
6	Agricultural Tractor –trailer	4.0	5.0

Slow vehicles			
7	Pedal cycle	0.4	0.5
8	Cycle rickshaw	1.5	2.0
9	Tonga (Horse drawn vehicle)	1.5	2.0
10	Hand cart	2.0	3.0

Table: 1.1 displays the equivalent PCU factors for fast moving vehicles and slow moving vehicles at 5% and 10% composition of vehicle type in traffic stream. It can be said that in fast moving vehicles the PCU factors are maximum for agricultural tractor or trailer and minimum for 2-wheelers. Other side the equivalent PCU factors are maximum for hand cart and minimum for cycle in slow moving vehicles.

II. LITERATURE REVIEW

Chandra et al. (1997) have related five methods of PCU estimation, namely multiple-linear regression method, homogenization coefficient method, Headway ratio method, Walker's method, and simultaneous equation method, using field data collected on a two-lane highway in India. They found that each of these methods yield a different set of PCU values demonstrating that PCU for a vehicle depends upon the method of derivation also.

Chandra and P.K sikdar (2000) have studied the dynamic nature of PCU. The variation of PCU with traffic and geometric variables is explained graphically. They develop computer program to estimate the PCU value for a vehicle type under given condition of composition and traffic volume per lane width. It is applicable to all traffic situations with a maximum number of five vehicle categories in the stream. And it is suitable for other cities also having similar conditions of traffic.

Chandra and Kumar (2003) have presented a new concept to estimate the passenger car unit of different types of vehicles under mixed traffic conditions. Data were collected at ten sections of two-lane in different parts of India. The video recording technique was used to collect the data. All vehicles were divided into nine different categories and their PCU's were estimated at each road section. It was found that the PCU for a vehicle type increases linearly with the width of carriageway.

Chetan R Patel and G.J. Joshi (2012) have carried out experimental investigation in the behavior of mixed traffic stream speed and flow rate on an access controlled urban arterial in Surat city in Gujarat state of India. Field traffic survey carried out to capture the classified volume and speed data through manual as well as video graphic technique. They determined the capacity based on speed flow behavior under mixed traffic condition and established level of service thresholds for the prevailing traffic condition. Multi regime speed-flow relation is developed based on the 5 minute data extracted from the field survey. The results are very useful for evaluation of traffic quality for access controlled urban arterials in mixed traffic condition.

Paul and Sarkar (2013) have done the study on four urban roads of Delhi city. They collected classified volume, speed, lateral clearance, and headway data on 30m trap length by video camera technique for three hours during peak hours. Calculation of PCU value is ratio of any type of vehicle to the space requirement of the vehicle with respect to the car. The result obtain from this study is shows that PCU value of two wheeler increase with increase in percentage of heavy motor vehicles and decrease in percentage of non-motor traffic. There is no significant relationship was observed between PCU value of auto and change in percentage of HMV and NMT. As the speed of stream decrease the PCU value of bus is increase. The PCU value of three wheeler and cycle also decrease with decrease in speed.

Ashish Dhamaniya and Satish Chandra (2013) have presents a methodology to convert a mixed traffic stream into a homogeneous equivalent without making use of PCU factors. Traffic volume and speed data collected on different six-lane urban arterial roads in India are analyzed to determine PCU values of five different categories of vehicles found on these roads. These PCU values are used to convert heterogeneous traffic volume in vehicles per hour to homogeneous volume in PCU per hour. A new term stream equivalency factor (SEF) is introduced in this study and denoted by K. It is the ratio of traffic volume in PCU per hour and volume in vehicles per hour. Proposed method is simple to use and expected to eliminate the problem of estimation of PCU factors required in many studies.

Chetan R. Patel and G. J. Joshi (2014) have studied mixed traffic speed-flow behavior under road side friction and non-motorized vehicles. In this paper an attempt is made to capture capacity values with varied conditions of arterial road by considering the Pune and Patna city of India. Study was carried out on six lane divided urban arterial road in Patna and Pune city of India. Both the road share having distinct differences in terms of the vehicle composition and the roadside parking. Arterial road in Patna city has 33% of non-motorized mode, whereas Pune arterial road dominated by 65% of two wheeler. Also road side parking is observed in Patna city. The field studies using videography techniques are carried out for traffic data collection. Data are extracted for one minute duration for vehicle composition, speed variation and flow rate on selected arterial road of the two cities. Speed flow relationship is developed and capacity is determine. Equivalency factor in terms of dynamic car unit is determine to represent the vehicle is single unit. The variation in the capacity due to side friction, presence of non-motorized traffic and effective utilization of lane width is compared at concluding remarks.

Muhammad Adnan (2014) has found the PCE factors for heterogeneous traffic environment in urban arterials of Karachi city, Pakistan. He had used four methods of estimation of PCE factors and compared them with each other and those which are currently used in different traffic studies of Karachi. His analysis showed that significant differences are found among the values of PCE factors from each method and what followed in Karachi.

A Mehar et al. (2014) has demonstrates the effect of congestion level (v/c ratio) on PCU of different type of vehicles on multilane interurban highways. Although the PCU values given are derived for Indian conditions, yet the methodology is quite general and can be used by other researchers to derive PCU values for traffic condition in their countries as well. The major objective of this research was to quantify the effect of traffic volume and composition on PCU values and authors have successfully demonstrated it.

Ankit Mahidadiya and Jayesh Juremalani (2016) reviewed on the PCU reveals that there are several methods used for calculating PCU values. And the PCU values depends upon the current road traffic condition. They demonstrated that it is also needs to revised PCU value in India. Because many cities of India undergoes rapid urbanization its result change in traffic condition, varying road width, and traffic composition. It been also seen that PCU values of vehicles considering all effects of factors such as grade, shoulder condition, roughness, percentage of vehicle, percentage of slow moving vehicles has not been calculated universally.

R. srinivasa Rao et al. (2017) reviewed on the different methods to estimate PCU value in homogeneous and heterogeneous traffic flow reveals that there are several methods available for calculating PCU values for mixed and homogeneous traffic flow. And each method has its own factors like density, headway, speed, delay, projected rectangular area etc. They demonstrated that India having mixed traffic condition hence there is a much need for considering all the factors such as geometric elements of road, traffic conditions, vehicle compositions, vehicle conditions etc. to develop model for deriving the most appropriate PCE values that can be adopted throughout the world.

Subhadip Biswas et al. (2017) have demonstrated the effects of traffic volume and its composition on individual speed and PCE in the context of urban mixed traffic. Traffic data on classified traffic volume and speed were collected at six-lane divided arterial mid-block road sections in New Delhi, India. A Computer system model was adopted to develop a volume-based speed prediction model for individual vehicle category. Validation results displayed a great deal of agreement between the predicted and the observed speeds. Then, the sensitivity investigation was performed utilizing the model developed in order to observe the effects of traffic volume and its composition on individual speed and corresponding PCE.

III. DATA COLLECTION

In this study, traffic volume and speed data collected at two urban roads sections of four lane road and six lane of Vadodara city to determine PCU factors for the different categories of the vehicles on both roads by two methods. The detail of the selected sections are given in table 3.1

Table 3.1: Details of the study sections

Sites	VIP road		Gotri road	
	Towards lion circle	Towards amitnagar circle	Towards harinagar	Towards gotri cross road
ROAD TYPE	3-Lane Road in one direction	3-Lane Road in one direction	2-Lane Road in one direction	2-Lane Road in one direction
CARRIAGEWAY WIDTH	15.5 M	15.5 M	12.74 M	12.74 M
WIDTH OF MEDIAN	1.9 M	1.9 M	1 M	1 M
ROAD SEGMENT	30 M	30 M	30 M	30 M

Videography method was used for data collection on both roads. A study trap of 30m was made on the road section to collect data regarding volume and speed of vehicles. Data on volume and speed of vehicles were recorded at section. To avoid distraction to the drivers by the video camera, it was placed in an obscured place such as under a tree or a roadside building with reasonable distance from the pavement. All vehicles are divided in different categories based on their physical size and operating conditions. Table 3.2 shows various vehicle categories and their projected rectangular area below.

Table 3.2: vehicle categories with corresponding average dimensions (Source: M. Mardani N, Chandra and I. Ghosh (2015) "Passenger car unit of vehicles on undivided intercity roads in India" Sciencedirect.)

Vehicle Category	Vehicles Included	Average Projected Rectangular Area	Area Ratio to Passenger Car to Vehicle Type
Small Car	Standard Car	5.36	1.0
Big Car	Jeep, Mini Vans	8.06	0.6650
Two Wheeler	Scooter, Motor Cycle	1.48	3.62
Three Wheeler	3 Wheeler Auto	4.48	1.1964
LCV	Mini Trucks, chhota hathi	12.81	0.4184
Bus	Buses, Mini Buses	25.73	0.2083
Bicycle	Non-motorized	0.86	6.2325

Traffic volume count and speed of different categories of vehicles were carried out at every five minute interval on both the road sections. Table 3.3 below displays the traffic composition on both roads. Speed of each type of vehicles included in every five minute count were estimated by measuring the time taken by the vehicle to cover the 30m trap on the road using stop watch. For accuracy in speed data videography is converted into 10 frames at every one second so the entry and exit of all vehicles identify clearly. Table 3.4 displays speed data collected on VIP and Gotri roads

Table 3.3: Traffic composition on both roads

Name of road	Traffic composition						
	2w	3w	4w sml	4w big	Bus	LCV	cycle
VIP	60.21	9.82	20.3775	4.6675	1.82	1.43	1.665
Gotri	60	15.515	15.0275	3.71	0.53	1.0425	4.16

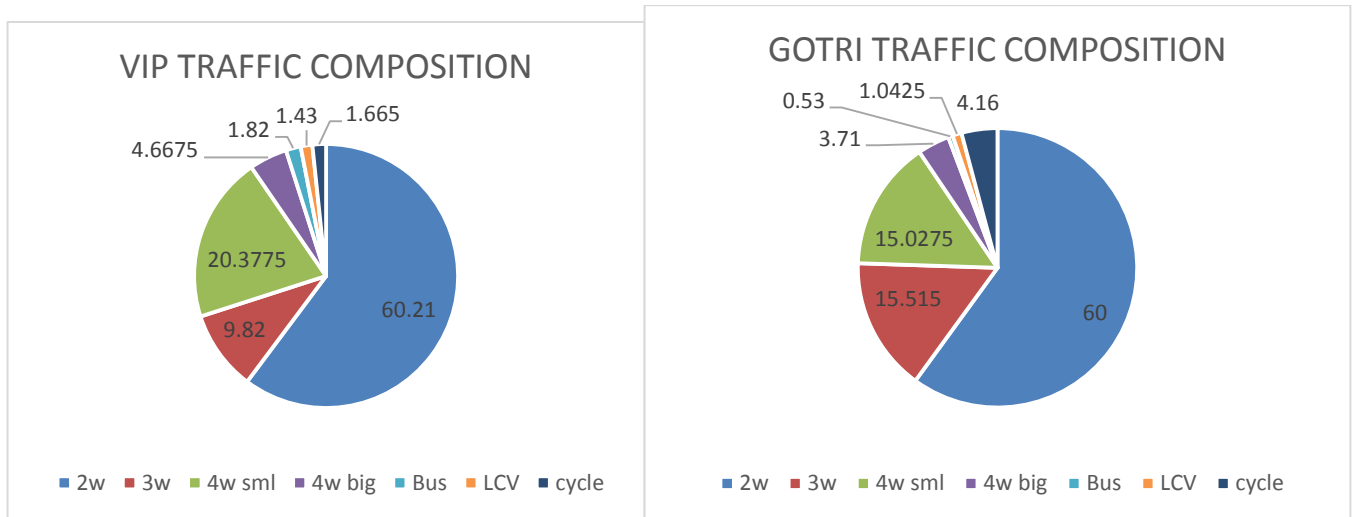


Fig.3.1 Traffic composition on VIP road and Gotri road

Table 3.4: Speed Data on VIP and Gotri Road

Speed Data on VIP Road							
speed criteria	2w	3w	4ws	4wb	bus	lcv	cycle
average	44.11	36.11	44.16	45	37.05	40.05	15.22
std dev	2.78	2.27	3.09	4.86	4.22	3.62	2.53
mini	40	31	40	36	27	30	12
max	50	39	52	55	45	45	22
Speed Data on Gotri Road							
speed criteria	2w	3w	4ws	4wb	bus	lcv	cycle
average	39.61	34.61	43.22	42.16	37.92	38.66	14.38
std dev	3.22	2.09	3.25	3.31	4.73	3.08	1.61
mini	36	29	36	37	32	31	12
max	47	38	49	49	51	45	17

IV. RESULTS AND DISCUSSION

4.1 Estimation of PCUs

In India all types of vehicles travel on same road space without any physical segregation so it can be said that traffic on Indian roads are mixed traffic. Small vehicles like motorized two wheeler travel on road can penetrates gaps between two large vehicles and make the operating condition poor. Passenger car units (PCU) of different types of vehicles are required to convert a mixed traffic stream into a homogeneous Equivalent, and thereby to express the mixed traffic flow in terms of equivalent number of passenger cars. Table 4.1 and 4.2 displays PCU values for different categories of vehicles and roads.

Table 4.1: PCU values for different categories of vehicles and roads using Chandra’s Method

PCU VALUE (Chandra’s method)							
Name of road	2W	3W	4WSML	4WBIG	BUS	LCV	CYCLE
VIP ROAD	0.28	1.00	1	1.56	5.67	2.68	0.47
GOTRI ROAD	0.31	1.04	1	1.53	5.63	2.66	0.49

Table 4.2: PCU values for different categories of vehicles and roads using Homogenization Coefficient Method

PCU VALUE (Homogenization Coefficient Method)							
Name of road	2W	3W	4WSML	4WBIG	BUS	LCV	CYCLE
VIP ROAD	0.52	1.09	1	1.29	3.76	1.66	1.33
GOTRI ROAD	0.59	1.13	1	1.26	3.74	1.65	1.40

Many scholars have recognized methods to estimate PCU for the vehicle type. For the present study the PCU values were estimated by using the equation 1 and equation 2.

➤ Chandra’s Method:-

$$(PCU)_i = \frac{(V_c/V_i)}{(A_c/A_i)} \dots \dots \dots (1)$$

Where,

Vc and Vi are mean speeds of car and vehicle of type i respectively and
 Ac and Ai are their respective projected rectangular area (length x width) on the road.

➤ **Homogenization Coefficient Method:-**

$$PCU = \frac{Li/Vi}{Lc/Vc} \dots\dots\dots (2)$$

Where,

Li and Vi are the length and speed of different types of vehicle.
 Lc and Vc are the length and speed of car.

4.2 Variation in PCUs

The PCU value is the amount of interaction caused by a vehicle type to the traffic stream of passenger cars. This interaction will be different at different traffic volume levels. It will change with composition of the traffic stream and speed as well.

Figure 4.1 and 4.2 shows variation in PCU value on VIP and Gotri road with traffic composition. It can be seen that PCU value changes with traffic composition using both the methods of estimating PCU factors on both the roads. Figure 4.3 and 4.4 displays variation in PCU factors with speed on both the roads. Figure shows that if the speed increase than PCU factors found by Chandra’s method goes down. But PCU value found by homogenization method decrease with increase in speed. Figure 4.5 and 4.6 shows the variation in PCU factors with carriageway width.

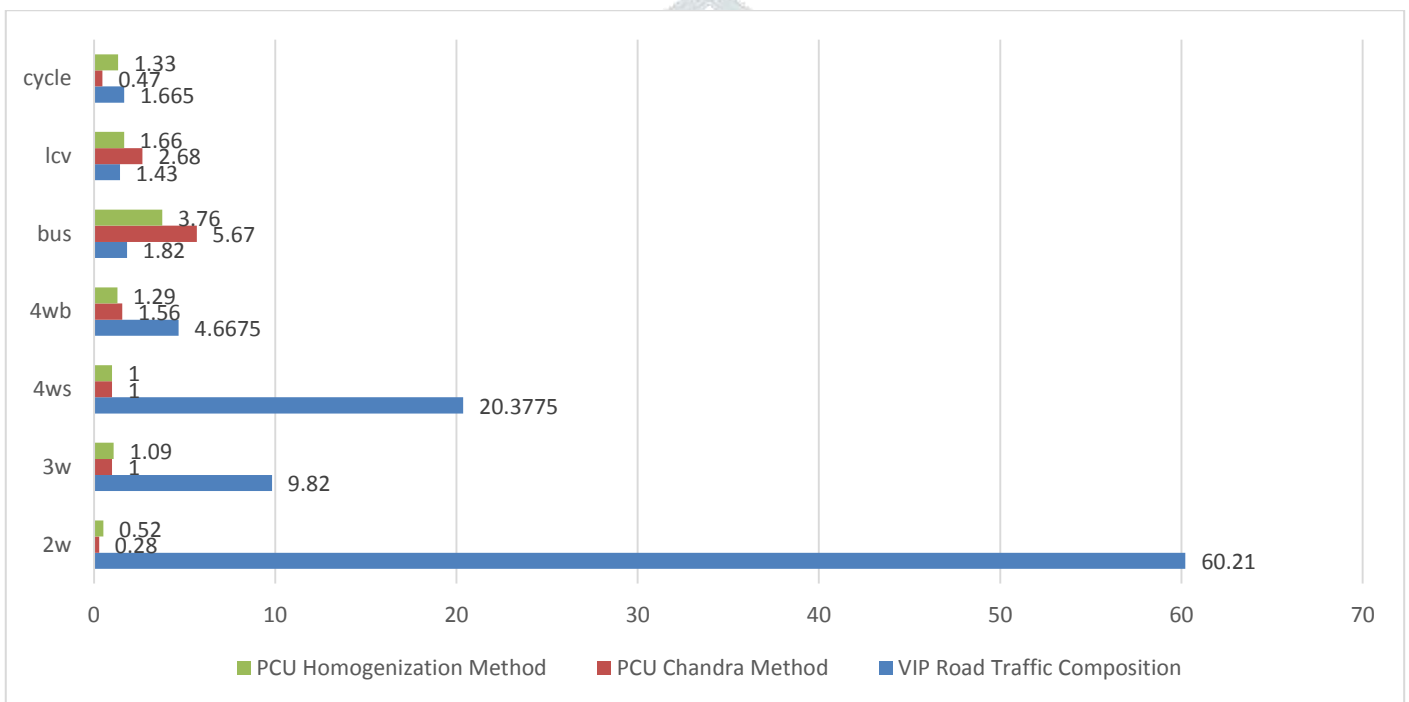


Fig 4.1 Variation in PCU with Traffic Composition on VIP road

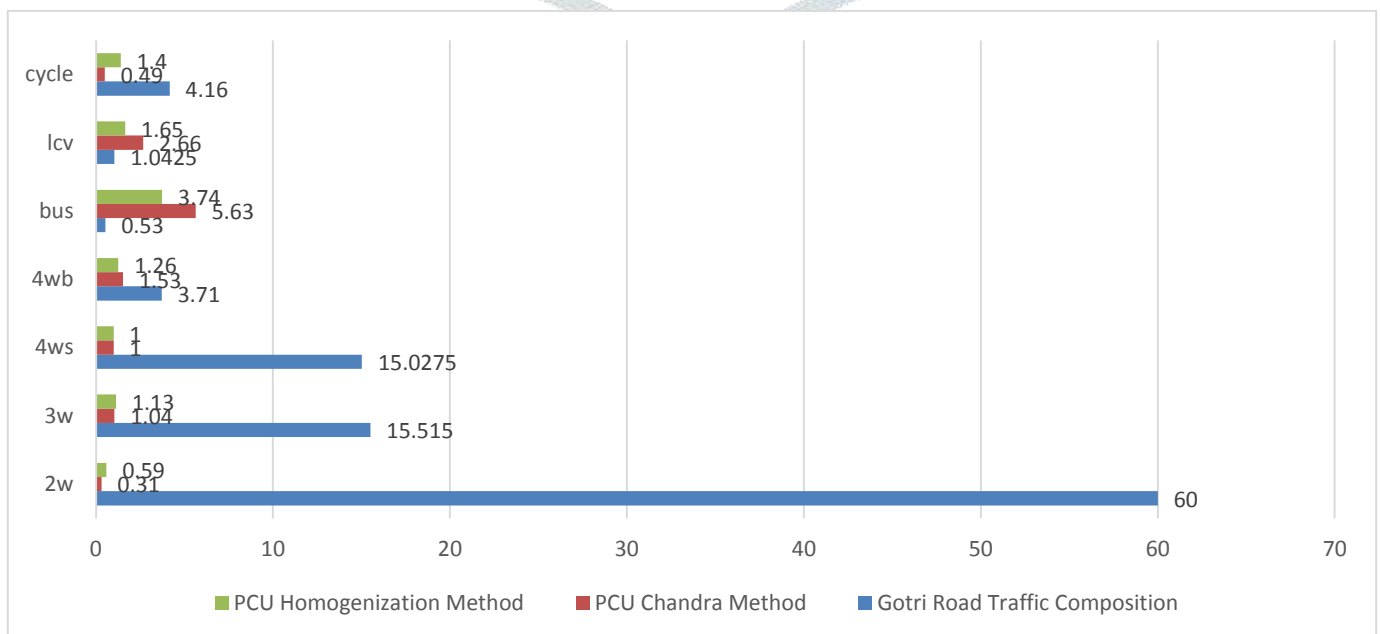


Fig 4.2 Variation in PCU with Traffic Composition on Gotri road

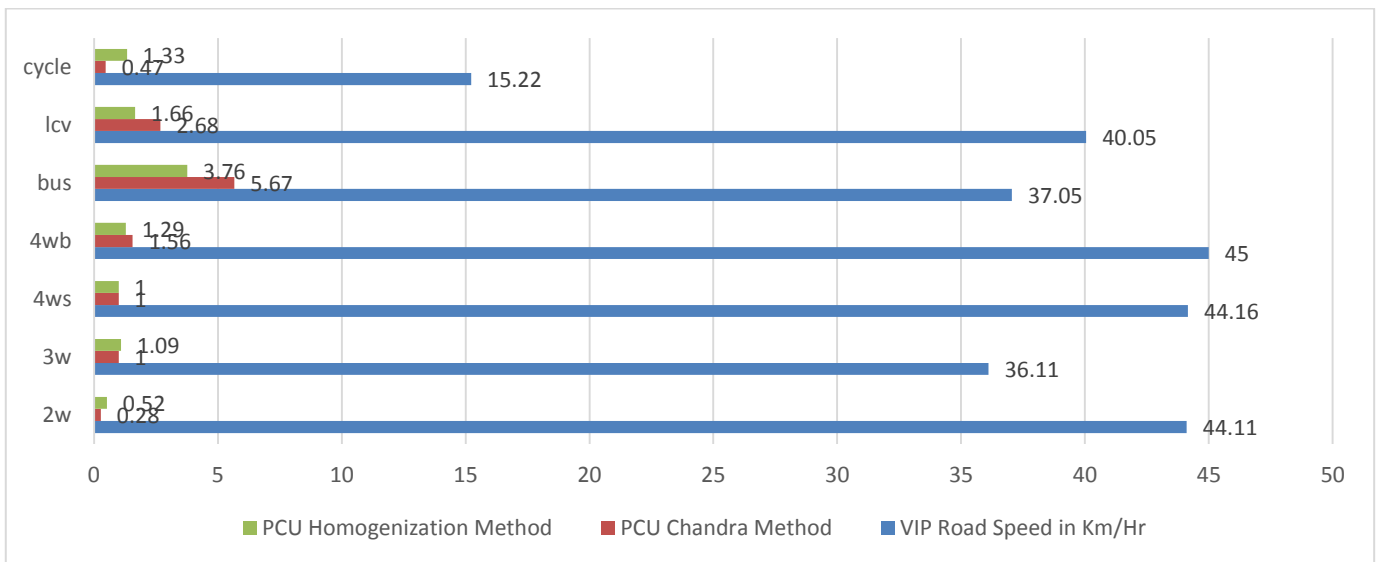


Fig 4.3 Variation in PCU with Speed on VIP road

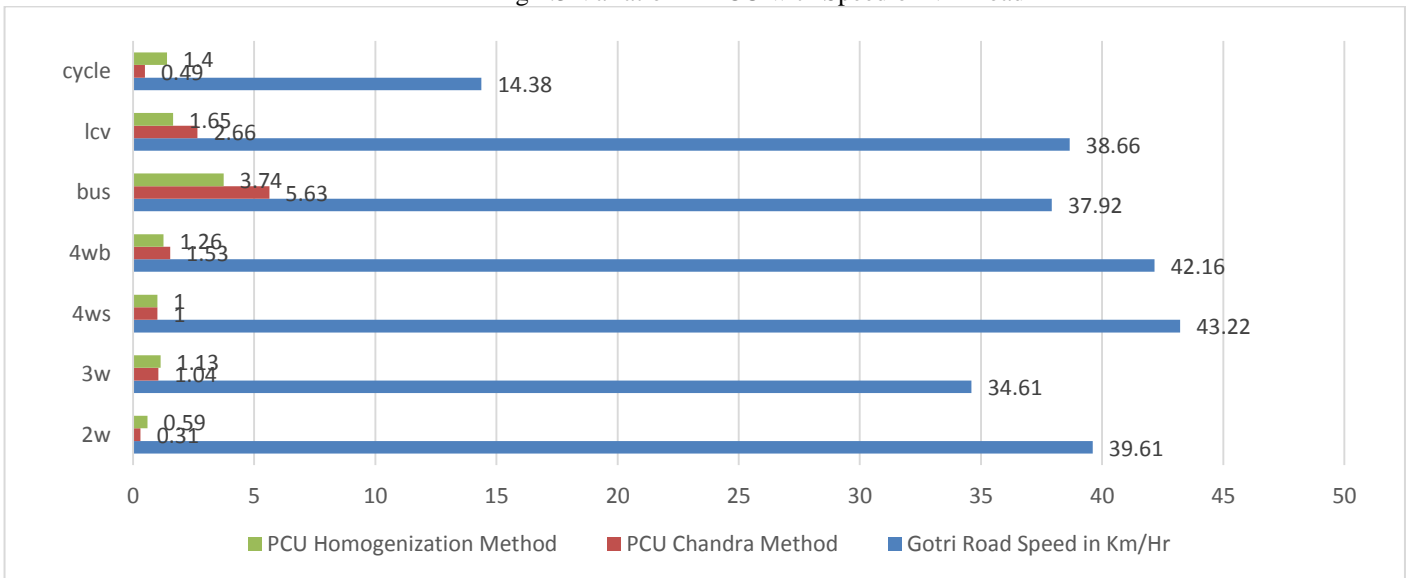


Fig 4.4 Variation in PCU with Speed on Gotri road

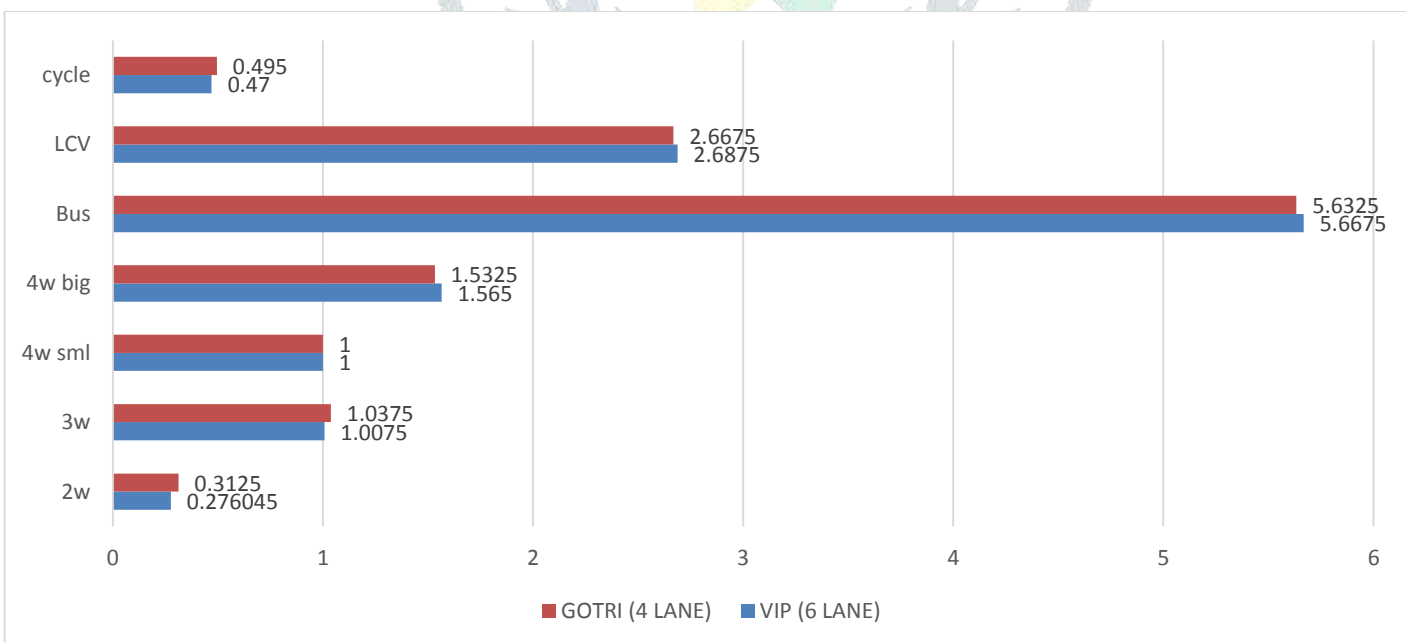


Fig.4.5 variation in PCU on different roads Using Chandra's method

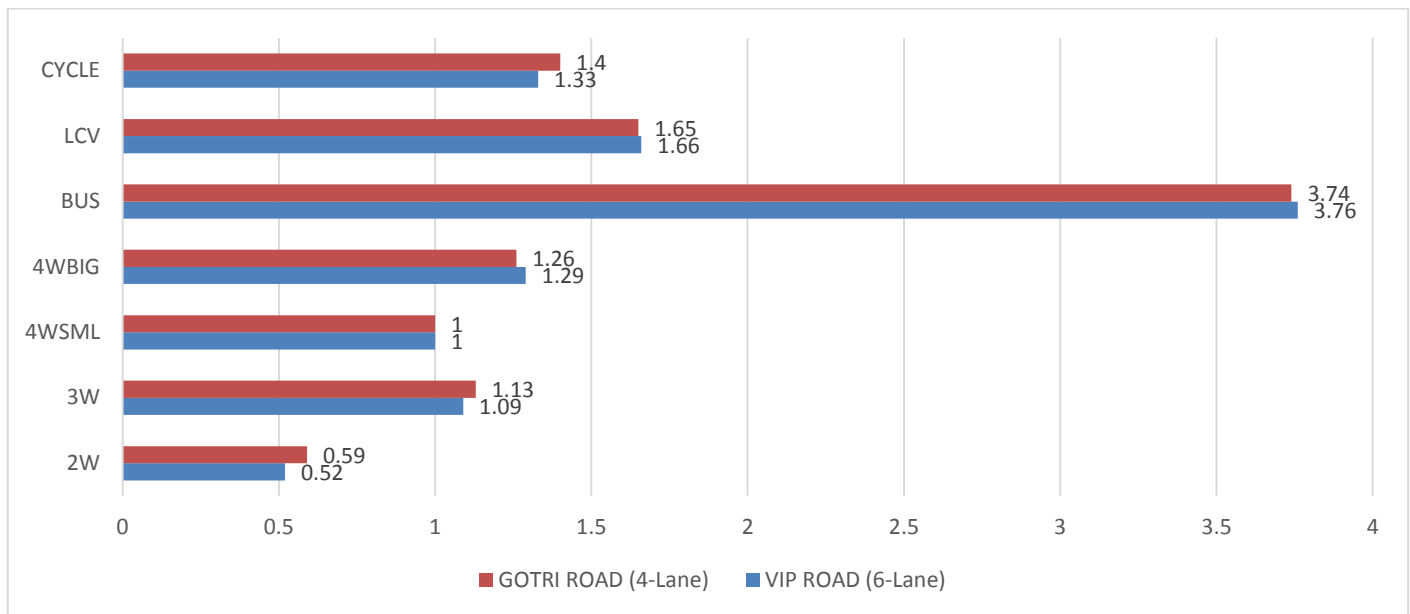


Fig.4.6 variation in PCU on different roads Using Homogenization Coefficient Method

V. CONCLUSIONS

The present study demonstrates the dynamic value of PCU factors on two different roads under highly heterogeneous traffic conditions. The PCU values are calculated using Chandra's method and homogenization coefficient method on both the roads. The PCU factors on both roads are found to be very sensitive to any changes in the traffic stream either in terms of traffic composition or in terms of traffic volume. It is also affected by the type of roads and speed of vehicles as well. Chandra's method for determining dynamic passenger car units takes into account longitudinal and lateral dimensions representing the vehicles as a box so the projected rectangular area of vehicle can be considered as an influencing parameter to passenger car unit which is satisfactory consideration for developing countries like India where transverse movements of vehicles are very frequent. Homogenization coefficient method takes into account only the longitudinal dimension of the vehicle assuming that vehicles are followed to the lane and frequent lane changing by vehicles is not taken into picture. In view of discussion in this Chandra's method for estimating the PCU factors is considered as reliable when compare to homogenization coefficient method discussed under this study.

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A. IRC Code:

- IRC-106-1990 Guideline for capacity of urban road in plain area