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**ABSTRACT**

In developing countries including India, mixed traffic condition prevails on road and highways. Transportation grew to become the 'economic' backbone of any country. It assumes greater significance in urban context. There is a wide variation in the static and dynamic characteristics of different types of traffic. The method of accounting for traffic analysis in traffic stream is to convert all vehicles into a common unit known as passenger car unit (PCU). A number of factors have been identified affecting PCU values. In this study we are dealing with mainly three methods, which are Modified density method, Homogenization coefficient method and Time head way method.

Modified density method assumes the homogeneous traffic and it is used by adjusting the method to handle heterogeneous traffic and is based on traffic entity and speed of the vehicle. Homogenization coefficient method depends on the size and speed of the vehicle whereas Time head way method depends on size, time head way and speed of the vehicles. Speed of the vehicle is calculated using spot speed studies by enoscope method. The PCU value for a vehicle is not a constant, it changes based on various parameters like speed, effective size of vehicle, road widths and from road to road and method applied for estimation of PCU.

**KEYWORDS:** passenger car unit, density, headway.

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**INTRODUCTION****1.1 Introduction**

Ameliorating the infrastructure is a boon to the economic growth of any country. India is a developing country, with second largest road network in the world after America. Even with high volume of road length we have crowded and congested roads in poor condition, certainly not justifying the vehicular requirements of Indian traffic. The urban traffic on roads in India is heterogeneous in character. The traffic consists of fast moving vehicles like carriers, trucks, cars, jeeps which move at higher speeds and slow moving vehicles like tractors, bicycles, etc. and because of this undulating speed, the capacity of the road is adversely affected and server congestion is resulted. One way to quantify the effect of different categories of vehicles on capacity is to convert all vehicles into equivalent number of a standard vehicle the universally accepted such vehicle is passenger car and hence all vehicles in a traffic stream are converted into equivalent number of passenger cars by assigning equivalency factors to all vehicles other than the car. This factor is known as passenger car unit or PCU and capacity is expressed in terms of PCU per hour or per day.

In view of the existing scenario, this research/study is intended to determine the Passenger Car Units (PCU) of a different class of vehicles by applying following methods in peak hours of flow.

Methods used for determining the passenger car unit of different classes of vehicles.

- Modified density method
- Homogenization coefficient method
- Time headway method

Sampling of the peak commuting periods was ensured with trip departure time between morning 11.00 am to 02:00 pm and evening 05:00 pm to 07:00 pm. Peak hours are taken based on previous year data of traffic collected by traffic police.

**1.2 Objectives of the study**

This research paper emphasizes in analysing the characteristics of the heterogeneous traffic flow to identify appropriate theoretical distributions for various traffic variables influencing the traffic stream characteristics, and study of the flow characteristics and vehicular interactions at micro level, wide fluctuations in speeds and

variations in speeds thereby increasing the travel time, the presence of both fast moving and slow moving vehicles to use the same roads and same lanes adds to the traffic regulatory problems.

### 1.3 Scope of the study

To quantify the impedance caused to traffic flow by the different categories of vehicles in heterogeneous traffic in terms of PCU. To study the effect of road width and traffic volume on PCU values of vehicles. To collect traffic data and study the traffic flow characteristics at selected corridors of Visakhapatnam city. To measure headway of vehicles at several corridors of the city used in the Time head way method adopted to estimate PCU of the different vehicle types. To study the variations PCU values by using different methods on different types of roads.

## METHODOLOGY

### 2.1 Methodology adopted for the study:

Various classes of vehicles are found to use common roadway facilities without segregation on most of the roads. Therefore the mixed traffic flow characteristics are very much complex when compared to homogeneous traffic consisting of passenger cars only. It is rather difficult to estimate the traffic volume and capacity of roadway facilities under mixed traffic flow. It is a common practice to consider the passenger car as standard vehicle unit to convert the vehicle classes. If the addition of a particular class in the traffic stream produces the same effect as that due to addition of one passenger car, then that vehicle class is considered equivalent to passenger car with a PCU value equal to 1.0.

Passenger car unit:

The PCU value of a vehicle class may be considered as the ratio of the capacity of a roadway when there are passenger cars only to the capacity of the same roadway when there are vehicles of that class only. PCU values suggested by Indian Road Congress (IRC), Heavy Vehicle(HV)- 3.0, Light Commercial Vehicles(LCV)- 1.2, car- 1.0, two wheeler- 0.5, three wheeler- 0.6.

Factors affecting PCU value

The PCU values of different vehicles classes depend upon several factors.

Vehicle characteristics such as dimensions, power, speed, acceleration and braking characteristics. Transverse and longitudinal gaps or clearances between moving vehicles which depends upon the speeds, driver characteristics and the vehicle classes at the adjoining spaces. Traffic stream characteristics such as composition of different vehicle classes, mean speed and speed distribution of mixed traffic stream, volume to capacity ratio etc. Roadway characteristics such as road geometries including gradient, curve, etc. access controls, rural or urban road, presence of intersections and the types of intersections.

### 2.2. Methods used to calculate PCU values

For estimating PCU values using these three methods for all traffic entities that comprise the heterogeneous traffic at four types of roads and vehicles are described.

2.2.1 Modified density method

2.2.2 Homogenization coefficient method

2.2.3 Time headway method

#### 2.2.1 Modified density method

This method is useful in calculating the PCU values in heterogeneous traffic condition. For estimating PCU values using modified density method, all traffic entities that comprised the heterogeneous traffic at 4 types of roads and vehicles of all classes. PCU value of a vehicle class from modified density method is as calculated from below formulae.

$$PCU = (K_{car} / w_{car}) / (k_i / w_{xi})$$

Where,

$K_i$  = density of a particular vehicle class

$K_{car}$  = density of the car

$q_i$  = flow of the corresponding vehicle class

$u_i$  = speed of the corresponding vehicle class

$w_{car}$  = width occupied by cars in heterogeneous traffic condition

$w_{xi}$  = width occupied by corresponding vehicle class in heterogeneous traffic condition.

#### 2.2.2 Homogenization coefficient method

In homogenization coefficient method, PCU of a vehicle is obtained by comparing the theoretical maximum capacity when different types of vehicles are exclusively using the road. The method compares the "all car" and "all other than car type" capacity of traffic lanes. Similar to modified density method all traffic entities that comprised heterogeneous traffic of 4 types of roads and vehicles are divided into 5 classes.

This method requires length and speed of vehicle to calculate PCU of a vehicle. No camcorder is required, speed is calculated by spot speed studies by taking average of 25 vehicles of same group or class. Length of the vehicles is calculated by manually calculated averaging the length of the vehicles belonging to same group on an average of 25 vehicles were taken and measured with the help of the tape. PCU value of a vehicle class from homogenization coefficient method is as calculated from below formulae.

$$PCU_i = (L_i/u_i) / (L_c/u_c)$$

Where,  
 $L_i$  = length of corresponding vehicle  
 $L_c$  = length of the car  
 $U_i$  = speed of the corresponding vehicle  
 $U_c$  = speed of the car

### 2.2.3 Time headway method

This method is based on the concept that a truck occupies more space than single passenger car, and therefore reduces capacity. The PCU values of the vehicles are determined from this method considers the effective size, mean speed and lower time head way.

Mean speed and effective width of the vehicles are calculated on spot by using stopwatches and an average of 25 vehicles values belonging to same group were taken and lower time head way is calculated from the recorded video of camcorder. Thus in this method PCU values of vehicles also depends on time head way, speed and width of the vehicles. PCU value of a vehicle class from time headway method is as calculated. Other vehicles like tractors, bicycles, pedestrians are neglected due to less flow when compared to other class of vehicles. PCU value of a vehicle class from time head way method is as from below formulae.

$$PCU_i = (W_i*t_i/u_i) / (W_c*t_c/u_c)$$

Where,  
 $W_i$  = width of corresponding vehicle  
 $W_c$  = width of the car  
 $t_i$  = average time head way of vehicles class with respect to other vehicles  
 $t_c$  = average time head way of car with respect to other vehicles  
 $u_i$  = speed of the corresponding vehicle  
 $u_c$  = speed of the car

## DATA COLLECTION AND ANALYSIS

### 3.1 Data collection

Four major traffic corridors were identified for carrying out the study that are corridor is subjected to disruption of smooth flow of traffic, Entity of different class of vehicles will be obtained, a very high volume of traffic plying on it especially during peak hours, topography of roads was different, which account in variation of static characteristics of vehicles.

The selection of study corridors is based on the following criteria. Based on the above factors the four corridors selected and listed below:

1. NATIONAL HIGHWAY-16, VISALAKSHI NAGAR
2. URBAN ROADS
  - I. CARE HOSPITAL ROAD
  - II. JAGADAMBA ONE WAY ROAD
  - III. CMR CENTRAL ROAD

Video of flow of traffic on every road is taken on mid-week days (Wednesday and Thursday) to obtain a representation of traffic sample in each month by using the camcorder. Peak data was collected in the morning at 11.00am to 02.00 pm or in the evening 05.00pm to 07.00pm for a half an hour duration from a certain elevation. Spot speeds are determined by using enoscope method. The time taken by the vehicle to travel the

known distance is noted, then by using the basic formulae. Width of each corridor is determined manually using measuring tape

Time headway and occupied road widths of different vehicle types were determined from the video recorded using camcorder. Occupied vehicular widths are obtained from video recorded and they are taken approximately as per lane widths measured by taking outer edges of the corresponding class of vehicle. Data about slow moving vehicles (non- motor vehicles), pedestrians were neglected due to their less percentage of entity.

### 3.2 Data analysis for Modified Density Method

Average spot speed of vehicles in (kmph)

An average of spot speed of 25 numbers of vehicles was taken to calculate the speed of the corresponding vehicle class. Spot speeds are determined by enoscope method. Vehicular speeds are determined and are recorded.

Observing the records on an average two wheelers move with a maximum velocity (35.58kmph) and heavy vehicles move with a minimum velocity (27.67kmph) on selected corridors of the city.

The data of this particular care hospital road is consider due to higher volume of traffic and represented in table 1.

**Table 1: Care hospital road- Analysis by Modified Density Method**

Vehicle type	Number of vehicles (N)	Flow $q_i$ veh/hr	Speed $u_i$ km/hr	Density $k_i=q_i/u_i$ veh/hr	$W_{xi}$ (m)	$K_{car}/w_{car}$ (1)	$K_i/w_{xi}$ (2)	PCU (1/2)
HV	17	34	16.60	2.05	2.4	4.7	0.85	5.53
LCV	43	86	24.85	3.46	7.0	4.7	0.50	9.40
CAR	558	1116	31.46	35.47	7.5	4.7	4.70	1.00
TWO-WHEELER	1600	3200	27.50	116.36	7.0	4.7	16.63	0.30
THREE-WHEELER	469	938	25.71	36.50	7.5	4.7	4.90	0.96

Model calculation for Light commercial vehicles

$N=43$ , duration= 0.50hr,  $q_i= N/.50 =86$ ,  $u_i= 24.85$ km/hr,  $k_i= q_i/u_i= 86/24.86= 3.46$ veh/km,  $w_{xi}= 7.0$ m,  $k_{car}= 35.47$ veh/km,  $w_{car}= 7.5$ m,  $K_{car}/w_{car}=35.47/7.5= 4.70$ ,  $K_i/w_{xi}= 3.46/7.0= 0.50$ ,  $PCU_i= 4.70/0.50= 9.40$

### 3.3 Data analysis for Homogenization Coefficient Method

Width and length of vehicles.

Widths and lengths of the vehicles are determined by using the measuring tape and an average of widths and lengths of corresponding vehicles are taken n recorded. The data for Care hospital road for homogenization method is represented in table 2.

**Table 2: Care hospital road- Analysis by Homogenization Coefficient Method**

Vehicle type	Length of the car $L_c$ (m)	Length of the vehicle $L_i$ (m)	Speed of the car $u_c$		Speed of vehicle $u_i$		$L_c/u_c$ (1)	$L_i/u_i$ (2)	PCU <sub>i</sub> (2/1)
			Kmph	m/s	Kmph	m/s			
HV	3.7	8.40	31.46	8.74	16.6	4.61	0.42	1.82	4.30
LCV	3.7	4.50	31.46	8.74	24.84	6.9	0.42	0.65	1.55
CAR	3.7	3.7	31.46	8.74	31.46	8.74	0.42	0.42	1.00
TWO-WHEELER	3.7	2.10	31.46	8.74	27.50	7.64	0.42	0.24	0.64
THREE-WHEELER	3.7	2.85	31.46	8.74	25.71	7.14	0.42	0.40	0.95

Model calculation for Light commercial vehicles

$L_c= 3.7$ m,  $u_c= 8.74$ m/s,  $L_i= 4.50$ m,  $u_i= 6.90$ m/s,  $(L_c/u_c)= 3.7/8.74= 0.42$ /sec,  $(L_i/u_i)= 4.5/6.9= 0.65$ /sec,  $PCU_i= (L_i/u_i)/(L_c/u_c)= 0.65/0.4= 1.55$

### 3.4 Data analysis for Time Headway Method

In time head way method time headway calculated from recorded video for different vehicle types are recorded. Remaining data like speeds and widths of the vehicles are taken from the recorded once previously. The data for Care hospital road for time headway method is represented in table 3.

**Table 3: Care hospital road- Analysis by Time Headway Method**

Vehicle type	Width of the vehicle $W_i$ (m)	Time head way of the vehicle $t_i$ (sec)	Time head way of the car $t_c$ (sec)	Speed of the vehicle class $u_i$ (m/s)	Speed of the car $u_c$ (m/s)	$(W_i*t_i/u_i)$ (1)	$(W_c*t_c/u_c)$ (2)	PCU <sub>i</sub> (2/1)
HV	2.40	1.52	1.51	4.61	8.74	0.79	0.26	3.05
LCV	1.60	1.48	1.51	6.9	8.74	0.34	0.26	1.32
CAR	1.50	1.51	1.51	8.74	8.74	0.26	0.26	1.00
TWO-WHEELER	0.55	1.62	1.51	7.64	8.74	0.12	0.26	0.45
THREE-WHEELER	1.35	1.52	1.51	7.14	8.74	0.29	0.26	1.12

Model calculation for Light commercial vehicles

$W_i = 1.6m$ ,  $W_c = 1.5m$ ,  $t_i = 1.48s$ ,  $t_c = 1.51s$ ,  $u_i = 6.9m/s$ ,  $u_c = 8.74m/s$ ,  $(W_i*t_i/u_i) = (1.6*1.48)/6.9 = 0.34$ ,  $(W_c*t_c/u_c) = (1.5*1.51)/8.74 = 0.26$ ,  $PCU_i = (W_i*t_i/u_i) / (W_c*t_c/u_c) = 0.34/0.26 = 1.32$

Likewise data on the other three corridors(NH-16, jagadamba road, CMR central road) are analyzed and the PCU values have been represented in tables 4,5,6.

## RESULTS AND DISCUSSIONS

The results are tabulated in table no.4,5,6 of all the three methods for every selected way.

**Table 4: Results of NH- 16 corridor**

Vehicle Type	Modified Density Method (PCU)	Homogenization Coefficient Method (Pcu <sub>i</sub> )	Time Headway Method (Pcu <sub>i</sub> )
HV	1.80	2.85	2.45
LCV	4.60	1.40	1.13
CAR	1.00	1.00	1.00
TWO-WHEELER	0.40	0.50	0.36
THREE-WHEELER	0.60	1.15	1.13

**Table 5: Results of Jagadamba road corridor**

Vehicle Type	Modified Density Method (PCU)	Homogenization Coefficient Method (Pcu <sub>i</sub> )	Time Headway Method (Pcu <sub>i</sub> )
HV	1.50	2.40	1.60
LCV	1.80	1.15	0.90
CAR	1.00	1.00	1.00
TWO WHEELER	0.14	0.50	1.34

THREE WHEELER	0.30	0.72	0.56
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**Table 6: Results of CMR central road corridor**

Vehicle Type	Modified Density Method (PCU)	Homogenization Coefficient Method (Pcu <sub>i</sub> )	Time Headway Method (Pcu <sub>i</sub> )
HV	1.00	2.40	1.60
LCV	3.45	1.10	0.96
CAR	1.00	1.00	1.00
TWO WHEELER	0.20	0.55	0.38
THREE WHEELER	0.34	0.90	1.08

## CONCLUSION

### 5.1 Modified Density Method

- National Highway-16

National highway is a 4-lane divided road with shoulders and width of road on one side is 7.5 meters which is measured manually with the tape. Camcorder the video for 30minutes and for a stretch of 45 meters from the certain preferred elevation.

By the observations, percentage of entity of light commercial vehicles is very less i.e, due to less entity the PCU value is abnormally high. This shows that vehicles with varying static and dynamic characteristic i.e, speed of vehicles affect the capacity of road even at low densities.

- Care Hospital road- Urban road

It is a 4-lane divided road with the provision of parking and raised kerbs and each side of road is 8.2m wide (including parking). Camcorder the video for 30minutes and for a stretch of 23m which was taken from an elevation covering the entire stretch clearly. So due to low densities of vehicles PCU values of corresponding vehicles are abnormally high.

- Jagadamba road - Urban road

Jagadamba road is a 2- lane one way road without any median and provided with parking. By using a camcorder recorder, the video was taken for 30minutes and a stretch of 20m was covered, which was taken from an elevation. The PCU values observed i.e, calculated on this type of road are not much derived from the normal values and they were nearer to the basic values.

- CMR road-Urban road

It is a 6 - lane road provided with 2 medians. It is a adjusting type road which is based on peak hour traffic flow and the roads were used towards the high flow of traffic. The middle part of the road is used either in any direction, width of road 7.5m. , the video was taken for 30minutes and a stretch of 23m. The observed PCU values on this type of road shows that the PCU value of heavy vehicles is equal to the car PCU values. This is due to affect of width occupied by heavy vehicles in heterogeneous traffic is much less on the density of heavy vehicles is less and unfortunately equals to one.

### 5.2. Homogenization Coefficient Method

- National Highway-16

This type of road PCU values of three wheelers (3-W) are slightly greater than car due to greater speed of cars than motorized three wheelers. Here the length of vehicles i.e, motorized three wheelers (2.85)m is less than that of car (3.7)m but speed variation dominated the value and results in higher PCU of three wheeler (3-W) than car, from this PCU of vehicles also depends on speed of the vehicles.

- Care Hospital road- Urban road

In this type of road heavy vehicles have slightly higher values due to more length of heavy vehicles and greater speed of cars than heavy vehicles from this; one can know that the length and speed also governs the PCU values of the vehicles. Due to provision of parking speed of traffic in this type road is less when compared to other roads this is due to less usage width of carriageway.

- For the remaining 2 roads (Jagadamba and CMR central road) are not showing that much variation in PCU factors from IRC recommended values and no more conclusions needed.

### 5.3. Time Headway Method

- National Highway-16

In this road PCU value of three wheelers (3-W) is slightly lighter than the car. This is due to higher car velocity than three wheelers (3-W) and time head way is greater than the car for three wheelers, and variation in width do not affect the PCU value more.

This resembles that the PCU value of vehicle also varies with the time headway and also speed of the vehicle irrespective of size of vehicle.

- Care Hospital road- Urban road

Three wheelers (3- W) have slightly higher PCU values than the car due to variation in speeds and sizes of vehicles does not affect the PCU value much.

- Jagadamba road - Urban road

Light commercial vehicles have slightly lesser PCU values than the car due to variation in time head way and speed of the vehicle. This resembles that the PCU value varies with time headway and speed irrespective of size of vehicle.

- CMR road-Urban road

Similar to above case light commercial vehicles have slightly lesser PCU values than the car and motorized three wheelers slightly higher PCU from the car.

### 5.4 Common Observations

On observing the PCU values obtained by all the three methods on the four corridors showed some observations that are represented below.

Modified Density Method depends on traffic entity and speed of traffic. Where, Homogenization Coefficient Method depends on size of vehicle and speed of vehicle. Where, Time Headway Method depends on size, time headway and speed of the vehicle.

Based on size, Light Commercial Vehicles (LCV) should have less PCU value than Heavy Vehicles (HV), but in modified density method there was a violation due to account of traffic entity.

Where in rest of the methods, PCU of Light Commercial Vehicles (LCV) is smaller than for Heavy Vehicles (HV) because due to considerations of effective size of vehicles.

But in the remaining two methods other than Modified Density Method, Three Wheelers (3- W) have more PCU value than car, due to account of speeds and time headway considerations.

## RECOMMENDATIONS AFTER CONDUCTING THE STUDY

Large PCUs of slow moving vehicles even at low density explains that these vehicles consume disproportionately high capacity of the road on highways where traffic stream includes a variety of models. Findings of the present study make a strong case for including service lanes for slow moving vehicles for improving the capacity of highways. The speed variation of traffic on the main carriageway would be reduced leading to fewer conflicts and improved speeds of the traffic stream. Provision of a service lane which can serve slow and local traffic, as a capacity enhancement strategy would have higher benefit cost ratio as compared to adding an extra lane on the main carriageway without a service lane.

For example, a four lane divided highway with service lanes will be a better option than six-lane divided highway without service lanes.

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