

# CAPACITY AND DYNAMIC PCU ESTIMATION OF URBAN ROADS FOR HETEROGENEOUS TRAFFIC: A CASE STUDY IN INDORE CITY

Rudraksha S. Joshi<sup>1</sup>, H.S.Goliya<sup>2</sup>

<sup>1</sup>JRF, Dept. of Civil Engineering, Shri G.S. Institute of Technology & Science, Indore, M.P. India

<sup>2</sup>Professor, Shri G.S. Institute of Technology & Science, Indore, M.P. India

\*\*\*

**Abstract** - Rapid urbanisation and population growth the number of vehicles on the road has increased drastically throughout the country. In India the traffic is purely heterogeneous i.e., consisting of various types of vehicles which vary in physical dimensions. To calculate the volume and capacity of such a heterogeneous traffic it is essential to convert different types of vehicle into passenger car unit and express the capacity in terms of passenger car unit per hour. The PCU is a universally accepted unit which is calculated by taking passenger car as a 'standard vehicle'. The present study focuses on estimation of passenger car unit of various categories of vehicles based on the dynamic properties of vehicles which is speed of the vehicle. Two six-lane divided roads are selected in Indore which are Vijay Nagar main road and AB road, survey work is carried out to find the speed of different categories of vehicle and the traffic volume. The composition of different categories of vehicle in the traffic is also found by dividing the vehicles into six categories which are small car which is taken as a standard vehicle, big car, Motorised three wheeler, Bus, Truck and Two wheelers. The PCU values of different categories of vehicles are found to differ a lot from the suggested PCU values given in IRC: 106-1990. The PCU values of two wheeler and Three wheeler vehicle is found to be less than the IRC suggested PCU values while the PCU values of Bus, Truck and Big car is found to be high than the IRC suggested PCU values. It is also found that the PCU values of different type of vehicle are different for different volume of traffic due to the dynamic characteristics. The capacity of the selected six lane divided roads is found to be 3661 and 3380 PCU/hr. which is less than the IRC values because of high percentage of two wheeler vehicles in the traffic composition and very low PCU value computed as per their dynamic characteristic. A mathematical equation is developed to forecast the PCU for several vehicular categories that has been statistically validated by student t-test.

**Key Words:** Passenger car unit, Dynamic capacity, Heterogeneous traffic, Road capacity, Level of service.

## 1. INTRODUCTION

The Passenger car unit or Passenger car equivalent is the unit which is adopted in the world for traffic volume and traffic capacity measurement. The passenger car unit is computed by considering the passenger car as a 'standard vehicle'. The knowledge of passenger car unit of various categories of vehicles is important for various purposes such as design of a road section, traffic operation on the road, management of traffic etc. The capacity of a road is the maximum hourly rate at which a vehicle can be expected to traverse a point or a uniform section of a lane or roadway during a certain time period under prevalent roadway, traffic and control conditions. It is very necessary to predict the capacity of a road for the purpose of planning, design of road and its operation. Apart from all other reasons, knowledge of capacity provides us the basis for determining the width of road and number of lanes to be constructed on a road section in accordance with the traffic volume and composition of various types of vehicle. Knowledge of capacity is also important for deciding the priority among various parallel projects, for estimation of funds needed for any project and also the future need of improvement. Capacity of a road is affected by various things out of which road user and the condition of road are major things. The capacity of road is also affected by various road geometric features such as road width, super elevation, camber, gradient of the road etc. capacity of a road increases with increases in width of the road as vehicles move at some higher speed.

## 2. OVERVIEW OF PREVIOUS LITERATURES

There are many studies available in literature to estimate the PCU of different categories of vehicles under heterogeneous traffic conditions in India and other countries. Chandra and Kumar (2003)(3), Studied the effect of lane width on PCU of different types of vehicle under mixed traffic conditions, They found that PCU for a vehicle type increases linearly with the width of carriageway. Chandra S. (2004) (4), studied the effect

of influencing parameters like gradient, lane width, shoulder width, traffic composition, directional split, slow moving vehicles and pavement surface conditions, on capacity of two-lane roads under mixed traffic conditions is evaluated and adjustment factors for each of these conditions are proposed. Chandra S. (2004) (5), Pointed out that Highway Capacity Manual 2000 States that the capacity of a two-lane rural highway under ideal conditions is 3200 passenger car unit per hour for both directions combined. The ideal conditions as given in the manual do not include the riding quality of a road, which deteriorates with time. His study shows that the capacity of a two-lane rural road is also affected by the road roughness. Basu et al. (2005) (2), studied reduction in stream speed caused by marginal increment in traffic volume by a vehicle type is compared with that of caused by an old technology car, for the estimation of PCE of that vehicle type. Dhamaniya A. et al. (2013)(6) proposed a methodology to convert a mixed traffic stream into a homogeneous equivalent without making use of PCU factors, 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. Adnan M. (2014) (1), His paper discusses the case of Karachi (A metropolitan city of Pakistan) traffic environment where degree of heterogeneity is significantly high, and based on the collected data set from 12 different urban arterials of Karachi; presents the estimation of PCE factors from four different existing methods. It is been found that method that incorporate vehicles speed along with projected area of vehicles are provide appropriate estimate of PCE values. Gajjar R. et al. (2014) (7), studied the critical assessment of road capacities on major urban roads in Mumbai, Maharashtra is done, it was observed that volume per lane for several major roads in Mumbai are way beyond the capacity. However, interestingly, no major congestion issues were found in these roads notwithstanding the excessive volume. Mardani M. et al. (2015) (10), studied the effect of the carriageway width on PCU of different vehicle categories. Data are collected at ten sections of intercity roads in different states in India. The results show that PCU value for a vehicle type varies with traffic volume and composition on the road and the carriageway width of the road being used. For example the average PCU for a big car varies from 1.46 to 1.59 on two-lane roads, 1.23 to 1.55 on intermediate roads and 1.58 on single-lane roads. MondalSatyajit et al. (2016) (12), Generated a mathematical model on the basis of the variation of PCU with traffic volume. The

model is developed to forecast the PCU for several vehicular categories that has been statistically validated at different ranges of traffic volume. Mankar U. et al. (2016) (11) analyse the capacity for urban roads in heterogeneous condition. They analysed the capacity by using dynamic PCU values. Patel B (2016) (13) In Rajkot city by using three different methods of estimating PCU, PCU value of different category of vehicles is found. This PCU factor is the ratio of the projected rectangular area of the vehicle type to the speed of the vehicle type, with respect to car. Factors influencing PCU value are classified volume of vehicles and Average speed .PCU values of different types of vehicles is determined on Rajkot Urban Road by different methods and suggest the reliable method. Roy N. et al. (2017) (14) Studied the effects of mixed traffic on capacity of two-lane roads. On the basis of field data collected on Indian highways, makes it clear that capacity reduces if the proportion of slower vehicles increases in the traffic stream. Since such vehicles are responsible for the formation of platoons, their increasing proportion in traffic would accordingly increase the equivalency factor of vehicles, thereby, resulting in variation in capacity. Koringa H. et al. (2017) (9) signify the concept of capacity and level of service for urban roads for heterogeneous traffic condition, Level of Service is found out from density and speed. Speed, Flow and density data are trained in MATLAB using Artificial Neural Network. Speed and flow data are taken as an input and density is taking as an output.

### 3. OBJECTIVE AND STUDY AREA

This study is concerned with finding the roadway capacity and PCU values for different categories of vehicles on mid-block of road under heterogeneous traffic condition on urban road and to see the variation of PCU value with respect to the volume for urban arterial.

Two study sections were selected for the study on the six-lane divided urban road based on criteria which are, there must be no on street parking, free from road side friction, bus stop pedestrian movement, curvature etc. A straight mid-block section is selected on both the roads for the data collection purpose.

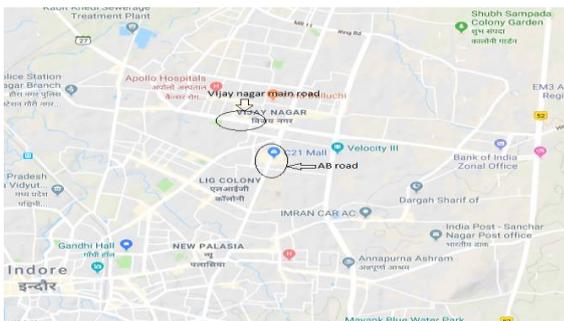


Fig 1 Indore and Neighbouring cities and location in Indore

#### 4. RESEARCH METHODOLOGY

The Method adopted in this thesis work to generate a model equation to calculate PCU is Speed-Area method which is developed by Dr Satish Chandra, present director of CRRI (central road research institute). In Chandra’s method speed is the basic factor for calculation of PCU. Hence, Chandra’s method is adopted for the research work. In this research work Standard Car (SC) is taken as the standard design vehicle. According to Chandra’s method PCU of any vehicle category can be found by using the following formula.

$$PCU_i = \frac{V_c}{V_i} \frac{A_c}{A_i}$$

In the above equation  $V_c$  is the mean speed of a standard vehicle and  $V_i$  is the mean speed of vehicle of any category  $i$  and  $A_c$  is the rectangular area projected by the standard vehicle while  $A_i$  is the rectangular area projected by the vehicle of any category  $i$ . speed is the actual representor of the interaction of a vehicle of its own type with other vehicles of same or different category. Speed is the main parameter used in the numerator because speed of any vehicle depends on the volume of the stream and also on the volume of different category vehicle and volume of its own category. In denominator the projected area of vehicle is used which represents the area usage with respect to

a standard vehicle. The physical dimensions of the vehicles are adopted as given by Chandra S.

Table 1 Vehicle Categories and Their Average Dimensions

Category	Average Dimension		Projected Rectangular Area on Ground (in msq.)
	Length (m)	Width (m)	
Standard car (santro, i10 etc.)	3.72	1.44	5.36
Big Car (suzukiciaz, Skoda rapid etc.)	4.58	1.77	8.11
Bus	10.1	2.43	24.74
Truck	7.5	2.34	17.62
Two Wheeler	1.87	.64	1.2
Three Wheeler	3.2	1.40	4.48

#### 5. FIELD DATA COLLECCTION

Traffic data for the research is collected on a weekday at Vijay Nagar Main Road and AB road from 9 am in the morning till 8 pm in the evening. 1320 Minutes of data is recorded in a video camera and speed of the vehicles is measured at the site by reference line methodology. For the measurement of volume on site and vehicle composition a trap length of 20 m is selected.

#### 6. DATA EXTRACTION AND PROCESSING

The collected field data have been brought to a work station to extract different traffic stream parameters such as:

##### Classified Traffic Volume and Composition

Traffic volume count study is done by playing the recorded video at the work location. All vehicles in the traffic flow are classified and divided into six categories. The vehicle count is done manually at every 15 minutes period from the recorded video-graphic footage

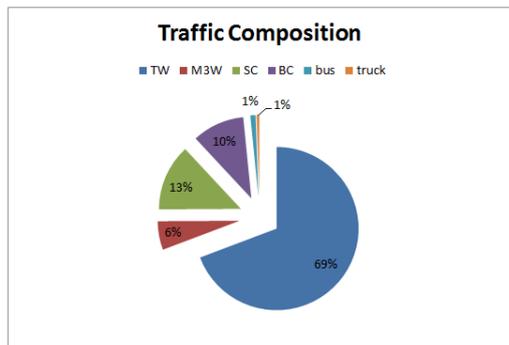
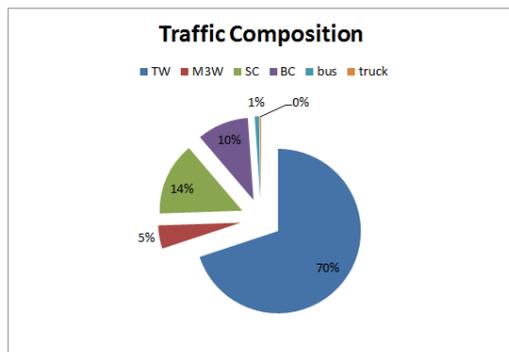


Figure 2 Evening and Morning Peak Hour Composition of Vijay Nagar Main Road

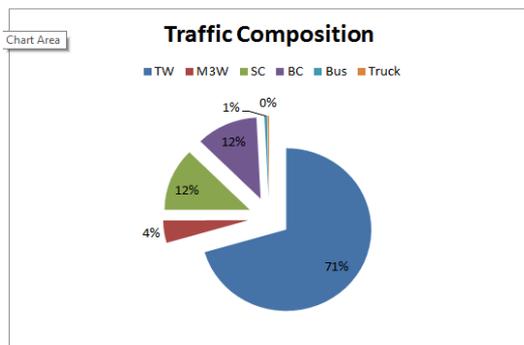
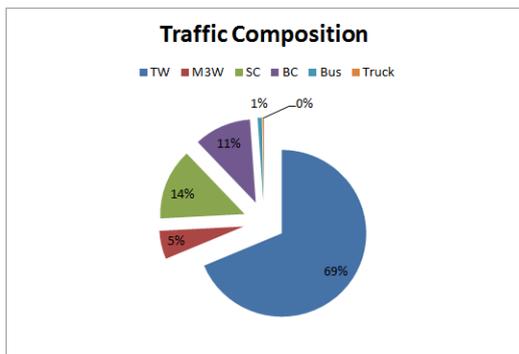


Figure 3 Evening and morning peak hour composition of A.B. Road

### Speed Data

The speed data is collected for different category of vehicles by reference line method. The variation of speed with time is shown in figure.

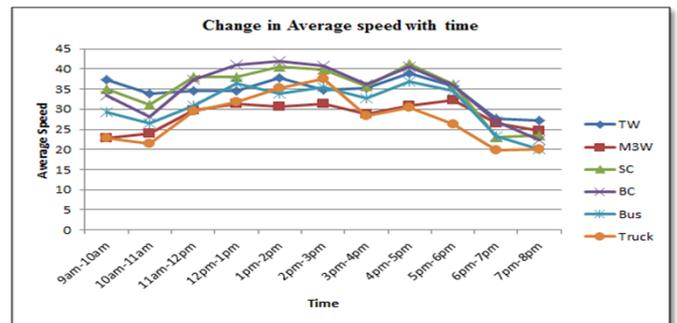


Figure4 Change in speed with time for Vijay Nagar main road

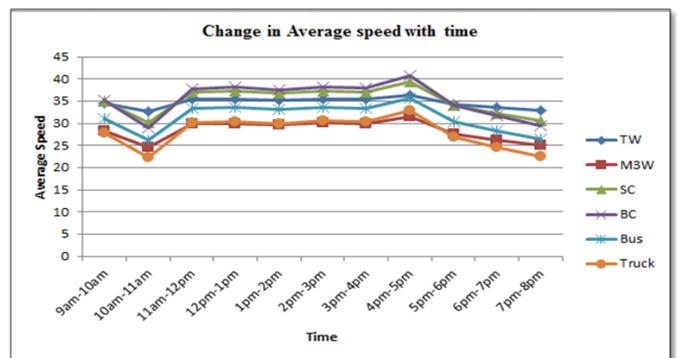


Figure5 Change in speed with time for A.B. road

### Change in speed with traffic volume

The change in speed of individual vehicle type against volume is shown in the figure 6 below.

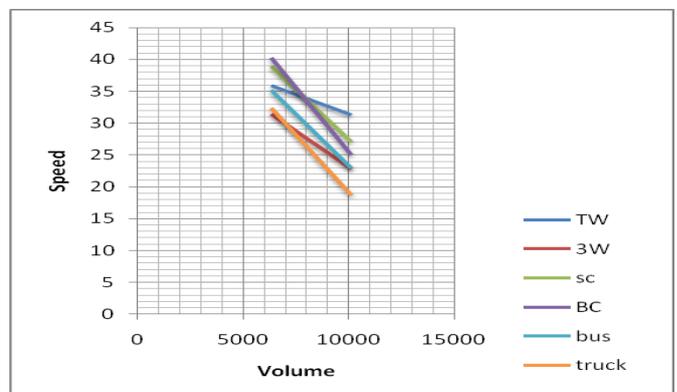


Figure 6 Speed Vs Volume Relationship for Vijay nagar Main Road

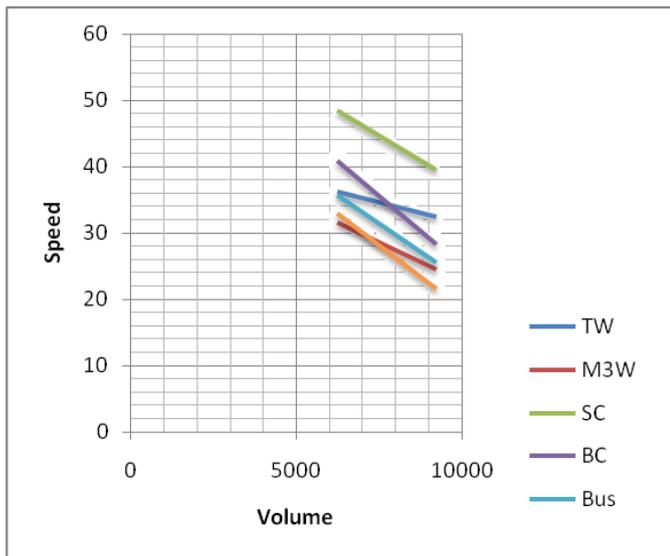


Figure 7 Speed Vs Volume Relationship for AB Road

**Variation of PCU with volume**

Fig 8 and 9 Represents the change in PCU value of different categories of vehicle with volume change.

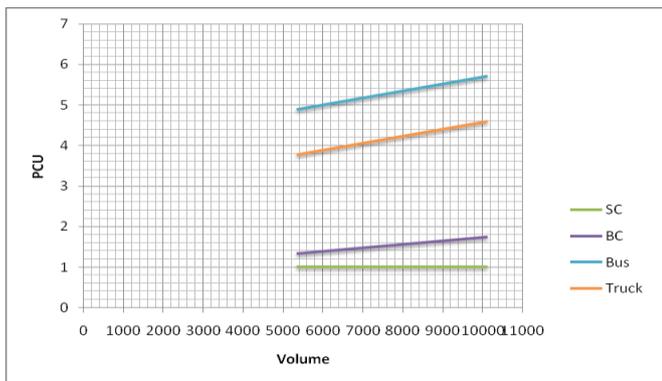


Fig 8 Variation of PCU with Volume at Vijay Nagar Main Road For SC, BC, Bus and Truck

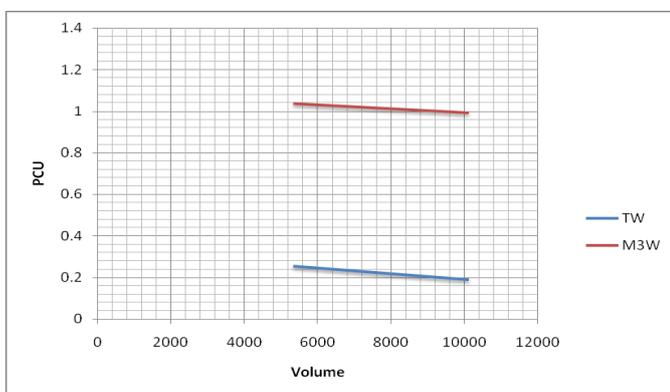


Fig 9 Variation of PCU with Volume at Vijay Nagar Main Road For TW and M3W

**Capacity and Level Of Service**

Level of service for Vijay Nagar Main Road and AB road is shown in table 2 and table 3 below.

**Table 2 Level of Service For Vijay Nagar Main Road**

Method	Volume (PCU/Hr)	Capacity (PCU/Hr)	LOS
Speed-Area Method	3661.2	4300	0.85
IRC guidelines	4829.75	4330	1.123

**Table 3 Level of Service For AB Road**

Method	Volume (PCU/Hr)	Capacity (PCU/Hr)	LOS
Speed-Area Method	3380.9	4300	0.78
IRC guidelines	4782.85	4300	1.112

The Level of service of both the road section lies in the F category as per the IRC PCU values.

**7. MODEL TO FIND PCU**

The PCU value of various categories of vehicles has been learned to vary linearly with increase in traffic volume. A mathematical model has been created based on variation of PCU values at varying volume levels for different categories of vehicles. The common form of the model is given in the following equation. A Linear Model is proposed for the determination of PCU values under heterogeneous conditions on an urban road based on the volume and PCU variation, the generated model is given below.

$$PCU_i = X(10^{-y})q + z$$

Where,  
 PCU i= PCU of vehicle type i  
 x,y, and z = Constants  
 q= Traffic Volume (Veh/Hr)

**Table 4 Values of Constants for Six Lane Divided Urban Arterial**

Vehicle category	Six lane road		
	x	y	z
Big car	8	5	0.8989
M3W	-9	6	1.087

BUS	2	4	3.9619
TRUCK	2	4	2.8393
TW	-1	5	0.3271

W					
SC	1	1	1	0	0
BC	1	1	1.507	-50.7	-50.7
Bus	2.2	3.7	5.482	149.18	-48.16
Truck	2.2	3.7	4.359	-98.13	-17.81

### 8. VALIDATION OF PCU VALUES AND MODEL

For the validation of the mathematical equation generated and to also check the validity of PCU values computed, Volume and speed data is collected at AB road six lane divided urban road. The PCU values of this location are computed with the help of generated mathematical equation. In table 7.2 the PCU values computed from the mathematical equation are compared with the PCU values estimated from the adopted methodology and the difference between the two values is checked by statistical two tail t-test for different categories of vehicles. In the t-test the t-critical values found to be higher against the t-statistical value at 95% confidence level which proves that there is no significant difference between the PCU values by model and the Speed-area method which validates the given mathematical equation.

**Table 5**t-test results comparing PCU of vehicles on Six-lane divided urban road (AB Road) with traffic volume

Vehicle category		Mean value	t0.05	t critical (Two Tailed)	Remarks
TW	Suggested value	0.226672797	-5.148	2.085	There is no significant difference
	Estimated value	0.251071818			
M3W	Suggested value	1.032084	1.768	2.085	
	Estimated value	1.018575			
Big Car	Suggested value	1.506741	-0.0144	2.085	
	Estimated value	1.507125			
Bus	Suggested value	5.182306	-4.704	2.085	
	Estimated value	5.482464			
Truck	Suggested value	4.140008	-2.729	2.085	
	Estimated value	4.359864			

### Percentage difference between IRC and Dynamic PCU values

Category	PCU values for traffic composition		PCU values generated from model	% difference for composition	
	5%	10% and above		5%	10% and above
TW	0.5	0.75	0.251	49.8	66.53
M3	1.2	2	1.018	15.16	49.1

Negative sign implies that the PCU values generated from the model is more than IRC value and Positive sign means the Dynamic PCU value from model is less than the value given by IRC

### 9. CONCLUSIONS

- PCU value of Two-wheelers Found by Speed-area method as well as generated model is found to be in range of .20 to .25 which is much lower than the IRC recommended value of .75, The IRC PCU values are 49.8% and 66.5% more for their composition in traffic stream 5% and 10% and above respectively, PCU of TW vehicles needs to be adjusted for accurate capacity estimation.
- PCU values for different category of vehicles are computed by the generated model and compared with PCU values found by speed-area method and no noteworthy dissimilarity is found in PCU values which are validated by T-Test
- PCU value for bus and truck is same in IRC 106:1990 while PCU of bus is 25.76% higher than that of bus as calculated by the Model.
- Roadway observed capacity of Vijay Nagar Main Road is computed to be 3661 PCU/hr and 4821 PCU/hr by use of Dynamic PCU values and IRC PCU values as compared to Capacity recommended by IRC for six lane divided road which is 4300PCU/hr given in IRC-106:1990.
- Roadway Capacity of AB road is found to be 3380 and 4782 by using the Dynamic PCU values and IRC PCU values as compared to Capacity recommended by IRC for six lane divided road which is 4300PCU/hr given in IRC-106:1990.
- Level of service of Vijay Nagar Main Road and AB road is found as 1.123 and 1.112 respectively by IRC Guidelines which lies in category F of LOS.

- A mathematical model is created depending on the variation of PCU with volume of various categories of vehicles.

## REFERENCES

1. Adnan M. "Passenger car equivalent factors in heterogenous traffic environment-are we using the right numbers?" *Procedia engineering* 77 (2014): 106-113.
2. Basu D., Maitra S., and Maitra B. "Modelling passenger car equivalency at an urban midblock using stream speed as measure of equivalence." (2006). *European Transport \ Trasporti Europei* n. 34 (2006): 75-87
3. Chandra S. and Kumar U. "Effect of lane width on capacity under mixed traffic conditions in India." *Journal of transportation engineering* 129.2 (2003): 155-160.
4. Chandra S. "Capacity estimation procedure for two lane roads under mixed traffic conditions." *Journal of Indian Road Congress*. Vol. 165. 2004.
5. Chandra S. "Effect of road roughness on capacity of two-lane roads." *Journal of Transportation Engineering* 130.3 (2004): 360-364.
6. Dhamaniya A. and Chandra S. "Concept of stream equivalency factor for heterogeneous traffic on urban arterial roads." *Journal of Transportation Engineering* 139.11 (2013): 1117-1123.
7. Gajjar R. and Mohandas D. "Critical Assessment of Road Capacities on Urban Roads–A Mumbai Case-Study." *Transportation Research Procedia* 17 (2016): 685-692.
8. IRC: 106-1990 Guidelines of Capacity of Urban Roads in Plain Areas. Indian Road Congress, New Delhi.
9. Koringa H.C., Patel B., Solanki R. "Estimation of Capacity and Level of Service for Urban Arterial Road – A Case Study of Rajkot City" *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 6, Issue 5, May 2017:9377-9383
10. Mardani M. et al., "Passenger Car Unit of Vehicles on Undivided Intercity Roads in India" *Procedia Computer Science* 52 (2015) 926–931.
11. Mankar U. Pratik, Khode B.V., "Capacity Estimation of Urban roads under Mixed Traffic Condition", *International Research Journal of Engineering and Technology (IRJET)*, Volume: 03 Issue: 04 | April-2016:2750-2755
12. Mondal, Satyajit, et al. "Capacity and Dynamic Passenger Car Unit Estimation for Heterogeneous Traffic Stream of Urban Arterials: A Case Study of Indian Metropolis" No. 17-00273. 2017.
13. Patel B.N., Jadeja M.,Vala M."Determination of Dynamic PCUs of different Types of Passenger vehicles on urban road: A case study of Rajkot city." *IJSRD*, Vol. 4, Issue 03, 2016:480-483
14. Roy N., et al. "Effect of mixed traffic on capacity of two-lane roads: case study on Indian highways." *Procedia engineering* 187 (2017): 53-58.