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Effect of Traffic Characteristics on the Dynamic PCU under Mixed Traffic Condition at Urban Signalised Intersection

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Abstract - *Second edition of HCM (1965) introduced the concept of passenger car unit (PCU) which enable the researcher around the world to deal with mixed traffic flow. Traffic conditions in India, and many of the developing countries, differ from the western country mainly in the composition and lane discipline. Under such conditions, vehicles widely varying in their size, accelerating abilities, and performance capabilities to share same lanes of the road, which is highly heterogeneous in nature. Especially at intersection. Hence, PCU values of several vehicles are not remain static. Different methods are used for estimation of PCU by some researchers on signalised intersection under mixed traffic. Hence, objective of the present study is to estimate PCU values at signalised intersection in under mixed traffic. This study illustrate the comparison of different dynamic PCU (DPCU) estimation methods (time occupancy method, area occupancy method, time headway method, and regression method). Which shows that time occupancy and area occupancy method performs better to find PCU of vehicles in mixed traffic condition. Effect of traffic flow characteristics on the DPCU value were analyse. With the use of estimated PCU by area occupancy method, mathematical models developed for estimation of DPCU of various category vehicles using regression technique and correlation of several traffic parameters with the DPCU are illustrate with the graphs. Four intersections with varying width and compositions have selected for this research work one from Noida city and three from the Ahmedabad city.*

Key Words: Urban area, Signalised intersections, Mixed traffic; Passenger car unit.

1. INTRODUCTION

Traffic conditions in India, having several vehicles with widely variation in their size, accelerating abilities, and performance capabilities share same lanes of the road. Which is highly heterogeneous in nature. Heterogeneous traffic behaves differently compared to the homogeneous traffic condition.

Fig -1 Heterogeneous traffic

Source: Author observed photo

As shown in Fig 1 (Parimal intersection, C.G road Ahmedabad) moving vehicles of heterogeneous traffic condition, may occupy any suitable lateral position on the road. Due to the mixed traffic flow intersections are take into account as more critical compare to straight road from safety point of view, which have different vehicles with static and dynamic vehicular characteristics. Therefore, to make an intersection secure is challenging part for traffic engineers. Hence for effective planning, design, operation, and management of given intersection the study of traffic operations and traffic characteristics at intersections is of topmost importance.

Hence, main aim of this research work is, to study the effect of traffic characteristics on the dynamic PCU under heterogeneous traffic condition at urban signalised intersection. In addition, to develop model for DPCU of different vehicles category. Other objectives of this study are to illustrate the comparison of different dynamic PCU (DPCU) estimation methods (time occupancy method, area occupancy method, time headway method, and regression method). To analyse effect of traffic flow characteristics on the DPCU value. To develop mathematical model for estimation of DPCU of various category vehicles using

regression technique and, to illustrate correlation of several traffic parameters with the DPCU with the graphs. Four intersections with varying width and compositions are selected, for this research work one from Noida city and three from the Ahmedabad city.

2. LITERATURE REVIEW

IRC – 1990 gives static PCU of ten categories vehicles that found on Indian road conditions. Since that, several research held on the PCU of various vehicles categories. Based on vehicle area and speed concept (Chandra et al., 1996) gave a methodology for the estimation of dynamic PCU. According to that given method, PCU values for different vehicles under mixed traffic situation is inversely proportional to the space occupancy (Area Occupancy) ratio and directly proportional to the clearing **speed.** (Mathew Sonu et al., 2016) To find PCU of vehicles on four-legged roundabout **Time Occupancy** concept is used. Instead of considering clearing speed ratio, ratio of time occupancy of subject vehicle to occupancy time of standard car is taken.

Arasan V T and Dhivya G have introduced new concept of **Area occupancy** in 2010 for the study of the mix traffic condition. (P. Preethi and R. Ashalatha; 2016) worked on the topic of the estimation of dynamic PCU using the area occupancy concept at signalised intersection. (Subhash Chand et al; 2017) also used concept area occupancy of vehicle in the analysis as key parameter. Area occupancy and time occupancy concepts were introduced to determine PCUs at signalised intersections in India.

(Partha SAHA et al; 2009**) used Headway ratio method** to estimate the PCE of different types of vehicle.

Branston and van Zuylen proposed Method for estimation of PCUs by regression, in 1978 and; in 1981, Branston and Gipps proposed the **regression model** for obtaining PCUs. This method evaluate PCU with consideration of saturation flow. Arasan and Jagadeesh also derived PCUs using the regression model in 1995 in which independent variables were the number of vehicles of each type crossing the stop-line during saturated green time, and dependent variable was the saturated green time.

3. SITE LOCATION

Following guidelines are followed for site selection.

- Up to 100 m from intersection, there is no Bus stop on approach.
- Up to 100 m from intersection, there is no parking on the approach.
- For the pedestrians there is no separate phase.
- There should be proper channelization on intersection with separate lane provided for left turning.
- 90-degree angle between approaches.
- Gradient should be flat.
- Aim is to find the effect of traffic characteristics on the PCU. Therefore, this study require selecting the different signalised intersections, which have the different traffic compositions, different approach width, different right turning flow rate and, different saturation flow rate. So that the effect of these parameters on the PCU can be found out.
- Videography is used for the data collection of the peak hours. So that the suitable location at the intersections should also be available from where, the videography can be done.

By considering the above criteria inventory survey on seven signalised intersections was carried out. And three intersections are selected on the basis of the criteria mention above

1) **Swastik intersection, C. G. road, Ahmedabad**
2) **Parimal intersection, C. G. road, Ahmedabad**
3) **Fortune landmark intersection, Ashram road, Ahmedabad**

And another signalised intersection in urban area of Noida, Delhi is selected, which has the different vehicle compositions from the Ahmedabad signalised intersections, and to evaluate the effect of different composition on the Dynamic PCU this intersections helps. Each of the approach have different widths ranging from 6.4 m to 10.3 m. During major part of the green time, approaches are nearing to saturated condition during peak hour when traffic flow is very heavy and lane discipline does not followed by the vehicles.

4. DATA COLLECTION

4.1. Inventory survey

Different parameters about selected intersections are collected, with the help of inventory survey. Which are useful for the study. Which includes width of the different approaches, Signal timing for all approaches, presence of separate left turning lane and, number of the lanes at the approaches. Data of the inventory survey shows in the following Table 1

4.2 Traffic Flow Data.

To find the peak hour of intersections Classified Volume Count Survey was conducted for 10 hours with 12 - 15 enumerators. From the CVC of 10-hour (8:00 AM – 6:00 PM) morning and evening peak hour are evaluated.

Various traffic surveys are requires for the study of the signalised intersections after the completion of Inventory

Table -1: Details of Signalised intersections

Intersetion	Name of Approach	Approach width (m)	No of Lanes	Signal Timing (Sec)			Cycle Time (Sec)
				R	A	G	
Swastik	Stadium road(N)	9.1	2	21	3	85	109
	Navrangpura (E)	8	3	25	3	81	109
	Girish circle (S)	10.5	2	20	3	86	109
	Gujarat university (W)	8.8	2	24	3	82	109
Parimal	Panchavati(N)	8	3	87	2	26	115
	Gujarat College (E)	11.5	2	92	2	21	115
	Paldi (S)	7.5	3	92	2	21	115
	Polytechnic (W)	11	2	83	2	30	115
Fortune Landmark	Wadaj (N)	11.4	3	82	4	26	112
	River Front (E)	5.2	2	86	4	22	112
	Income Tax (S)	10	3	82	4	26	112
	Ring Road (W)	6.6	2	86	4	22	112
Stadium Chowk	Spice mall(N)	9.0	2	94	3	30	127
	DND (E)	10.3	2	94	3	30	127
	Noida Mor (S)	6.4	2	99	3	25	127
	Chora Mor (W)	9.7	2	94	3	30	127

survey, and classified volume count survey. Videography method is used to collect peak hour data for selected intersections. Traffic data collected at the selected intersection include various parameters like,

1) Classified Volume Count
2) Traffic flow rate per cycle in veh/hr
3) Time headway
4) Time Occupancy of vehicles

Fig -2: Camera view at intersections

Camera was set in such location from that whole clearance area of intersection and up to 10 m from the stop line approach should be visible so that clearance time of straight and right moving vehicles can be counted as shown in **Fig 2**

Traffic flow were recorded using the above video camera set up on working day during the morning peak period from 10:00 am to 12:00 noon and, the signal timing of each approach was noted manually at intersection.

4.3 Data Extraction

Classified vehicular volume and time occupancy measurements for individual vehicles are extracted from the recorded videos using Avidemux Software. To ensure accuracy vehicles were counted at five seconds intervals and after completion of vehicle count for five seconds time occupancy of sampled vehicle for the same five seconds vehicles are measured.

For the measurements of time occupancy (difference between the time when vehicle enters in the intersection from stop line and time when vehicle exit the intersection from the stop line of exit approach) of straight traffic and right turning vehicle the video was rewound for every single vehicle reading. If the stop line marking are not available on the intersections than with any screen marking tool the imaginary stop line can be marked as shown in the **Fig 3** in which the screen of theAvidemux Software is shown with the imaginary stop lines which were marked with the screen marker tool.

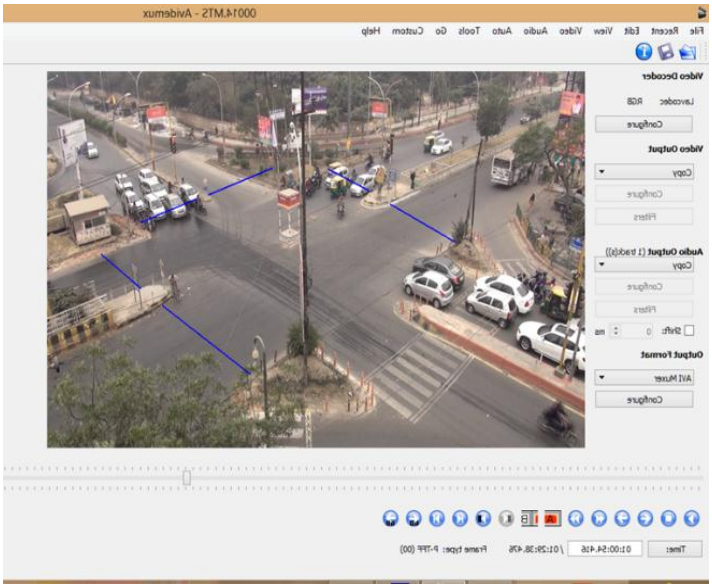


Fig -3: Screen of the Avidemux Software with the imaginary stop lines marking

To ensure the validity of results, a representative and a statistically accepted sample was chosen in which data of the following vehicles were rejected and excluded from the analysis:

• The vehicles which discharging from the queue before green signal starting.
• Vehicles impeded by pedestrians or turning vehicles.

Traffic behaviour at signalised intersection in mix traffic condition is such that even before the green signal starts vehicles in front-row get set in to motion. Hence, start-up time loss is low in such cases due to this reason in Indian condition when CVC of intersection is carried out; there is no need to calculate loss time, but some vehicle set to motion and few are not so that during calculation of PCU of vehicles in such condition; PCU should be calculate for those vehicle who are set in motion only after the green signal start.

5. DATA ANALYSIS

5.1 Methods of PCU Estimation

DPCU are calculated with four techniques (Time Headway method, Regression method, Time Occupancy method, Area Occupancy method)

1. Time Headway Method

To find the DPCU with Time Headway method. Time headway of the vehicle category (x) and Time headway of car is required. Time headway of the vehicle category (x) is the difference between the pass of the fronts of successive vehicles (One vehicle exact followed by other) of category (x) at a specified point. It is measured in seconds.PCUs is calculated by using the following equation

PCU(x-x) = hA(x-x)/hA(c-c)

Where,
hA(c-c) = Adjusted Mean headway of a car followed by a car
hA (x-x) = Adjusted Mean headway of a type x vehicle followed by a type x vehicle.

2. Regression Method

In method of evaluating the DPCU by regression technique. Independent variables are the number of vehicles of each different category crossing the stop-line during saturated green time and dependent variable is the saturated green time.

$T = a_0 + a_1*X_1 + a_2X_2 + a_3X_3 + \ldots\ldots a_n*X_n$

Where,
T = Saturated green time (sec),
a_0= Intercept,
a_1, a_2, a_3, a_4, a_5 are coefficients of vehicle types,
X_1, X_2, X_3, X_4, X_5 = Number of vehicles of each category.

Then, Passenger car unit of vehicle type i, PCUi= a_i / a_{car}

3. DPCU by Time Occupancy Technique

Following equation used to evaluate Dynamic Passenger Car Unit (DPCU) using Time Occupancy method. Here equation for finding the DPCU is shown.

$$PCUi = \frac{Occupancy\ time\ ratio\ of\ i\ vehicle\ to\ standard\ car}{Space\ ratio\ of\ car\ to\ the\ i\ vehicle}$$

$$PCU_i = \frac{Ti/Tc}{Ac/Ai}$$

Where

PCUi =is the PCU of the vehicle of *i category*;
*T*c = Average time occupancy of standard car in seconds for 5-sec interval;
*T*i = Average time occupancy of subject vehicle in seconds for 5-sec interval;
*A*c = Projected rectangular area of a car as reference vehicle in m^2, and
*A*i = Projected rectangular area of the vehicle of i category in m^2.

The physical dimensions for different vehicle categories used for the estimation of PCU value are given in the following **Table 2**

Table -2: Physical dimensions for different vehicle categories for PCU estimation

Vehicle type	Physical dimension (m)		Area (m2)
	Length	Width	
Two Wheeler	1.87	0.64	1.20
ThreeWheeler	2.6	1.4	3.64
Small car (CS)	3.72	1.44	5.36
Big car (CB)	4.58	1.77	8.11
LCV	5.0	1.9	9.50
Buses and HCV	10.3	2.5	25.75

(Source: Mathew Sonu et al, 2016)

4. DPCU by Area Occupancy Technique

Area occupancy is the proportion of the time set of observed vehicle occupy the chosen stretch. It is non-dimensional parameter and its value ranges from 0 to 1. Area occupancy of an individual vehicle category is the sum of the area occupancy of that category vehicles during the observed time which shown in the following equation 1 and 2. In this study observed time taken as 5 seconds.

$$AO = \Sigma_i (AO)i \quad (1)$$

$$AO_i = \frac{a_i \Sigma_n t_i}{TA} \quad (2)$$

Where

AO_i = the area occupancy of "i" category vehicle.
a_i = horizontal projected area of "i" category vehicle.
t_i = time occupancy of "i" category vehicle.
T = observed period in seconds.
A = area of study stretch.

Let $(A_{eq})_i$ be total standard car horizontal projected area equivalent to "i" category vehicle clearing the observation area during observed green time and t_s be the average occupancy time of the all vehicles passing the stop line during the observation green time in the intersection area. So that equivalent standard car occupancy corresponding to the observed area occupancy is $\frac{(A_{eq})_i t_s}{TA}$ total occupancy of a vehicle category "i" can be converted to standard car area occupancy as shown in Eqs (3) and (4).

$$AO_i = \frac{a_i \Sigma_n t_i}{TA} = \frac{(A_{eq})_i t_s}{TA} \quad (3)$$

$$(A_{eq})_i = \frac{a_i \Sigma_n t_i}{t_s} \quad (4)$$

Let $N(cs)i$ is the equivalent number of standard car spaces corresponding to "i" category vehicle, present in the intersection area during observed green time can be determined using Eq (5)

$$N(cs)i = \frac{(A_{eq})_i}{a_{sc}} \quad (5)$$

Where
a_{sc} = the horizontal projected area of standard car in m^2.
The number of standard car spaces obtained through Eq.(5) Can be considered as the equivalent number of passenger cars to the total number of "i" category.
Take ni be the number of vehicles in the "i" category then the dynamic PCU value of "i" category vehicle can be calculated out using following Eq (6).

$$PCU_i = \frac{N(cs)i}{n_i} \quad (6)$$

Where
n_i is number of vehicle of "i" category whose time occupancy are used for the calculation of PCU
Here put the value of $N(cs)i$ from Eq.(5)

$$PCU_i = \frac{(A_{eq})_i}{a_{sc} n_i} \quad (7)$$

After calculation of PCU using four methods, following results are derived.

1) Using Time Headway method PCU can be calculated for those vehicles who are coming successive at the approach. In mixed traffic condition like India only 2W and small car coming successive one behind other so that PCU can be calculate for 2W and , small car only.
2) With the help of Regression method PCU cannot be evaluated for that vehicles, whose percentage are negligible compare to other vehicles
3) With the help of the Time Occupancy method and Area Occupancy method PCU can be calculated for all category of vehicles in specific time interval so these two methods can be used to find PCU of vehicles in mixed traffic condition like India.

In this study PCU are calculated using Area Occupancy method. Results of the four methods for Chor Mor approach is shown in the **Table 3**

Table -3: Results of the four methods for Chor Mor approach

Vehicle Category	Time Headway		Regression	Time Occupancy		Area Occupancy	
	Straight	Right		Straight	Right	Straight	Right
2 W	0.505	0.643	0.354	0.15 - 0.28	0.20 – 0.25	0.18 - 0.23	0.20 – 0.22
3 W	-	-	0.392	0.62 - 0.71	0.63	0.70 - 1.00	0.81 – 1.20
Car	1	1	1	-	-	0.87 - 1.07	0.93 – 1.15
BC	-	-	-	1.75 - 2.18	-	1.35 - 1.73	1.46 – 1.66
LCV	-	-	-		2.00	1.45 - 1.67	1.41 – 1.61
HV/BUS	-	-	2.316	4.7 - 7.3	-	3.86 – 6.35	5.4 – 6.1

5.2 Determination of the Dynamic PCU by Area Occupancy Method

DPCU for all the approaches are calculated with this method after comparison of the four methods. In the following **Table 4** range of Dynamic PCU values at the selected intersection approaches are shown. And in **Table 5**, range of right turning percentage, approach width and, average compositions are shown.

Table -4: Range of DPCU values at selected approaches

Approach No	Range of Dynamic PCU Values						
	2W	3E	CS	CB	LVC	BUS	HCV
1	0.17 - 0.24	0.58 - 0.85	0.90 - 1.47	1.10 - 2.00	1.69 - 2.01	5.27	5.04 - 5.58
2	0.13 - 0.23	0.58 - 0.94	0.91 - 1.33	1.30 - 1.93	1.77 - 2.29	5.8	-
3	0.16 - 0.23	0.55 - 0.85	0.83 - 1.26	1.46 - 1.76	1.80 - 2.30	5.23 - 6.78	5.72
4	0.17 - 0.24	0.74 - 0.97	0.76 - 1.20	1.32 - 2.02	1.23 - 1.86	5.00 - 5.04	4.52 - 5.96
5	0.19 - 0.22	0.57 - 0.88	1.01 - 1.29	1.55 - 2.01	2.00 - 2.00	-	-
6	0.17 - 0.30	0.69 - 1.53	0.68 - 1.37	0.95 - 1.98	1.45 - 1.93	4.50 - 6.97	3.86 - 9.48
7	0.14 - 0.23	0.50 - 0.9	0.94 - 1.28	1.30 - 2.02	1.53 - 2.35	5.01 - 8.73	5.97
8	0.15 - 0.27	0.51 - 1.18	0.71 - 1.35	1.06 - 2.04	1.62 - 2.32	4.26 - 7.79	5.63 - 8.08

Table -5: Average range of right turning percentage and average composition of vehicle

Approach No	Avg. % of Right turning	Approach Width (in m)	2W	3W	CS	CB & LCV	Bus & HVC
1	30.77 - 52.63	6.4	46	4	38	4	1
2	37.14 - 48.1	7.5	69	12	16	2	0
3	32.29 - 50.65	8.8	67	13	16	2	1
4	2.86 - 31.25	9	31	5	47	6	3
5	14.81 - 28.95	9	71	13	13	1	0
6	15.79 - 42.86	9.7	40	5	34	8	7
7	6.90 - 21.21	8.45	37	41	7	5	8
8	3.85 - 30	10.3	32	5	41	10	7

6. EFFECT OF VARIOUS TRAFFIC FACTORS ON PCU VALUES

In mixed traffic condition at intersections vehicle of several category cross the stop line with varying compositions during green saturated time. Hence, the effect of considerable changes can be observed on DPCU value with the changes in the vehicles compositions, Flow rate, Approach width, and Right turning percentage. To show the effect of above traffic characteristics average PCUs of straight moving vehicle of green phase are used.

6.1 Effect of Traffic Composition on Dynamic PCU value.

Here effect of percentage of vehicle on its own PCU value are described considering the composition on different approaches as shown in Table 5

PCU of 2W have the negative correlation with proportions of 2W. In **Fig -4** graph of percentage of 2W to the PCU of 2W are shows for 6.4 m & 7.5 m approach width. As the percentage of 2W increase with 5%, PCU of 2W decrease with 0.66%. For different approaches, rate of decrease in PCU of 2W are different.

PCU of 3W decreases with increase in its own percentage, as shown in **Fig 5** i.e. For 9 m & 9.1 m approach width PCU of 3W decrease 3.476 %with increase in 5% of its own percentage. For different approaches, rate of decrease in PCU of 3W are different.

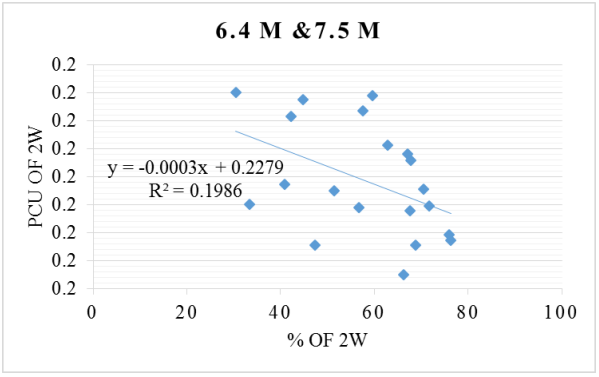


Fig –4: Effect of 2W proportion on the PCU of 2W.

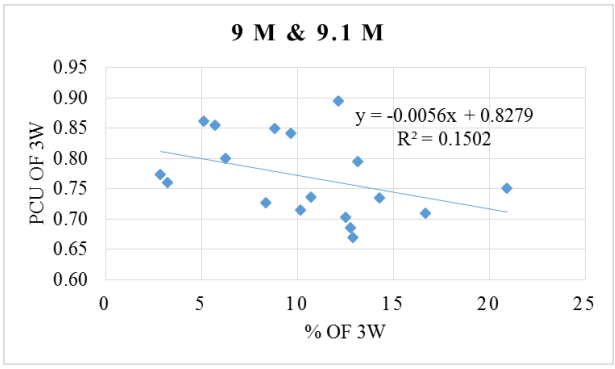


Fig -5: Effect of proportion of 3W on PCU of 3W

Percentage of small car as increase PCU of small car increases in all approaches as shown in the **Fig 6**, for 10.3 m approach width PCU of small car increase 4.24% with 5% increase in its own percentage. For different approaches, rate of increase in PCU of small car are different.

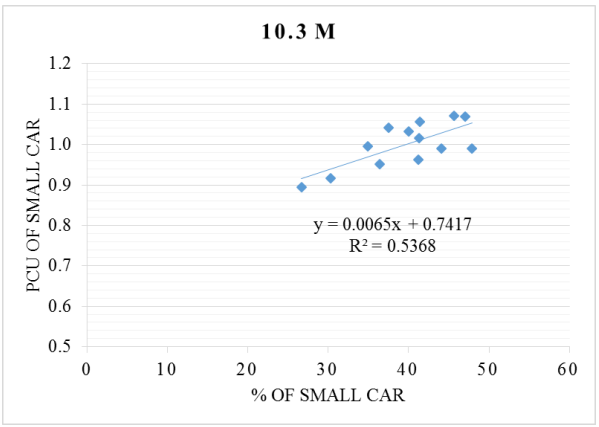


Fig -6: Effect of small car (CS) proportion on the PCU of CS

PCU of big car (CB) have the negative correlation with its own proportions. In **Fig 7** graph shows the effect of proportion of big utility vehicles (BUV) which include percentage of light commercial vehicles (LCV) and big car (CB) to the PCU of big car for 9 m approach width. As percentage of BUV increases with 2%, PCU of big car decrease with 5.64 %. Hence, PCU of CB decreases with its

own proportion indirectly. For different approaches, rate decrease in PCU of big car are different.

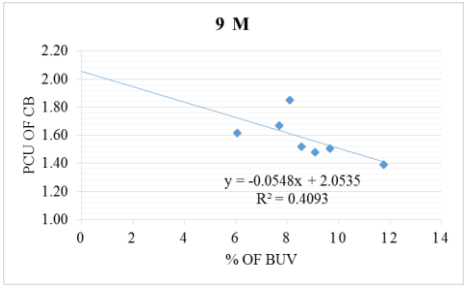


Fig -7: Effect of BUV proportion on PCU of CB

PCU of LCV is not having any significant correlation with percentage of BUV for different approach width as shown in **Fig 8** so for the model development of PCU of LCV, Proportion of big utility vehicle are not used as independent variable.

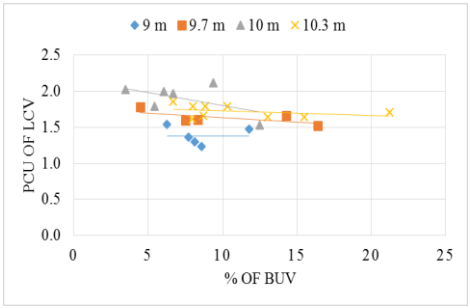


Fig -8: Effect of proportion BUV on PCU of LCV

PCU of BUS have the positive correlation with the proportion of heavy vehicles (which includes the proportion of Bus and HCV) for 10.3 m approach width that is clearly shown in **Fig 9**. Which show the impact of the HV for 10.3 approach width, PCU of Bus increase with 2.9 % with 5 % increase in the proportion of heavy vehicles For different approaches, rate of increase in PCU of Bus are different.

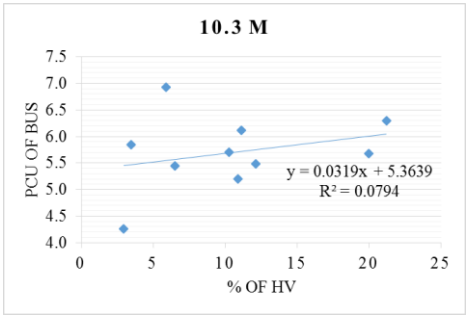


Fig. 9 Effect of proportion of HV on the PCU of Bus.

PCU of HCV have the positive correlation with the proportion of heavy vehicles (which includes the proportion of BUS and HCV) for various approach width rate of increase in PCU are different. For 9 m approach width PCU of HCV increase with 7.97 % with increase 2% in percentage of heavy vehicle, that shown in **Fig 10**.

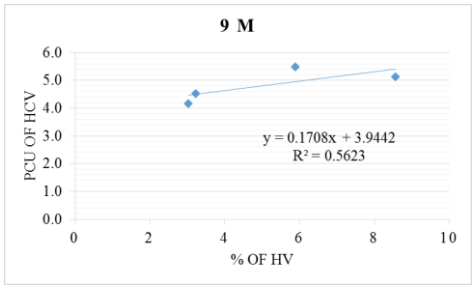
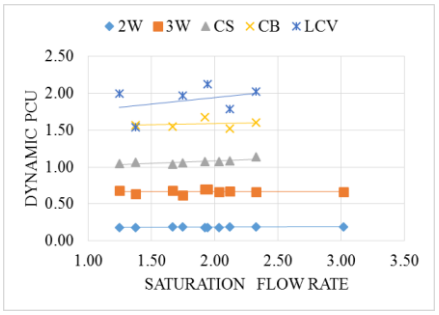


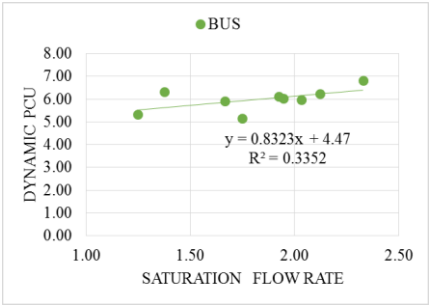
Fig -10: Effect of HV proportion on the PCU of HCV

6.2 Effect of Saturation Flow Rate on PCU

An effort was also made to investigate the effect of saturation flow rate on PCU of all vehicles, which are calculated with area occupancy method. In Saturation Flow Rate, straight moving and right turning vehicles both are included. For the same flow rate compositions can be varies, but for the same approach the composition remain almost same. So to illustrate the effect of saturation flow rate on PCU, individual approach is considered. Rate of increase in PCU of all vehicle category with increase in the saturation flow rate depends on the size of vehicle, as size of vehicle increase the rate of increase in the PCU of vehicle is more. For example on 10 m approach width when saturation flow rate increase with 0.5 veh/sec PCU of 2W, small car, LCV, and BUS increase with 1.09 %, 3.09 %, 4.91%, and 7.28 % respectively. Graphs for 10 m approach width are shown in the **Fig 11**.



(a)

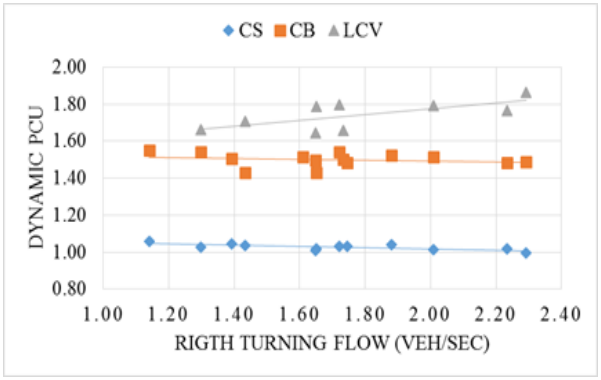


(b)

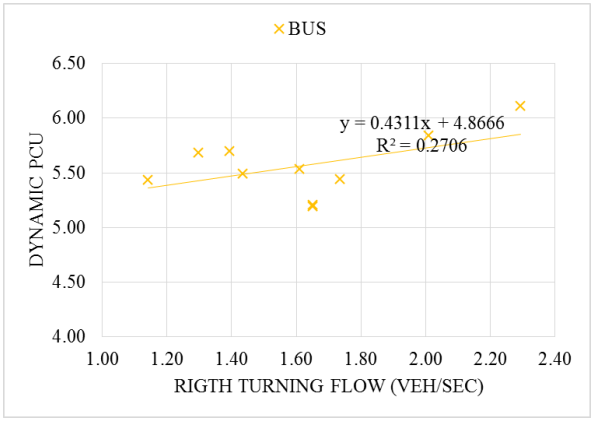
Fig -11: Effect of Saturation Flow Rate on PCU

6.3 Variation in PCU of vehicles in presence of Right Turning Traffic

To understand the effect of right turning traffic on the PCU of straight moving vehicle where both directions (straight + right) movement were present in the same approach without separate lane marking has been taken. Right turning traffic does not have unique effect on the PCU of different vehicles, although **Fig 12 (a)** & **(b)** shows the effect of right turning traffic on the PCU of several category vehicles for approach having 10.3 m width as example. For this approach PCU of small car and big car are decrease with 1.63 % and 0.97 % respectively with increase in 0.5 veh/sec flow rate in right turning traffic, and PCU of LCV and BUS increase with 4.79 % and 4.07 % respectively with increase in 0.5 veh/sec flow rate in right turning traffic.



(a)

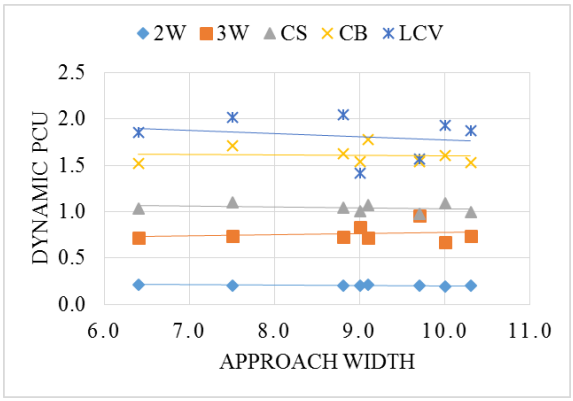


(b)

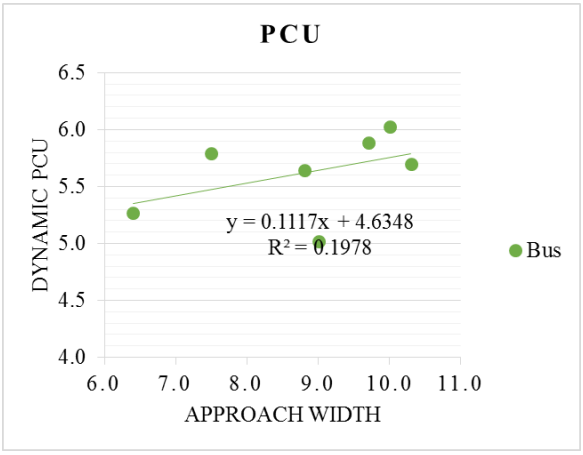
Fig -12: Variation in PCU with right turning traffic.

6.4 Variation in PCU with Approach Width

For the condition of 8 approaches as shown in Table 5; With increase 1 m in the width of approach PCU of 2W, small car (CS), big car (CB) and, LCV decrease with 1.53%, 0.94%, 0.38% and, 1.7% respectively; and PCU of 3W and Bus are increase with 2.05% and 2.3% respectively. That illustrate in the **Fig. 13.** (a) & (b).



(a)



(b)

Fig -13: Effect of approach width on PCU

7. DYNAMIC PCU MODEL

Variation in Dynamic PCU described in section 6 are based on individual parameters of the traffic stream. Complete variation on PCU due to change in the traffic stream condition can be explain by developing mathematical model based on regression analysis. Mathematical model enable the easy and quick estimation of PCU values for the prevailing geometric and traffic stream condition. Proposed mathematical regression based model for various vehicle category are in the following form. In this model percentage of different vehicles, saturation flow rate, right turning flow rate and approach width are included.

$$PCU_i = a_0 + a_{2W}P_{2W} + a_{3W}P_{3W} + a_{CS}P_{CS} + a_{BUV}P_{BUV} + a_{HV}P_{HV} + a_S S + a_{rt}N_{rt} + a_W W$$

Where
PCUi is the PCU of "i" category vehicle;
a_0, a_{2W}, a_{3W}, a_{CS}, a_{BUV}, a_{HV}, a_s, a_{rt}, a_W are the regression coefficients;
P_{2W}, P_{3W}, P_{CS}, $P_{BUV\ and}$, P_{HV} are the percentage of the 2W, 3W, small car, Big utility vehicles (Big car and LCV) and, heavy vehicle (BUS and HCV);

S is saturation flow rate (straight + right) of the approach in veh/sec;
N_{rt} is the flow rate of right turning traffic in veh/sec and;
W is the width of the approach in meter.

Coefficients of the developed regression model are shown in the **Table 6** and **Table 7**, values given in the parenthesis are the "t" values of coefficients, which were found at 95% confidence level, and mostly all t values are more than 1.96, which specifies the strength of models for estimating the PCU values (C R Kothari, "Research Methodology" third edition. R square value of models are also shown in Table 7

Table -6: Coefficients of the PCU models for various vehicle category

PCU of	a_0	a_{2W}	a_{3W}	a_{CS}	a_{BUV}	a_{HV}
2W	0.2334 (31.34)	0.0003 (-2.77)	0.0004 (-6.65)	-	-	0.001 (-4.10)
3W	0.402 (8.82)	0.0030 (5.79)	0.0017 (2.92)	0.0044 (7.80)	0.0079 (8.22)	
CS	0.5251 (8.69)	0.0076 (10.20)	0.0066 (8.38)	0.004 (5.08)	0.0106 (8.10)	
CB	1.1573 (8.66)	0.0057 (4.29)	0.0041 (2.89)	0.004 (2.51)	0.0032 (-1.51)	0.004 (2.13)
LCV	-	0.0145 (5.93)	0.001 (5.78)			0.0085 (-1.53)
Bus	-	0.0315 (5.67)	0.0425 (12.31)	0.041 (14.69)	0.0417 (3.974)	0.062 (6.96)
HCV	-		0.097 (3.42)	0.076 (7.75)		0.116 (2.84)

Table -7: Coefficients of the PCU models for various vehicle category

PCU of	a_Q	a_{rt}	a_W	R^2
2W	0.006 (3.10)		0.003 (-3.22)	0.61
3W	0.008 (1.32)			0.8
CS	0.036 (-3.77)	0.029 (-1.99)		0.72
CB		0.034 (-1.36)		0.67
LCV	0.307 (-3.29)	0.447 (3.65)	0.154 (12.07)	0.99
Bus	1.276 (8.34)	0.934 (-4.39)		0.99
HCV		1.766 (2.82)		0.98

8. RESULTS AND DISCUSSION

Effect of composition on the PCU of vehicle as described in section 6.1 can be justified by the time occupancy of subject vehicle and occupancy of total stream. As shown in Fig 6 PCU of small car increase with increase in its own percentage because the PCU of subject vehicle is directly proportional to time occupancy of subject vehicle and inversely proportional to the average time occupancy of traffic stream. As shown in the **Fig 14** with increase in 5% small car percentage, time occupancy of small car increase with 3.82% while average time occupancy of traffic stream decrease with 1.26 %. As the dynamic PCU of subject vehicle is estimated based on the ratio of area occupancy of subject vehicle and average time occupancy of traffic stream, PCU of small car increase with increase in its own percentage. Same as effect of vehicle percentage on its own PCU can be illustrated from the time occupancy concept.

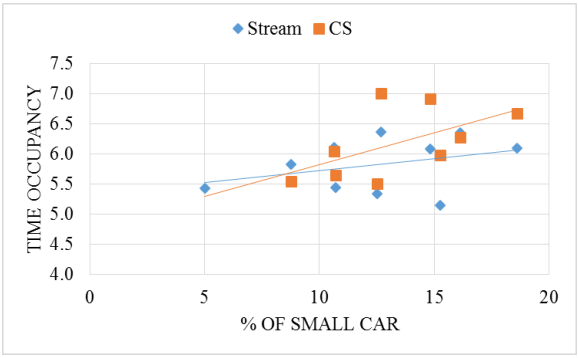


Fig -14: Effect of proportion of small car on time occupancy

For the condition described in Table 5, effect of saturation flow rate on PCU of through traffic can also justified with time occupancy concept. As saturation flow increase, maneuverability of the vehicle decrease, hence time occupancy of the subject vehicle and average time occupancy of traffic stream increase and from the Eq. 4 in section 5.1, as the time occupancy of traffic stream inversely proportional to the equivalent homogeneous traffic stream area. As shown in the Fig 11 (a), PCU of LCV increase with increase in the saturation flow rate, this effect can be justified with the following Fig 15; in which with increase in saturation flow, the rate of increase in time occupancy of LCV is more than the rate of increase in average time occupancy of traffic stream.

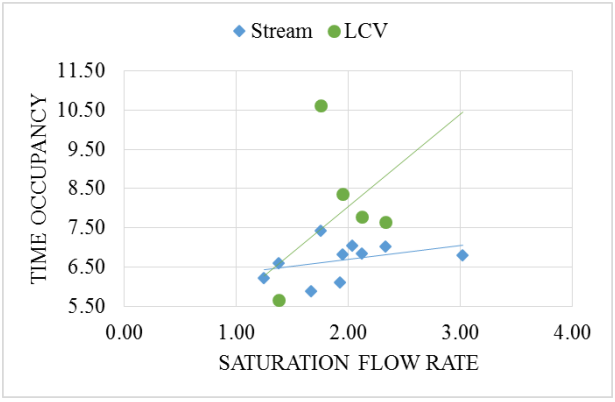


Fig -15: Effect of saturation flow rate on time occupancy

For the composition of vehicles and percentage of right turning vehicles as shown in the Table 5, effect of right turning traffic is not unique for all approaches. However,

for the individual approach effect of right turning traffic on PCU of through traffic PCU can be justified with time occupancy.

For this research work, approaches were selected having the approach width range from 6.4 m to 10.3 m. For the condition described in Table 5, effect of width on PCU of vehicles is shown in the Topic 6.4. These effects can be justified by the time occupancy of subject vehicle and average time occupancy of traffic stream. As a sample effect of width on Bus can be explain through the **Fig 16**, as it is clearly seen that as approach width increase by 1 m, time occupancy of bus decrease with 2.38% while average time occupancy decrease with 4.97 %. As dynamic PCU of subject vehicle is estimated based on the ratio of the area occupancy of the subject vehicle and average time occupancy of the traffic stream, the PCU of bus increase with increase in 1 m approach width.

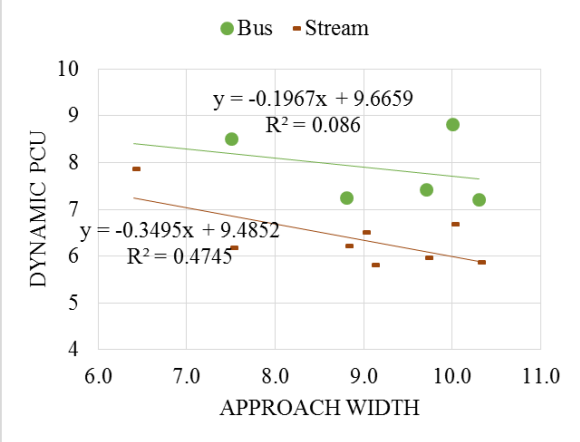


Fig -16: Effect of approach width on time occupancy

9. CONCLUSIONS

This study illustrate the comparison of different dynamic PCU (DPCU) estimation methods (time occupancy method, area occupancy method, time headway method, and regression method). Which shows that time occupancy and area occupancy method are suitable to estimate PCU of vehicles in mixed traffic condition. To analyse the effect of traffic flow characteristics on the DPCU value correlation of several traffic parameters with the DPCU are illustrate with the graphs. mathematical model are developed for estimation of DPCU of various category vehicles using regression technique and. In addition, following results are concluded for the selected approaches.

Traffic compositions, saturation flow rate, right turning traffic and approach width has the significant effect on PCU of various vehicles.

- PCU of 2W, 3W and, big car have a negative correlation with its own proportion.
- PCU of small car, bus and heavy vehicles have the positive correlation with proportion of heavy vehicles. Which includes the proportion of BUS and HCV.
- PCU of LCV is not having any significant correlation with percentage of big utility vehicles (BUV)

An effort was also made to investigate the effect of saturation flow rate on PCU. In Saturation Flow rate both straight moving and right turning vehicles both are included. Rate of increase in PCU of all vehicle category with increase in the saturation flow rate depends on the size of vehicle, as size of vehicle increase the rate of increase in the PCU of vehicle is more.

Right turning traffic does not have unique effect on the PCU of different vehicles

With increase 1 m in the width of approach PCU of 2W, small car (CS), big car (CB) and, LCV decrease with 1.53%, 0.94%, 0.38% and, 1.7% respectively; and PCU of 3W and Bus are increase with 2.05% and 2.3% respectively.

Mathematical model enable the easy and quick estimation of PCU values for the prevailing geometric and traffic stream condition. Mathematical regression based model for various vehicle category were developed. Even though model developed based on the traffic conditions of eight approaches from various intersections, this model can be used for other signalised intersection having heterogeneous traffic conditions where all type of vehicles are present.

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