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ESTIMATION OF SATURATION FLOW AT SIGNALIZED INTERSECTION UNDER MIXED TRAFFIC CONDITIONS

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Abstract - *Traffic in India consists of both motorized and non-motorized vehicles. It imposes heavy loads on the urban road network. Due to lack of lane discipline various types of vehicles make the traffic flow heterogeneous. Therefore, it is necessary to estimate the saturation flow at the signalized intersection. This study analyses the effect of traffic flow on saturation flow and capacity. The study has been conducted with the help of videography to determine saturation flow with composition of vehicles, percentage right turn and arrival rate at various intersections of the Ahmedabad city during peak hour. Saturation flow model has been developed to know the relation between the discharge rate and composition of the vehicles. It shows that percentage composition of 2W, 3W and right turn decreases the with the increment in the discharge rate. While the percentage composition of small car, big car, LCV, HCV and arrival rate increases with the increase in the discharge rate.*

Key Words: **Intersection; Saturation flow; Mixed traffic; Traffic signal; India**

1. INTRODUCTION

Traffic signals are mainly used to control traffic movements and stop conflicts among them in urban and semi urban areas of the developing and developed countries. Study of saturation flow at signalized intersections is one of most credible and prompt measure to enhance the capacity of road intersections and reduce the congestion on the roads. Saturation flow estimation is useful to design or improve geometric design criteria, traffic control aid and evaluation of existing transportation facilities. Definition of the saturation flow is the rate at which vehicles those have been waiting in a queue during the red signal cross the stop line of a signalized intersection approach lane during the green signal. In developing countries there are many types of vehicles, which causes heterogenous traffic conditions. The existing saturation flow models are made for homogeneous traffic flow conditions. However, few studies have been carried out for saturation flow in mixed traffic conditions. This study is concerned with the saturation flow rate by observing various types of vehicle compositions.

2. LITERATURE REVIEW

Basic parameter used to determine capacity of the intersection is saturation flow rate at signalized intersection. It is derived based on the minimum headway that the lane group can sustain across the stop line. The Transportation Research Board manual named US-HCM 2000, has derived a traffic model for the calculation of the saturation flow. Which gives the result of 1900 pcu/hr of green time for single lane at signalized intersection. It also has assigned some adjustment factors in the calculation. In developing countries where mixed traffic is running, we cannot use this HCM model directly because it has been developed for the homogeneous traffic conditions. Model given by HCM 2000 to determine saturation flow is listed below.

$$S = s_0 \, N \, f_w \, f_{HV} \, f_g \, f_e \, f_{bb} \, f_a \, f_{LU} \, f_{LT} \, f_{RT} \, f_{Lpb} \, f_{Rpb}$$

Where S= saturation flow rate for single lane (veh/s), s_o =base saturation rate for single rate (pcu/h/lane), N= number of lanes, fw= adjustment factor for lane width, fHV = adjustment factor for heavy vehicles in traffic stream, fg = adjustment factor for approach grade, fp = adjustment factor for existence of a parking lane and parking activity adjacent to lane group, fbb = adjustment factor for blocking effect of local buses that stop within intersection area, fa = adjustment factor for area type, flu = adjustment factor for lane utilization, flT = adjustment factor for left-turn vehicle presence in a lane group, fRT = adjustment factor for right-turn vehicle presence in a lane group, fLpb = pedestrian adjustment factor for left-turn groups, and fRpb = pedestrian-bicycle adjustment factor for right-turn groups. Indian Roads Congress has also given the equation to calculate the saturation flow considering the factors like heavy vehicles proportion, road width and turning vehicles proportion. Which is validated at signalized intersection in Mumbai, India.

$$S = 525 * w$$

Where S= saturation flow rate for lane group (pcu/hr), w=width of the road. Only valid for the 5.5m to 18m.

Zhang Hui (2009) has conducted the study for characteristics of traffic flow including motorized transport and non-motorized transport. And described flow rate variations in mixed traffic flow conditions. Statistical methods were also applied to analyze the flow rate variations.

Shengai (2011) has conducted the study to improve the capacity of the intersection. And concluded that it can be increased by organizing pedestrians and cyclists, by improving signal timings and drainages.

Pinakin Patel (2015) has carried out the survey to find the effect of mixed traffic on saturation flow and passenger car unit. It includes the study of saturation flow during saturated green time at signalized intersection. And concluded with the discharge flow model for the mixed traffic conditions in Surat, India.

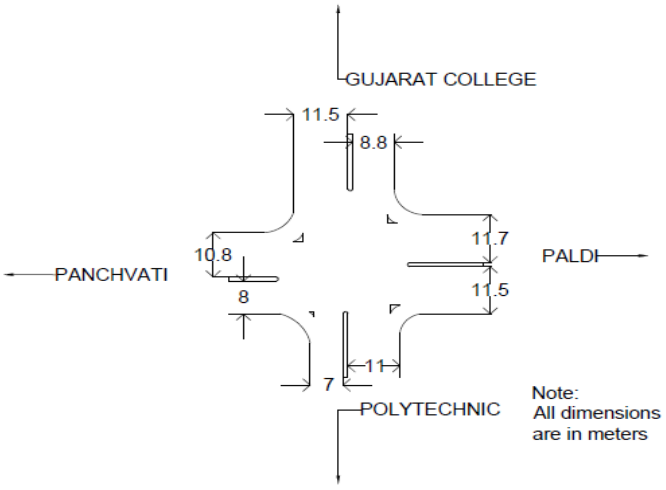
3. METHODOLOGY

Methodology of the research paper consists of discharge rate model of signalized intersection for selected intersections of the Ahmedabad, India. It includes traffic survey, intersection inventory, saturation flow model. Traffic data has been collected by videography technique. Micro level saturation flow study has been carried out and with the help of that model has been prepared. Video recording of the traffic intersection has been carried out.

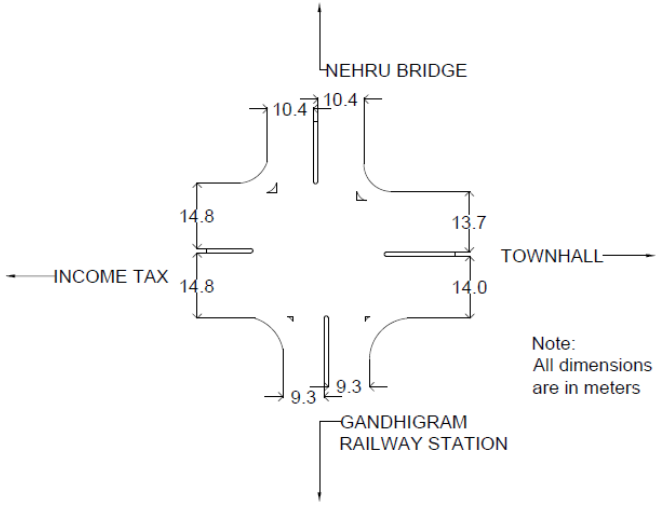
4. DATA COLLECTION

The data collection has been done from three intersections in the Ahmedabad, India namely Parimal garden intersection, Nehru Bridge intersection and Panjrapole intersection. Former intersection approach has a width of 7m with two lanes. Median intersection approach has a width of 13.8m with four lanes. While later intersection has a width of 11m with three lanes. All the approaches have working traffic signals, traffic signs, traffic aid and markings. Camera has been placed at higher elevation in the vicinity of the intersection to record the traffic flow data during peak hours. The procedure for determining saturation flow is given.

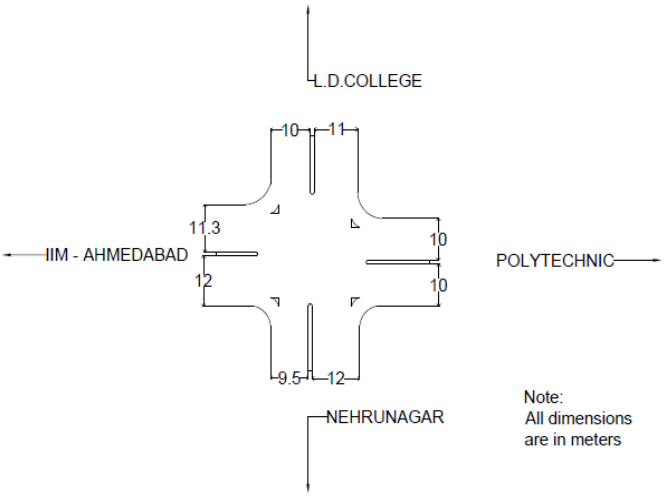
An observation point has been selected in the video recording on the particular approach. It is taken as a stop line normally. Start of green is noted down and discharge flow from the video has been calculated using avidemux software to gain the micro second accuracy. Now video recording is replayed and saturation flow of different directions are found out for each category of vehicles. Repeating the same procedure, saturation flow is measured of all remaining approaches for different categories of the vehicles like two-wheelers, three-wheelers, small car, big car, LCV and HCV.



PARIMAL GARDEN INTERSECTION



NEHRU BRIDGE INTERSECTION



PANJARAPOLE INTERSECTION

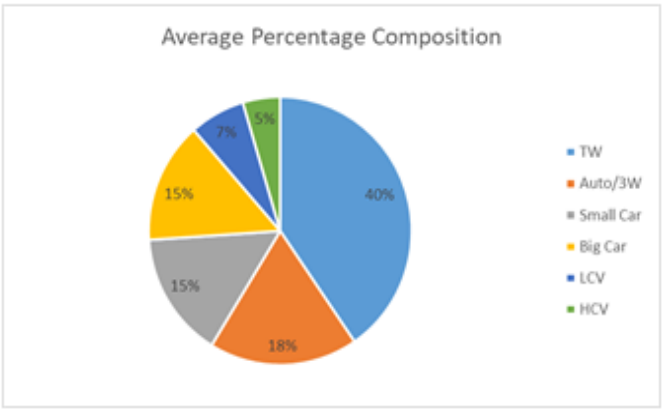
Figure 1 Intersection Geometry

5. DATA ANALYSIS

Average traffic flow composition is given in table below.

Table 1 -: Average vehicle composition of vehicles

TW	Auto/3W	Small Car	Big Car	LCV	HCV	%Right Turn	Arrival rate	DR Veh/s	DR PCU/s
40.452	18.290	15.19	14.634	6.835	4.590	42.867	0.169	1.499	1.111



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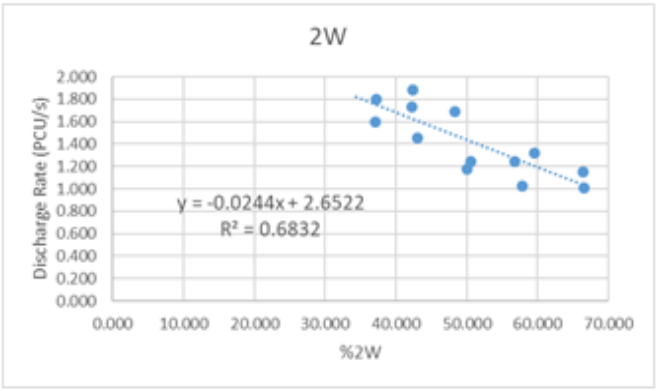

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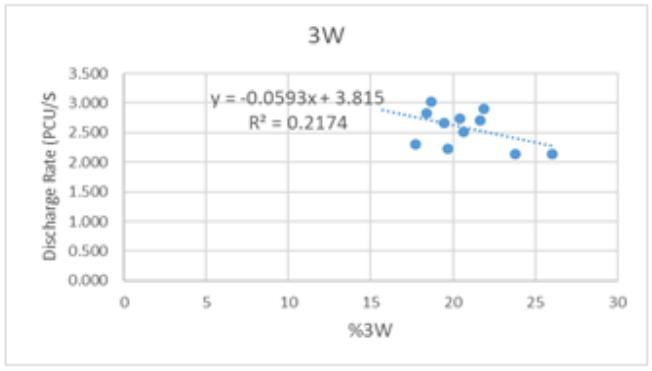

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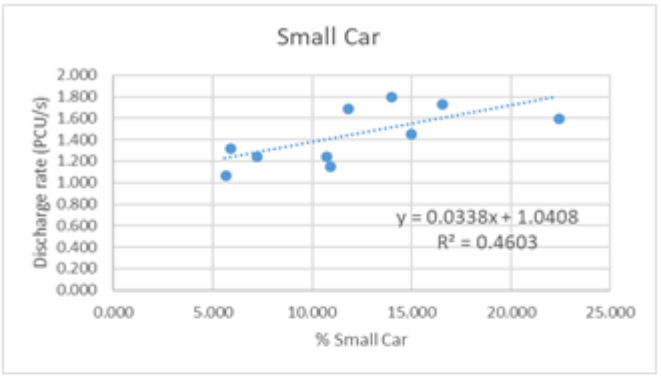

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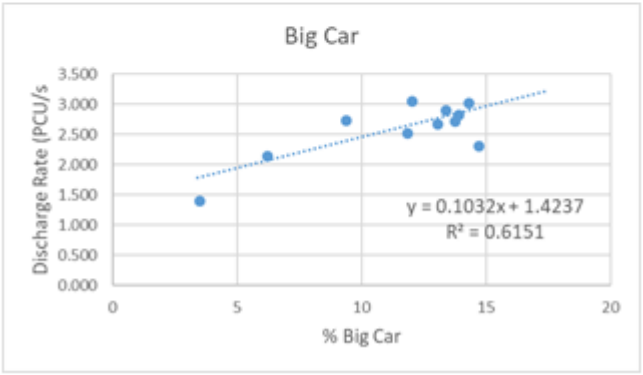

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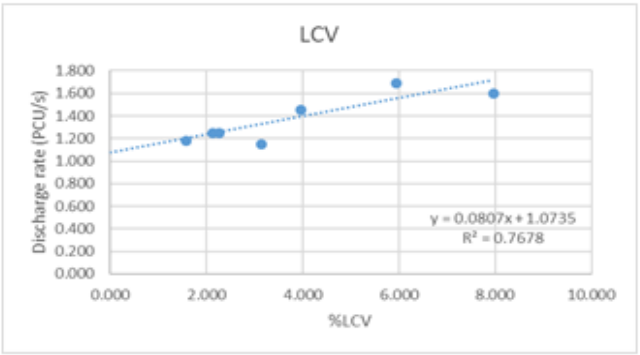

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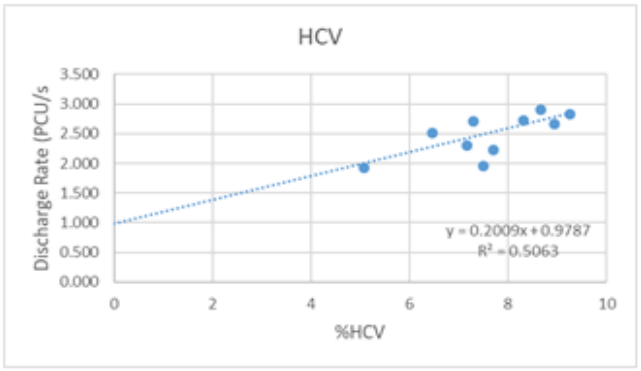


(g)

Above figures indicate various positive and negative effect of categories of vehicles with discharge rate. Two-wheeler and three-wheeler has high maneuverability, therefore their saturation flow may high in the beginning and may reduce after that. While on the opposite side cars, LCV and HCV has low maneuverability, so their saturation flow may less in the beginning and may increase as the discharge rate increases.

5.1 Saturation Flow Model

An attempt has been made to develop a multiple linear regression model. In which discharge rate is taken as a dependent variable while percentage composition of vehicles, arrival rate and percentage right turn are taken as an independent variable.

$$y = 0.031X_1 - 0.019X_2 + 0.009X_3 + 0.034X_4 + 0.013X_5 + 3.752X_6$$

Where, X_1= %Two-Wheeler, X_2= % Three-Wheeler, X_3= % Small car X_4= %Big car X_5= % Right turn X_6= Arrival rate

Table 1 Summary Output of Model

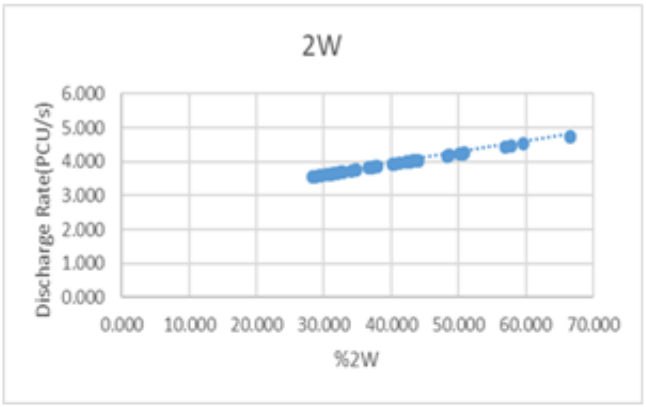
SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.991258364
R Square	0.982593145
Adjusted R Square	0.954720471
Standard Error	0.226385752
Observations	45

Table 2 t Stat and P value

	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
TW	0.031	0.002	11.296	7.268E-14
3W	-0.01976Z	0.0075	-2.619	0.012
Small Car	0.00958	0.00730	1.31207	0.19716
Big Car	0.034752	0.00570	6.09438	3.829E-07
%Right Turn	0.013142	0.00383	3.42965	0.00144
Arrival rate	-3.752101	0.7302284	-5.13825	8.089E-06

5.2 Sensitivity Analysis

To conduct the sensitivity analysis saturation flow model has been used. Sensitivity is observed by fluctuating one variable and keeping other variables constant of mean value. Mean value of percentage vehicles of above listed categories are 40.452,18.29, 15.199, 14.634, 6.853, 4.59, 10.6, 42.867.



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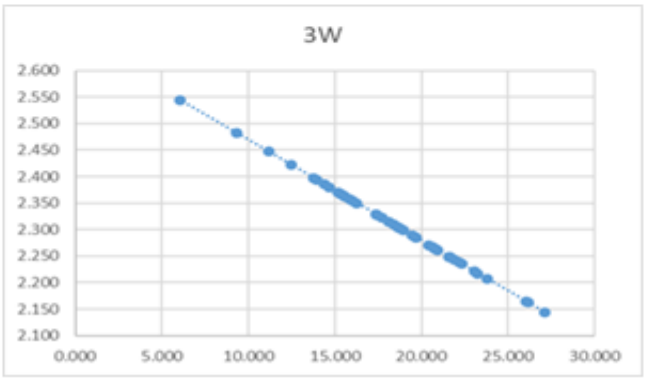

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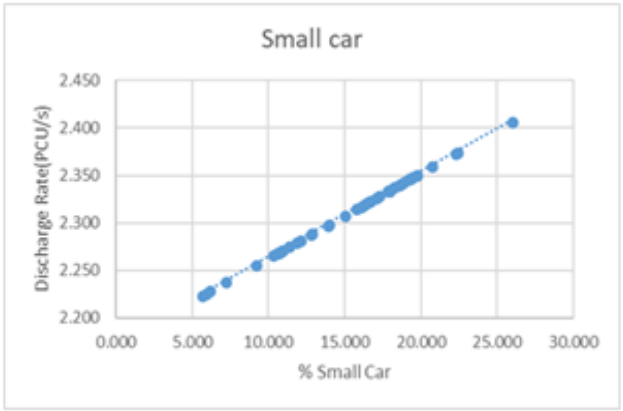

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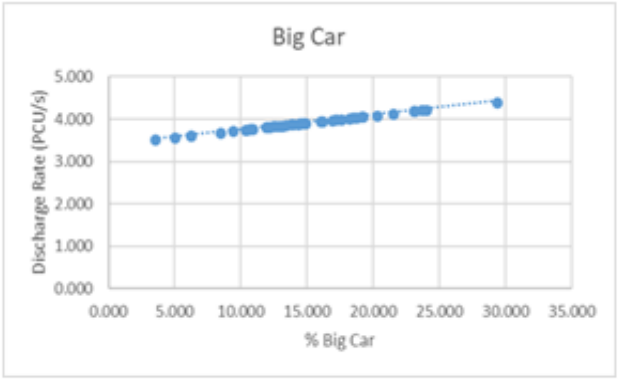

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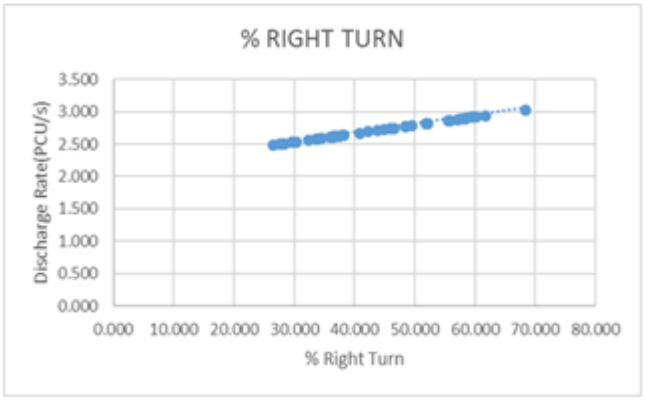

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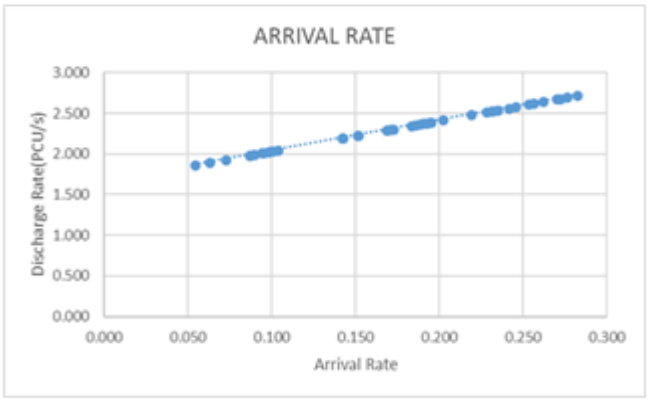

(m)

Figure (h) to (m) show the impact of discharge rate on various categories. The plot between discharge rate and 3W and discharge rate and small car has higher slope than other categories. Which shows notable effect by them. Minor changes in the composition of 3W and small cars can cause major change in discharge rate.

6.0 CONCLUSION

Data collection has been done through videography to obtain high accuracy. But it takes more time in data extraction. HCM 2000 suggests initial lost time of 10 sec. Which means calculation of saturation flow should be started after 10 sec of green time initiation. But it is found that two wheelers and three wheelers found their way between the other categories of the vehicles. Also, during red period many vehicles come near the stop line. And it is observed that initial lost time for the selected approaches are 2-4 sec. Regression model has been developed to estimate the saturation flow in this condition. This model can be used in mixed conditions where % composition of the vehicles, % right turn and arrival rate of the vehicles are known. Sensitivity analysis shows that the small car and 3W has more slope than other vehicle categories. Therefore, it is observed that minor change in the 3W and small car may affect the discharge rate.

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