Capacity Estimation at Signalised Intersection Under Mixed Traffic Condition

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Abstract: Capacity is an important on the basis of which other operational measures are calculated for signalised intersections as well as the most widely used concept in traffic engineering practice. This study investigates the capacity of signalised intersection under mixed traffic condition at urban signalised intersection. Estimation of lane capacities of signalised intersection is important factor considered while its planning, design and operation. In this study the effect of vehicle composition in lane on capacity of signalised intersection. A statistical analysis has been performed to understand the relationship between capacity and its number of lanes.

In this study, data has been collected at IIM circle and Pakwan Chaar Rasta in Ahmedabad city using videography and data extraction has been carried out using AVIDEMUX software. Vehicle composition of each lane has been obtained by data extraction from videography and effect of each lane on capacity of signalised intersection has been studied. Lane wise capacity has been converted into PCU/hr which further compared with Vehicle/hr. Adjustment factor for 2W has been calculated and capacity model has been prepared based on effect of vehicle composition of lane on signalised intersection. This study concluded that effect of vehicle composition on capacity of signalised intersection and also result show the relation between VPH and PCU.

***Index Terms* - Capacity, Lane Utilisation, Signalised Intersection, Vehicle Composition, Flow Rate.**

I. INTRODUCTION

Traffic flow is defined as the number of vehicles or pedestrians passing over a selected stretch or cross-section of a roadway during unit time. Traffic flow system includes vehicles, commuters, road width and road intersection.

1.1 Capacity:

The capacity of a lane group is defined as the number of vehicles that can be discharged through the intersection per hour during the allocated green time. Mathematically, it can be expressed as:

$$c = \frac{sg}{C} \quad \text{(1)}$$

where
c is the capacity of a lane group,
s is the saturation flow rate,
g is the green time and
C is the cycle time.

1.2 Intersection:

Intersection can be defined as the general area where two or more roads join or cross, including the roadway and roadside facilities for traffic movement with it (AASHTO). There are three types of intersection:

1. Intersection at grade
2. Grade separation without ramps
3. Interchanges

Intersection at grade: Intersection at grade is one where two or more highway joint, with each highway radiating from an intersection and forming part of it. these approaches are referred to as intersection legs.
Grade separation without ramps: when two highway cross each other at a different grade, with no connection, the arrangement is referred to as a grade separation.

1.3 Literature Review

Many research works have been carried out in the field of Estimation of capacity at signalised intersection under mixed traffic condition.
Yang Xiao-Bao et al, 2009. This paper attempts to investigate the impact of the number of lanes on highway capacity. It provides a better understanding of the relationship between highway capacity and numbers of lanes upon the statistical analysis of the survey. The result show that avg. capacity per lane decreases significantly as the number of lanes increases. It indicated that the increase of lane changing activity and its associated disturbance to traffic stream is the principal factor of the decrease of average capacity per lane on highways.

D. Patrick Allen,1998. Pedestrians and bicycles occupy different conflict zones with right-turning motor vehicles, but their effects on right-turning vehicles are related because they both may occupy their zones at the same time. Once the overlap between pedestrian and bicycle occupancies is known, an analyst can easily compute the overall occupancy for both pedestrians and bicycles by subtracting the overlap from the sum of the two occupancies.

LIANG Xiao et al,2011. This paper summarized the most popular methods used for calculating the traffic capacity of signalised intersections. conflict point method, the stop line method, and the HCM method, most of which take the predicted value from the mathematic exceptive value from statistical probability as traffic capacity.

Satish Chandra et al,2003, here researcher introduce a new concept to estimate the PCU of different types of vehicles under mixed traffic conditions. All vehicles were divided into nine different categories and PCU's were estimated at each road section. It was found that the PCU for a vehicle type increases linearly with the width of carriageway. The capacity of a two-lane road also increases with total width of the carriageway and the relationship between the two follows a second-degree curve. This relationship is used to derive the adjustment factors for substandard lane widths.

Nabanita Roy et al,2017 This paper focuses on effects of mixed traffic on capacity of two-lane roads. On the basis of field data collected on Indian highways, the present paper 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.

Sagar Kurle et al,2016 the researcher eight hours of video graphic data has been collected from a road stretch on Delhi-Gurgaon Expressway, incorporating both peak and off-peak hours. The lane discipline behaviour is studied for five different vehicle categories. SPSS software is used for multivariate analysis with lane utilization factor over a wider range of traffic flow rates. A structural equation model has been established for all the four lanes separately and the influence of the vehicles on lane utilization is studied ultimately. The results of the present study in the form of lane utilization and lane discipline behaviour by different vehicle types may help in differentiating the characteristics of traffic on expressways in relation to the other roads in India.

1.4 IRC SP41:

IRC SP 41 is the recommended guideline for the design of at-grade intersections in India. As per this guideline, the capacity of a signalized intersection is determined from the following expression;

$$c = s * \frac{g}{c} \quad \text{...} (2)$$

Where,
c = Capacity (pcu/hr)
s = Saturation flow (pcu/hr)
g = Effective Green Time for the phase (s)
C = Cycle Length (s).

1.5 INDO HCM:

In this manual, an intersection is categorized as base intersection if it conforms to the following listed conditions:

- Each approach is uniform in its width leading to the stop line.
- There is no bus stop (far side or near side) in the vicinity i.e. within 75 m from the nearest stop line of intersection.
- The pedestrian flow is negligible, or phasing plan allows protected pedestrians crossing at the intersection.
- The longitudinal gradient of all the approaches is almost zero.
- Through vehicles are not hindered by the right turning vehicles sharing the same approach and waiting for their phase.

1.4 Aim of the study

To study Capacity Estimation at Signalised Intersection Under Mixed Traffic Condition

1.5 Objectives of the study

1. To analyse the effect of lane on capacity of signalised intersection.
2. To study lane utilization behaviour for different category of vehicles at signalised intersection.
3. To develop appropriate model for capacity estimation at signalised intersection.

2. STUDY AREA PROFILE

- Site Selection should be carried out very precisely which can effectively fulfill our desired objectives. To construct the strong raw database, we need to collect the data from different intersections through video recording. For that some intersections of the Ahmedabad. **IIM circle Vijay and Pakwan** following intersections are selected for videography based on the criteria's mentioned above.

3. METHODOLOGY

The methodology in this study involves six stages. In the first stage, the signalised intersection has been identified, selected and the video graphic data has been collected. In the second stage, data extraction has been carried out using Avidemux software for selected signalised intersection. CVC, lane utilisation, flow rate and capacity has been calculated for different signalised intersection. In the third stage, Flow rate and capacity convert in to PCU. In the fourth stage, Capacity Analysis has been carried out for each signalised intersection as per IRC SP41 and HCM 2000. In the fifth stage, Comparing the capacity of each signalised intersection with each other and made conclusion.

4. DATA COLLECTION AND EXTRACTION

The Data is collected by videography method. The Data is extracted manually using Avidemux (version 2.6) Software. The Screen is marked using Screen Marker (Version 1.0.0.1) Software. The Data entry was directly inputted in MS Excel. The Screenshot are as follows:

Figure 1 Pakwan Intersection Data Extraction in Avidemux Software

5. DATA ANALYSIS

Data analysis has been carried out for different signalised intersection on which the data already extracted from the videography.

5.1 Lane Utilisation

Table 1 Lane Utilisation

Lane	LU-M	LU-CM	LU-CE	LU-E
VPH	15.29	13.22	26.86	44.63
PCUs	13.59	31.83	28.89	25.6883

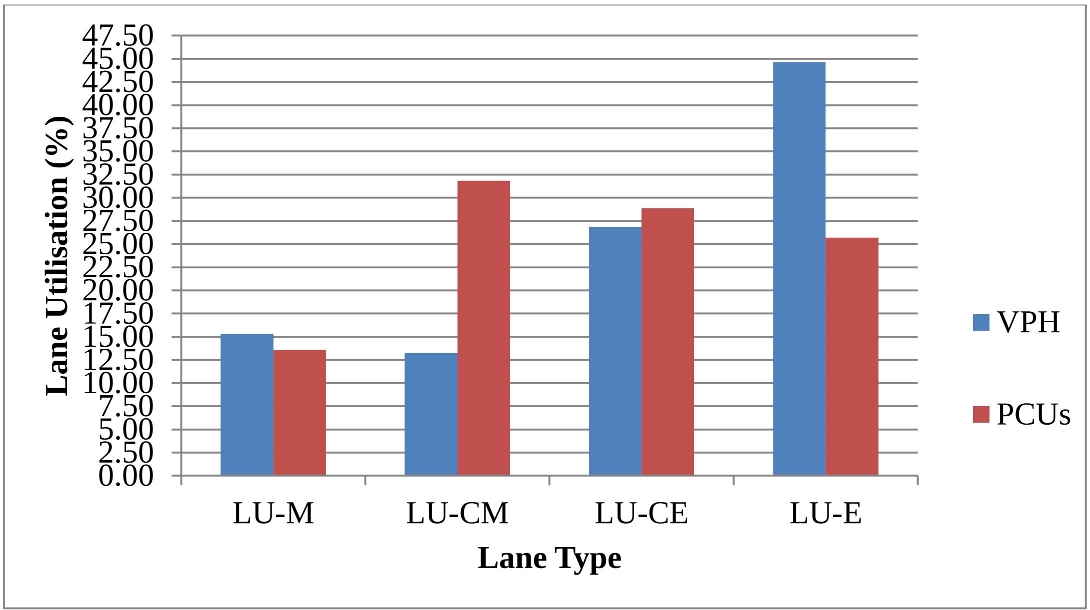

Figure 2 Lane utilisation

Graph show the edge lane contain higher percentage vehicle compare with other lane but in PCU it decreases that means there is higher percentage of two-wheeler in edge lane.

5.2 Flow Rate

Flow (or Volume): It is the number of vehicles that pass-through a given point on a road during a time interval. Since road have a certain width and the required number of lanes is accommodated within the available width, flow is always expressed in relation to the given width. The time unit selected is one hour. Flow Rate: It is a macroscopic flow characteristic and is defined as number of vehicles passing a point in a given period of time. It is usually expressed as an hourly flow rate.

Table 2 Flow Rate

Lane	M	CM	CE	E	TOTAL
VPH	2220.00	1920.00	3900.00	6480.00	14520
PCUs	1137.60	2664.00	2417.40	2149.80	8368.80

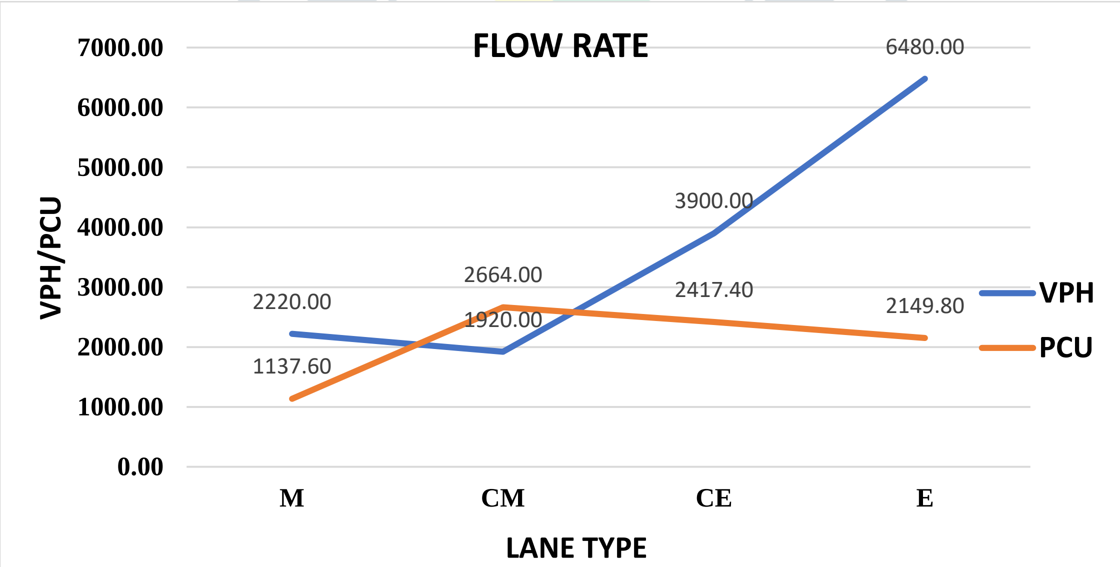

Figure 3 Flow Rate

Hourly flow has been calculated from data extracted sheet and graph plotted according that data. Flow rate also convert in pcu and compare with vph.

5.3 Capacity Analysis

Table 3 Calculation of Capacity (VPH)

	CYCLE1	CYCLE2	CYCLE3	CYCLE4	CYCLE5	CYCLE6	CYCLE7	CYCLE8	CYCLE9	CYCLE10	CYCLE11	CYCLE12	CYCLE13	CYCLE14	CYCLE15
SATURATION FLOW	16320	17200	18320	14320	17440	17200	14960	15120	15840	12720	11360	13200	14400	12720	11920
GREEN TIME	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
CYCLE TIME	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190
CAPACITY	4724.21	4978.95	5303.16	4145.26	5048.42	4978.95	4330.53	4376.84	4585.26	3682.11	3288.42	3821.05	4168.42	3682.11	3450.53

For calculate the capacity first determine the saturation flow of signalised intersection and use capacity equation for calculating capacity.

Table 4 Capacity with Vehicle Proportion

			VEHICLE %					
	CAPACITY	TW	3W	SC	BC	LCV	Bus	Truck
CYCLE1	4724.21	66.53	8.68	7.02	15.29	1.65	0.41	0.41
CYCLE2	4978.95	61.75	9.82	12.28	13.33	2.11	0.35	0.35
CYCLE3	5303.16	63.46	7.97	10.96	15.95	1.00	0.33	0.33
CYCLE4	4145.26	65.02	9.05	9.05	14.81	0.82	0.41	0.82
CYCLE5	5048.42	64.53	6.04	11.70	15.47	1.89	0.00	0.38
CYCLE6	4978.95	60.89	8.87	17.34	11.29	0.81	0.40	0.40
CYCLE7	4330.53	50.00	14.78	24.35	8.70	0.43	0.87	0.87
CYCLE8	4376.84	53.04	8.70	23.91	11.74	1.74	0.43	0.43
CYCLE9	4585.26	52.46	7.38	20.90	16.80	2.05	0.00	0.41
CYCLE10	3682.11	49.23	6.67	22.56	18.46	2.56	0.51	0.00
CYCLE11	3288.42	45.09	12 .14	19.07	20.81	1.73	0.58	0.58
CYCLE12	3821.05	43.65	6.60	19.29	27.41	2.54	0.51	0.00
CYCLE13	4168.42	47.35	9.73	20.80	15.93	4.87	0.00	1.33
CYCLE14	3682.11	41.94	10.75	20.43	23.12	3.23	0.00	0.54
CYCLE15	3450.53	40.80	12.07	17.82	24.14	4.60	0.57	0.00

After calculating capacity using saturation flow to show the effect of different type of vehicle on capacity plot graph Capacity Vs vehicle category. Capacity comparing with different type of vehicles and plot graph and derive relation between capacity Vs vehicle. Finding relation between capacity and vehicle.

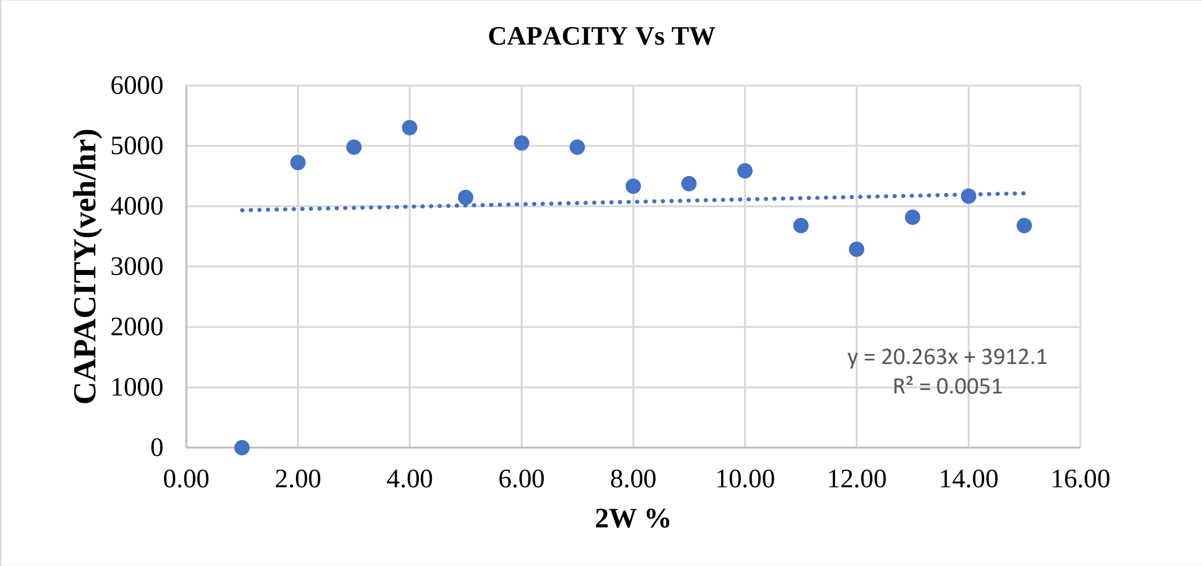

Figure 4 Capacity Vs 2W%

The graph clearly shows that the effect of two-wheeler proportion. the number of vehicles increase then increase capacity. From the above graph observation made that the slope is positive which means that there is a positive correlation of two-wheelers with the discharge rate. In the equation of graph show the number of two-wheeler increases, the capacity in terms of VPH increases. The reason is that; as the two-wheelers are small in size, they can penetrate in the space between other vehicles and leave the intersection at a faster rate. Thus, the capacity increases. From the graph and equation, we clearly say that the number of two-wheeler increase then increase the capacity of this signalized intersection.

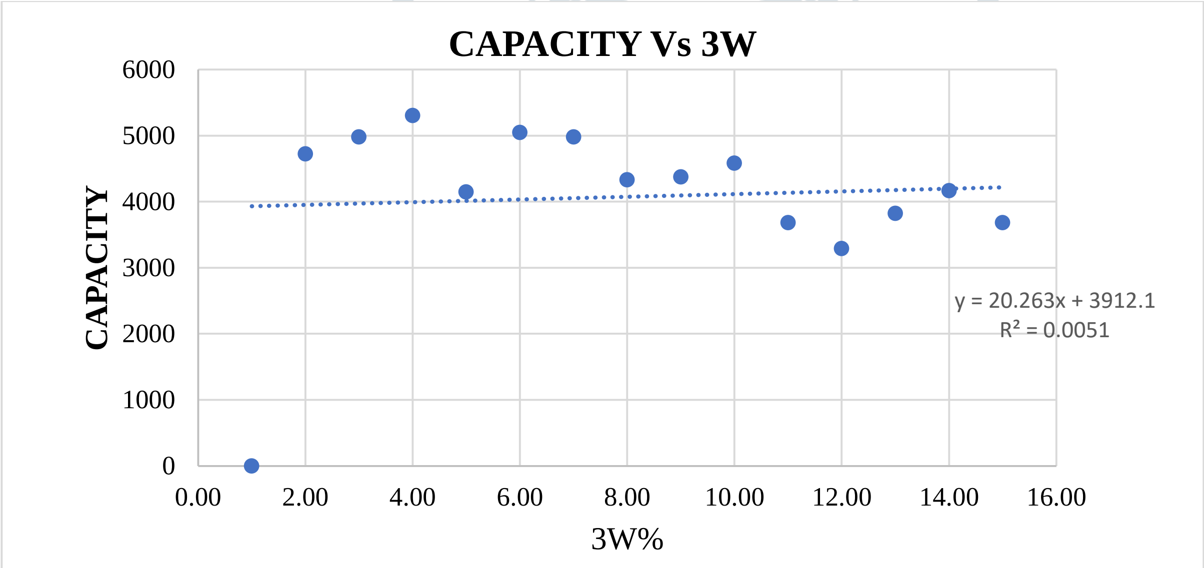

Figure 5 CAPACITY Vs 3W

From the above graph observation made that the slope is negative which means that there is a negative correlation of three-wheelers with the Capacity. In the equation of graph show the number of three-wheeler increases, the capacity in terms of VPH decreases.

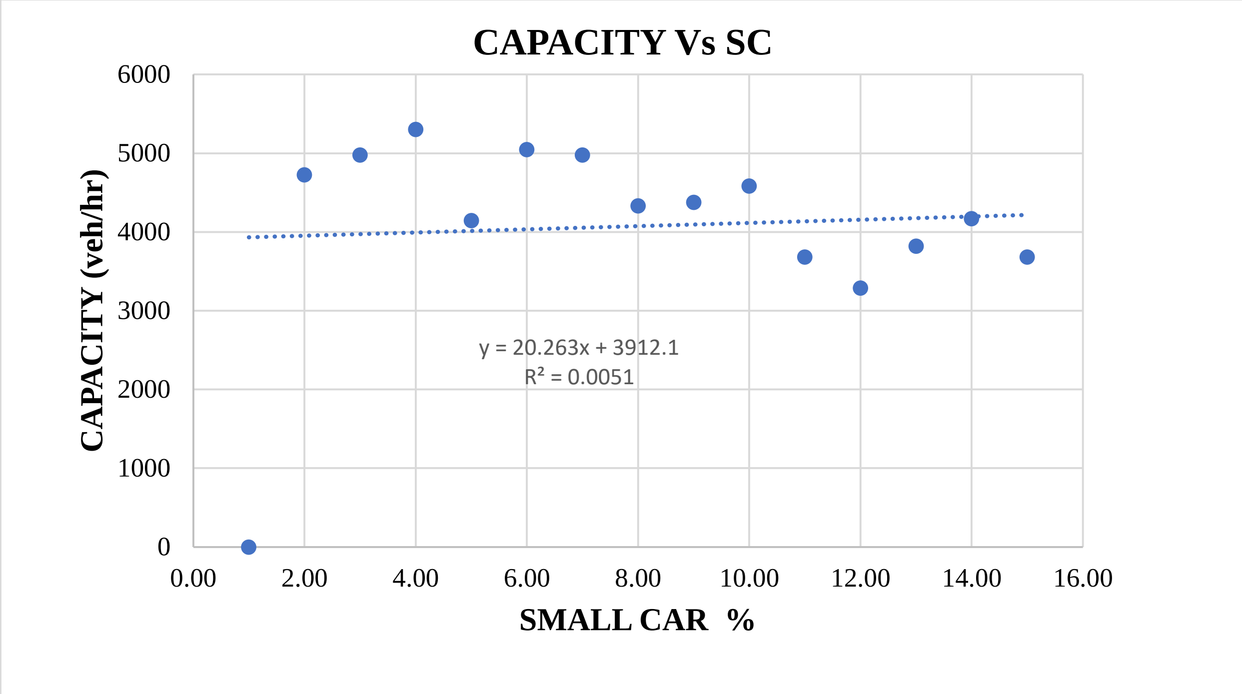

Figure 6 CAPACITY Vs SC

From the above graph observation made that the slope is negative which means that there is a negative correlation of Small Car with the Capacity. In the equation of graph show the number of small car increases, the capacity in terms of VPH decreases.

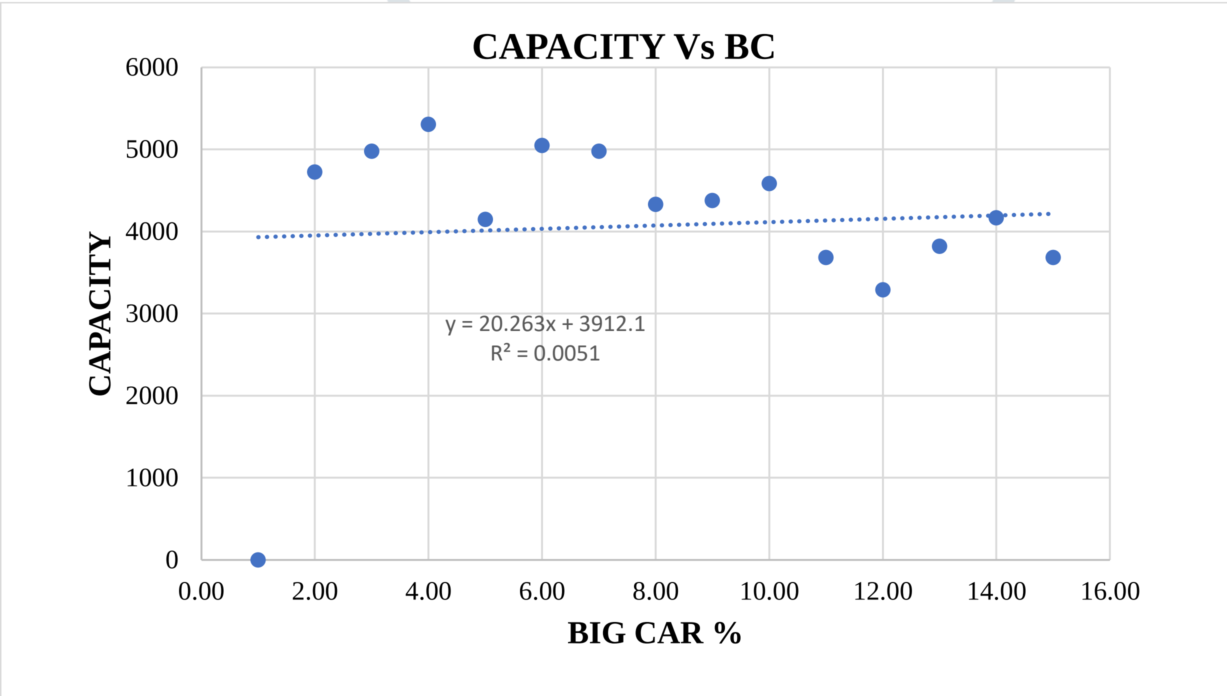

Figure 7 CAPACITY Vs BC

From the above graph observation made that the slope is negative which means that there is a negative correlation of big Car with the Capacity. In the equation of graph show the number of big car increases, the capacity in terms of VPH decreases.

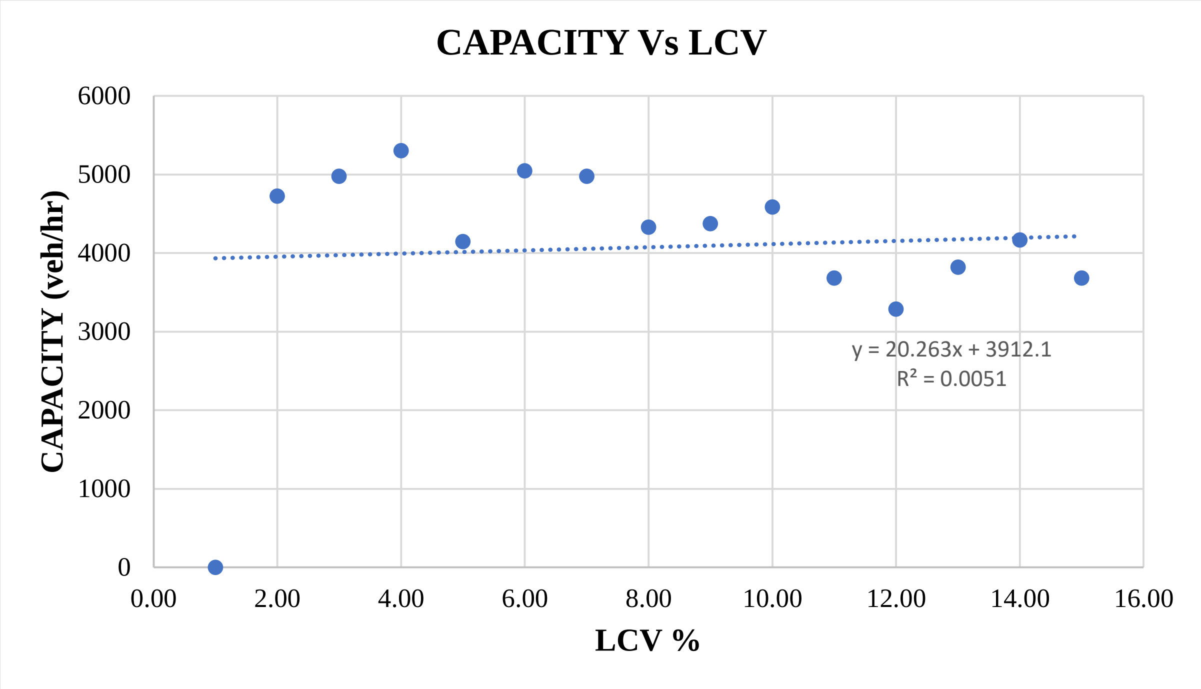

Figure 8 CAPACITY Vs LCV

From the above graph observation made that the slope is negative which means that there is a negative correlation of big Car with the Capacity. In the equation of graph show the number of big car increases, the capacity in terms of VPH decreases.

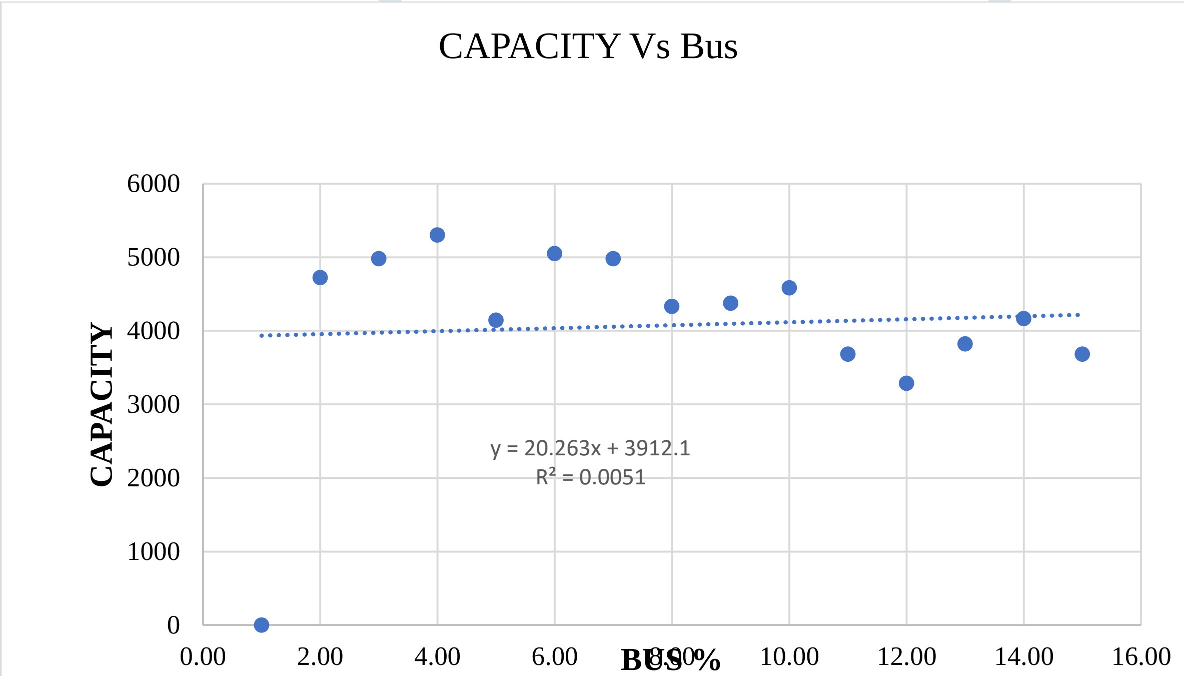

Figure 9 CAPACITY Vs Bus

From the above graph observation made that the slope is negative which means that there is a negative correlation of big Car with the Capacity. In the equation of graph show the number of big car increases, the capacity in terms of VPH decreases.

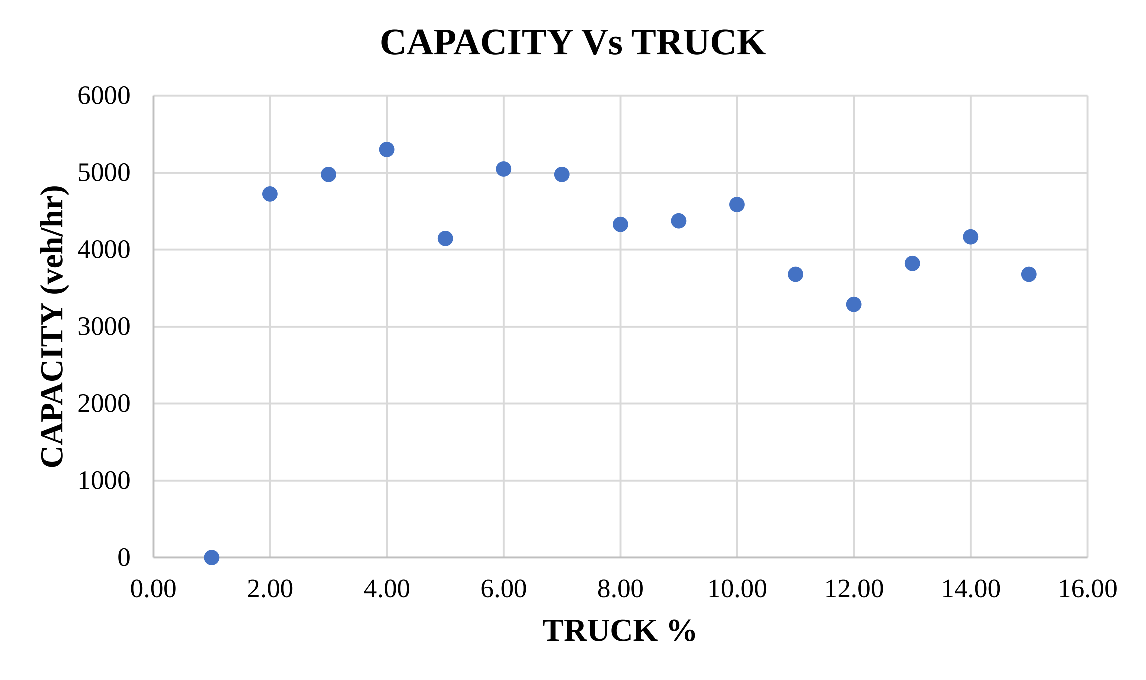

Figure 10 CAPACITY Vs TRUCK

The graph clearly shows that the effect of two-wheeler proportion. the number of vehicles increase then increase capacity but increase proportion of tree wheeler, small car, big car, bus, truck capacity decrease.

Table 5 Capacity Comparison of Signalised Intersection

	Cycle	Number of lanes	HCM 2000 CAPACITY (veh/hr)	FIELD CAPACITY (veh/hr)	Volume (veh/hr)	Widt h(m)	2w%	V/W Ratio (veh/ hr/m)	AF
PAKWAN	cycle1	4	2189.57	3450.53	4585.3	14	66.53	327.5	1.57589
	cycle2		1938.08	4978.95	5400	14	61.75	385.7	2.56901
	cycle3		1953.22	5303.16	5703.2	14	63.46	407.4	2.71508
	cycle4		1664.41	4145.26	4187.4	14	65.02	299.1	2.49054
	cycle5		2079.91	5048.42	5021.1	14	64.53	358.6	2.42723
	cycle6		1735.99	4978.95	4698.9	14	60.89	335.6	2.86807
	cycle7		1822.11	4330.53	4357.9	14	50.00	311.3	2.37665
	cycle8		2148.74	4376.84	4357.9	14	53.04	311.3	2.03693
	cycle9		1709.22	4585.26	4623.2	14	52.46	330.2	2.68267
	cycle10		1582.09	3682.11	3694.7	14	49.23	263.9	2.32737
	cycle11		2221.21	3288.42	3277.9	14	45.09	234.1	1.48047
	cycle12		2167.57	3821.05	3732.6	14	43.65	266.6	1.76283
	cycle13		2176.05	4168.42	4282.1	14	47.35	305.9	1.91559
	cycle14		2203.74	3682.11	3524.2	14	41.94	251.7	1.67084
	cycle15		2189.57	3450.53	3296.8	14	40.80	235.5	1.57589
IIM	cycle1	3	1002.96	5301.82	5563.64	12	76.4706	463.6	5.28615
	cycle2		1259.21	5439.27	6201.82	12	81.0026	516.8	4.31958
	cycle3		1283.83	5085.82	5890.91	12	77.1635	490.9	3.96143
	cycle4		1588.16	5458.91	4418.18	12	78.4062	368.2	3.43726
	cycle5		1216.80	4869.82	5301.82	12	76.8519	441.8	4.00215
	cycle6		1587.14	5969.45	6038.18	12	82.1622	503.2	3.76114
	cycle7		1218.28	4555.64	5383.64	12	75.9878	448.6	3.73941
	cycle8		1030.72	4162.91	4860	12	79.8365	405	4.03884
	cycle9		790.73	4555.64	4827.27	12	77.2881	402.3	5.76132
	cycle10		1588.80	5046.55	5023.64	12	75.3247	418.6	3.17633
	cycle11		1241.52	5910.55	5841.82	12	79.6089	486.8	4.76073
	cycle12		1145.19	4025.45	4189.09	12	67.5676	349.1	3.51509
	cycle13		1584.38	4673.45	4778.18	12	73.9726	398.2	2.9497
	cycle14		1152.12	3907.64	4303.64	12	74.5247	358.6	3.39168
	cycle15		1585.65	4752.00	5203.64	12	72.7273	433.6	2.99687
vijay	cycle1	2	1083.37	3914.89	3034.3	10	61.9835	303.4	3.61362
	cycle2		857.50	3404.26	2802.9	10	58.7156	280.3	3.96995
	cycle3		898.09	4042.55	3214.3	10	60.8	321.4	4.50126
	cycle4		919.06	3191.49	2854.3	10	54.955	285.4	3.47254
	cycle5		1122.55	3659.57	3265.7	10	60.6299	326.6	3.26005
	cycle6		884.06	3489.36	3162.9	10	65.4135	316.3	3.94697
	cycle7		953.63	3787.23	2725.7	10	65.0943	272.6	3.97139
	cycle8		1062.53	3191.49	2751.4	10	56.0748	275.1	3.00366
	cycle9		925.97	3148.94	2314.3	10	56.6667	231.4	3.40071
	cycle10		902.46	3829.79	3265.7	10	58.8652	326.6	4.24373
	cycle11		936.74	4085.11	3471.4	10	65.5172	347.1	4.36097
	cycle12		797.08	2595.74	2340	10	45	234	3.25655
	cycle13		987.71	3659.57	3420	10	65.9259	342	3.70511
	cycle14		1100.68	4042.55	3137.1	10	60.6299	313.7	3.67279
	cycle15		999.22	3957.45	2802.9	10	57.7982	280.3	3.96054

Comparison table show the different type of intersection have different capacity and different type of vehicle composition. Table also show the width wise capacity comparison of different intersection. HCM 200 give capacity for homogeneous traffic flow but here traffic flow is heterogeneous at signalised intersection the different between this capacity show that the HCM 200 is use for homogeneous condition not for heterogeneous traffic condition.

6. CAPACITY MODEL DEVELOPMENT

Vehicles Model for Pakwan Intersection:

$$\textbf{Capacty}\left(\frac{\textbf{veh}}{\textbf{hr}}\right) = 73.49\ 2W\% + 55.82\ 3W\% + 39.05\ SC\% - 19.78\ BC\% + 20.59\ LCV\% - 885.29\ Bus\% - 490\ Truck\%$$

PCU Model for Pakwan Intersection:

$$\textbf{Capacity}\left(\frac{\textbf{pcu}}{\textbf{hr}}\right) = 11.068\ 2W + 39.20\ 3W + 18.53\ SC + 20.28\ BC + 11.37\ LCV + 2.066\ Bus - 2.86\ Truck$$

Vehicles Model for IIM Intersection:

$$\textbf{Capacity}\left(\frac{\textbf{veh}}{\textbf{hr}}\right) = 793\ 2W\% + 2230.567\ 3W\% - 1770.99\ SC\%\ 1321.38\ BC\% + 3254\ LCV\% + 9400.52\ Bus\% - 2642.59\ Truck$$

PCU model for IIM Intersection:

$$Capacity\left(\frac{pcu}{hr}\right) = 7.36\ 2W - 3.99\ 3W + 14.70\ SC + 38.78\ BC - 24136\ LCV - 14.91\ Bus + 15.31\ Truck$$

Where,

2W% = Two-Wheeler Percentages, 3W% = Three-Wheeler Percentages, SC% = Small Car Percentages,
BC% = Big Car Percentages, LCV% = LCV Percentages, Bus% = Bus Percentages, Truck% = Truck Percentages.

7. MODEL VALIDATION

Three different intersections in the city of Ahmedabad, India, were considered for validation:

- Pakwan Intersection
- IIM Intersection
- Vijay Char Rasta.

The saturation flow, capacity and vehicles details of the intersection are represented. The capacity is measured at these junctions for selected approaches and is also calculated using the original US-HCM 2000 model using equation (1).the actual value of capacity is compared with the US HCM 2000 capacity. The validation results are shown in Table 5. different saturation flows have been plotted. It can be seen that saturation flow measured using the calibrated US-HCM 2000 model is closer to the field-measured saturation flow. Percentage errors before and after calibration of the US-HCM 2000 model are shown in Fig. which shows a significant decrease in the percentage error after calibration.

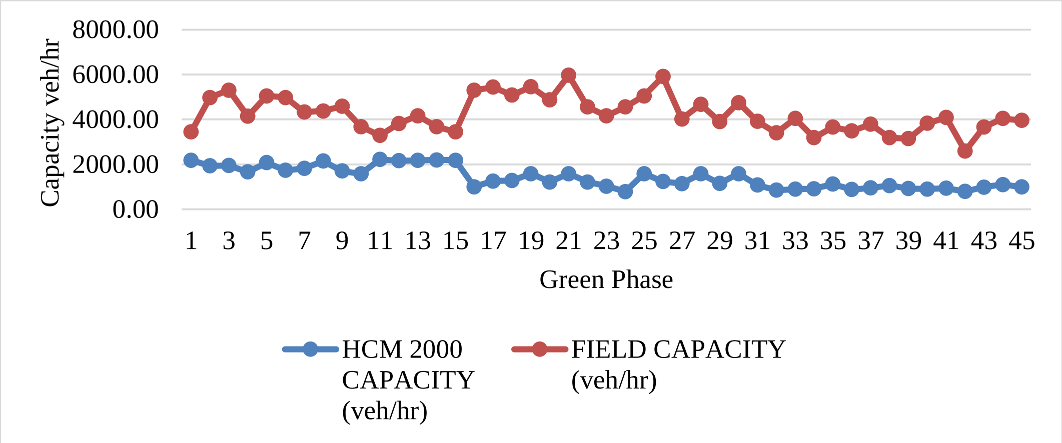

Figure 11 Comparison of US HCM 2000 Capacity and Field Capacity

8. CONCLUSION

Following are the conclusions of present study:

- Signalised Intersection capacity varied directly with the increase in the volume of two-wheelers, it was inversely proportional to the increase in volume of all other categories of vehicles.
- Lane utilisation Graph show the edge lane contain higher percentage vehicle compare with other lane but in PCU it decreases that means there is higher percentage of two-wheeler in edge lane and two-wheeler is major factor to increasing capacity of signalised intersection.
- The capacity estimated using US-HCM 2000 model is closer to field values, which implies that the effects of two-wheelers and approach volume are to be considered while modelling of capacity in Indian conditions.

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