Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 01, January -2018

Development of Model for Estimating Saturation Flow using Width and Roughness of Road for Mixed Traffic Condition in Urban Area

Nikhil G. Raval[1], Dr. P. J. Gundaliya[2]

[1]*Research Scholar, KSV University, Gandhinagar*
[2]*Professor, Civil Engineering Department, L. D. College of Engineering, Ahmedabad*

Abstract — *Saturation flow rate is basic parameter and used for design of signals. Saturation rate for the prevailing conditions can be determined directly from the field measurements. The equation of saturation flow, determined in developed countries, do not consider the non-lane based traffic conditions prevalent in India and developing countries. Hence, it is necessary to develop the saturation flow model for non-lane based heterogonous traffic condition. In present study, the relationship is developed between saturation flow and roughness of urban roads from the field observations using regression techniques. The developed relationship is validated statistically at 95% significant level. The developed models are compared with existing models also. The difference between observed saturation flow and output of existing models is considerably higher. In the study observed saturation flow and estimated saturation flow using developed models are compared and validated. It is observed that developed model predicts saturation flow close to the observed saturation flow at field compared to other models. The usefulness of developed model can be checked by comparing it with other Indian cities having similar characteristics.*

Keywords- *Heterogeneous traffic, Saturation flow, Roughness, Traffic Flow modeling*

I. INTRODUCTION

The saturation flow, lost time and passenger car unit (PCU) are the important parameters for planning, design and control of intersection. These factors are conventionally measured, in western countries, based on the research conducted on roads and on public streets, where car dominated traffic is moving in defined lanes. However, the traffic movement in India and in other European countries is concentrated in more complexes due to the varied characteristics of the traffic flow using the same right of way. The stream includes slow push carts at one extreme and the fast-moving passenger cars at the other, with many intermediate types of vehicles depicting an extensive variation in stationery and mobile characteristics. As in heterogeneous traffic operation no single vehicle clearly dominates the traffic stream, estimation of saturation flow is more sensitive to the vehicle mix than in western countries where the traffic is largely motorized and car dominated. In the developed countries, various methods and models are developed to measure the saturation flow rate, delays and optimum cycle length, where homogeneous traffic is flowing with lane discipline. While in India, for heterogeneous traffic, these methods cannot be effectively used. Hence, it is necessary to develop saturation flow model for heterogonous traffic condition which estimate saturation flow. In the present study, the model is dev eloped for estimating saturation flow considering width and roughness of road in heterogeneous traffic condition for Ahmedabad city.

II. STUDY AREA

The study is carried out at various intersections of Ahmedabad city. Data are collected in March, August and November months which covers almost all three types of weather conditions. Traffic data are collected manually in the field. Seven numbers of intersections are selected in Ahmedabad City for analysis. All signals are fixed time signals. The intersections are carefully chosen considering the geometry of the intersection. The traffic data are recorded for 120 minutes for each approach. Simultaneously data on signal timing i.e. cycle length, number of phases, phase length are collected manually using stopwatch. The width of approaches is measured for all Intersections. Following are the intersection selected for the study:

1) Paldi Intersection
2) Nehru Bridge Intersection
3) IIMA Intersection
4) Income Tax Intersection
5) Shastri Nagar Intersection
6) Memco Intersection
7) Vijay Cross Road Intersection

All intersections comprise both motorized and non-motorized vehicle. In this study, for analysis purpose traffic have been grouped into five classes:

1) Car (Car, Jeep, Taxi)
2) Large Bus

3) Two wheelers
4) Auto rickshaws
5) Bicycle+

III. METHOD AND DATA COLLECTION

Saturation flow rate is the maximum discharge rate during green time. It is calculated either in PCU/hr or Vehicles/hr. Saturation period is defined as number of vehicles crossing the stop line during effective green time. The stable moving queue has been crossing the stop line and movement wise classified traffic volume are counted for the whole approach as vehicle does not move in a disciplined way.

3.1 Measurement of Saturation Flow:

The observation point is normally stop line (desired position to stop). Start of the green was noted down. Conventional stop watch was used to measure time in seconds. Saturation flow ends when the rear axle of the last vehicle from a queue crosses the stop line. This time different types of vehicles count are done for each movement (Left turn, through and right turn separately). Initial 3 seconds from the start of green are left to consider start up loss time. The above procedure was repeated for each cycle of saturation period.

Following data are collected for measurement of saturation flow at various Intersections of Ahmedabad city:

a. Inventory Data
b. Signal Timings
c. Traffic Volume
d. Traffic Composition

Inventory data are collected and presented in Table 1. The width of all approaches of intersections, no. of lanes, width of footpath and width of median are measured and tabulated.

Table 1: Inventory data for selected intersections

Sr. No.	Name of intersection	Leg (Towards)	Width of carriage way (m)	No. of lane (Two way)	Width of footpath (m)	Width of median (m)
1	Paldi Intersection	S.T.	9.00	4	1.5	0.5
		V.S. Hospital	8.75	4	1.5	0.5
		Vasana	9.30	4	1.5	0.5
		Jalaram Temple	8.90	4	1.5	0.5
2	Nehru Bridge Intersection	Nehru Bridge	5.00	6	1.5	0.5
		Income Tax	8.85	6	1.5	0.5
		Station	4.50	6	1.5	0.5
		Ellis Bridge	8.85	6	1.5	0.5
3	IIM Intersection	Memnagar	7.50	4	1.5	BRTS
		Shivranajani	7.50	4	1.5	BRTS
4	Shastri Nagar Intersection	Ghatlodia	8.50	4	1.5	BRTS
		Ankur Society	7.30	4	1.5	BRTS
		Akhbarnagar	9.00	4	1.5	BRTS
		AEC Bridge	9.00	4	1.5	BRTS
5	Income tax Intersection	Gandhi Bridge	9.70	4	1.5	0.5
		Under pass	9.70	4	1.5	0.5
		Usmanpura	10.50	4	1.5	0.5
		Paladi	9.55	4	1.5	0.5
6	Memco Intersection	Bapunagar	11.50	4	NA	BRTS
		Amdupura	9.50	4	NA	BRTS
		Over Bridge	11.50	4	NA	BRTS
		Naroda	8.00	4	NA	BRTS

3.2 Measurement of Roughness:

Road roughness is a vital parameter for the estimation of surface condition of a road. Automatic Road Roughness Recorder gives speedily a quantitative integrated estimation of surface irregularities on a digital counter. It contains a trailer of single wheel with a pneumatic tyre (Inflation Pressure 2.1 kg/cm^2) mounted on a chassis over which an integrating device is fitted. The machine has a panel board fitted with LCD / digital counters for counting the length in Meter and Bumps in Centimeter. Direct reading at a reference point by pressing push Button are recorded. The survey was conducted on 14th April 2017. In the present case, the 50 meter is taken as preset length. The operating speed of the machine is 30±1/2 km/hr. The machine is towed by a vehicle, Mahindra Jeep. Its wheel runs on the pavement surface and the upright reciprocating motion of the axle is converted into unidirectional rotary motion by the integration unit. The accumulation of this unidirectional motion is recorded by operating Sensor inserted in the circuit of digital counter, once for every 1 cm of accumulated unevenness. Length of Path is indicated directly on LCD / Digital counter through Micro-Switch actuated by the cam fitted on the hub of the wheel with least count of 1 Meter. The LCD counter readings give the unevenness index value in terms of cm /km and mm/km. The differential movement between the rare axle and the body (floor) due to road unevenness is measured by the upward vehicle motion of the wire, which is transmitted into unidirectional rotary movement into electronic pulses which can be recorded in the computerised device. The data collected are decoded using the software Road Measurement Acquisition System. Automatic Road Unevenness Recorder with solid rear axle (half car) was fitted on Mahindra JEEP vehicle. Before carrying out the survey, all necessary checks were made about wheel alignment, wheel balancing, suspension and tyre pressure etc. was carried out to match correctly the pulses with distance. The vehicle attached with Automatic Road Unevenness Recorder was moved along the wheel paths at a minimum speed of 30 ± 2 km/h over the section of the project road. A four run was made in up direction. The unevenness index is measured along the length of approach leg of intersection. The unevenness index is converted into mm per km length.

IV. DATA ANALYSIS

The vehicles passed the intersection through effective green time is category wise measured and its composition is found out. The percentage composition of each category of vehciles is determined and presented in Figure 1 to 7.

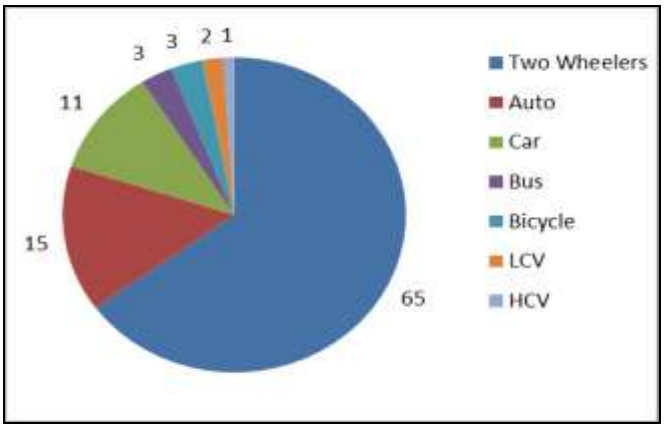

Figure 1: Traffic composition at Paldi intersection in %

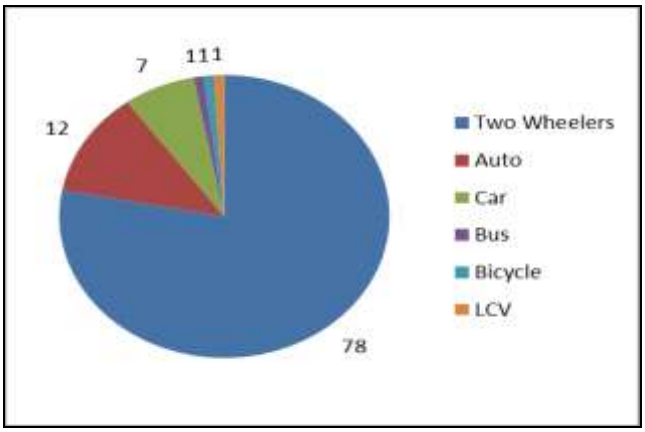

Figure 2: Traffic composition at Nehru Bridge intersection in %

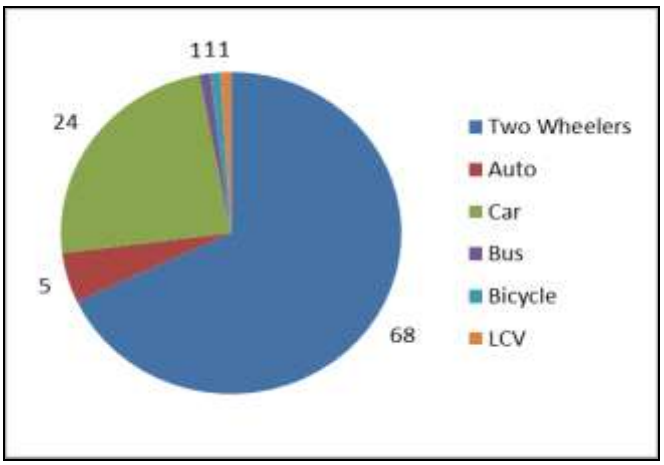

Figure 3:Traffic composition at IIMA intersection in %

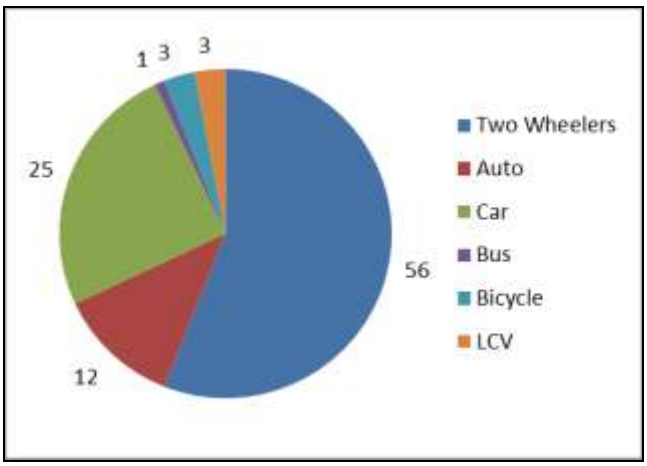

Figure 4: Traffic composition at Shastri Nagar intersection in %

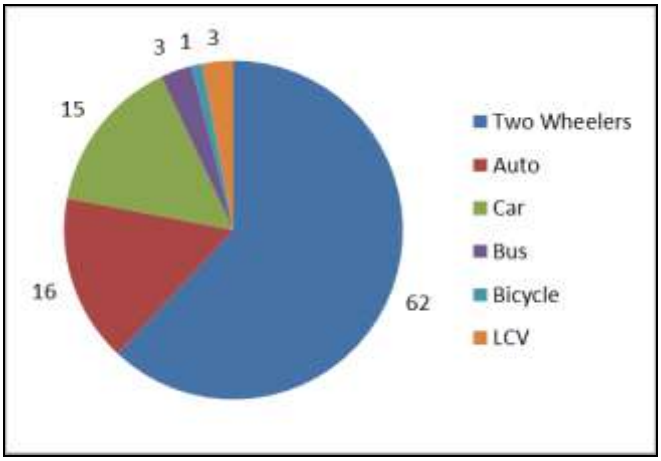

Figure 5: Traffic composition at Income Tax intersection in %

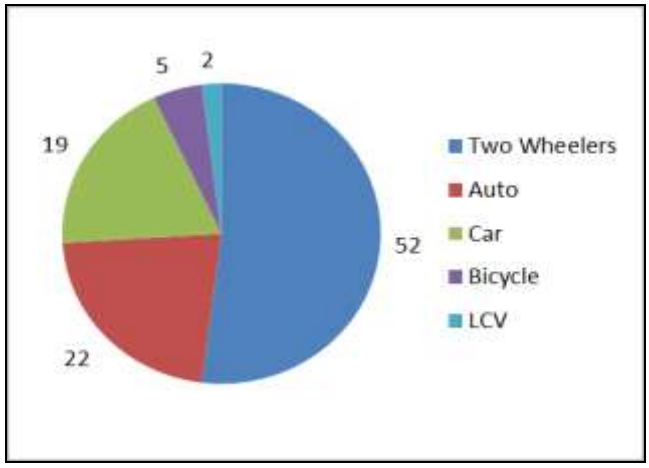

Figure 6:Traffic composition at Memco intersection in %

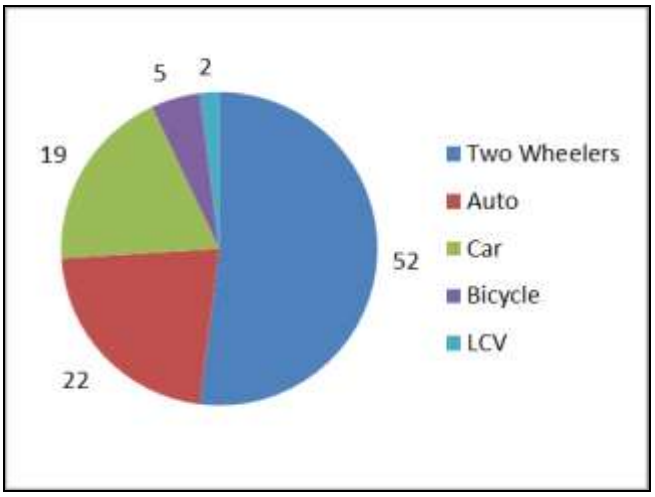

Figure 7 : Traffic composition at Vijay Cross Road intersection in %

It is observed from Figure 1 that major share of vehicles are of two wheelers, auto and car in the proportion of 65%, 15% and 11% respectively at Paldi Intersection. It is observed from Figure 2 that major share of vehicles are of two wheelers, auto and car in the proportion of 78%, 12% and 7% respectively at Nehru bridge Intersection. It is observed from Figure 3 that major share of vehicles are of two wheelers, car and auto in the proportion of 68%, 24% and 5% respectively at IIMA Intersection. It is observed from Figure 4 that major share of vehicles are of two wheelers, car and auto in the proportion of 56%, 25% and 12% respectively at Shahstrinagar Intersection. It is observed from Figure 5 that major share of vehicles are of two wheelers, auto and car in the proportion of 62%, 16% and 15% respectively at Income Tax Intersection. It is observed from Figure 6 that it is observed that major share of vehicles are of two wheelers, auto and car in the proportion of 52%, 22% and 19% respectively at Memco Intersection. It is observed from Figure 7 that major share of vehicles are of two wheelers, auto and car in the proportion of 52%, 22% and 19% respectively at Vijay Cross Road Intersection. Referring to the Figure 1 to 7, it is observed that major share of vehicles are of two wheelers, auto and cars. The percentage of two wheelers are in the range of 52% to 78%, which significantly affecting the saturation flow at intersections. The share of cars is ranging from 7% to 25%. The share of auto is ranging from 12% to 22%.

All approaches of selected intersections are four lanes divided roads. The width of carriageway of all approaches is varying from 7.1 meter to 11.5 meter. Traffic data are collected from all the approaches of all selected intersection in morning and evening peak hours for various cycles and presented in Table 2.

Table 2: Summary of saturation flow for various intersections

Sr. No.	Locations	Width of Road (m)	Observed Maximum Saturation Flow (PCU / hr)
1	**Paldi Intersection (Morning Peak Hours)**		
	Leg towards S.T.	9.00	11400
	Leg towards Vasana	9.30	12360
	Leg towards Jalaram temple	8.90	6960
	Leg towards V.S. hospital	8.75	10620
	Paldi Intersection (Evening Peak Hours)		
	Leg towards S.T.	9.00	9300
	Leg towards Vasana	9.30	12300
	Leg towards Jalaram temple	8.90	10440
	Leg towards V.S. hospital	8.75	10560
2	**Nehru Bridge Intersection (Morning Peak Hours)**		
	Leg towards Nehru bridge	5.00	6668
	Leg towards Income tax road	8.85	12440
	Leg towards Station road	4.50	6640
	Leg towards Ellis bridge road	8.85	15800
	Nehru Bridge Intersection (Evening Peak Hours)		
	Leg towards Nehru bridge	5.00	5372
	Leg towards Income tax road	8.85	10840
	Leg towards Station road	4.50	9540
	Leg towards Ellis bridge road	8.85	16169
3	**IIM Intersection (Morning Peak Hours)**		
	Leg towards Memnagar	7.50	10530
	Leg towards Shivranajani	7.50	11220
	IIM Intersection (Evening Peak Hours)		
	Leg towards Memnagar	7.50	9740
	Leg towards Shivranajani	7.50	10700
4	**Shastri Nagar Intersection (Morning Peak Hours)**		
	Leg towards Ghatlodia	8.50	7740
	Leg towards Ankur society	7.30	7740
	Leg towards Akhbarnagar	9.00	6331
	AEC bridge	9.00	7480
	Shastrinagar Intersection (Evening Peak Hours)		
	Leg towards Ghatlodia	8.50	7380
	Leg towards Ankur society	7.30	7740
	Leg towards Akhbarnagar	9.00	6563
	Leg towards AEC Bridge	9.00	7560
5	**Income tax Intersection (Morning Peak Hours)**		
	Leg towards Gandhi bridge	9.70	9420
	Leg towards Under pass	9.70	9828
	Leg towards Usmanpura	10.50	8892
	Leg towards Paldi	9.55	12600
	Income tax Intersection (Evening Peak Hours)		
	Leg towards Gandhi bridge	9.70	10209
	Leg towards Under pass	9.70	10500
	Leg towards Usmanpura	10.50	10548
	Leg towards Paldi	9.55	15615
	Income tax Intersection (Morning Peak Hours) (IInd sets of data)		
	Leg towards Gandhi bridge	9.70	10137
	Leg towards Under pass	9.70	10440
	Leg towards Usmanpura	10.50	9450
	Leg towards Paldi	9.55	15403
6	**Memco Intersection (Morning Peak Hours)**		
	Leg towards Bapunagar	11.50	7292
	Leg towards Amdupura	9.50	6184
	Leg towards Over bridge	11.50	7750

Sr. No.	Locations	Width of Road (m)	Observed Maximum Saturation Flow (PCU / hr)
	Leg towards Naroda	8.00	6100
7	**Vijay cross Intersection (Morning Peak Hours)**		
	Leg towards L. D. College	9.00	6480
	Leg towards Gurukul	8.00	8287
	Leg towards Darpan five road	10.20	9360
	Leg towards Commerce six road	7.10	7842

Table 3 shows roughness index of approaches of the selected intersections.

Table 3: Summary of roughness at various intersections

Sr. No.	Name of approach	Length of stretch in meter	Roughness in mm/km
Shastrinagar Intersection			
1	AEC approach	430	106
2	Ankur approach	610	69
3	Pragatinagar approach	580	71
4	Ranna Park approach	970	172
Nehru bridge Intersection			
1	Ellis bridge approach	645	164
2	Gandhigram approach	465	60
3	Natraj approach	530	90
4	Lal darwaja approach	590	185
Paldi Intersection			
1	Jalaram Temple approach	160	175
2	V. S. Hospital approach	645	140
3	Mahalaxmi approach	470	89
4	Jamalpur approach	490	139

It is observed from Table 3 that road roughness of the study area in the range from 60 to 185 mm/km. The higher value of roughness is observed on the Ranna park approach, Lal Darwaja approach and Jalaram Temple approach in the study area.

V. DEVELOPMENT OF MODEL

Model is developed for predicting saturation flow at the study area. In statistics, linear regression is an approach for modeling the relationship between a scaler dependent variable 'y' and one or more explanatory variables denoted as 'x'. Following model is developed for estimating saturation flow considering width and roughness of road.

Model 1

Saturation Flow, S = 1014 W + 13U, (1)

Where,

W = Width of road in meter
U = Average roughness in mm/km
R square = 0.93

Statistical validation

The null hypothesis is:

Ho : $\mu = 0$; i.e. any difference in saturation flow is due to chance

Mean of difference = 122

Standard Deviation, SD = 2644.36

Standard Error, SE = 763.36

$t_{obs} = 0.16$

$t_{crit} = 2.20$

T - test is performed for statistical validation of the developed model. p- value = 0.88 $\geq$ 0.05, hence it is concluded with 95% confidence that the difference in observed saturation flow and determined saturation flow with Model S6 is not due solely due to chance.

VI. RESULTS AND DISCUSSION

The observed saturation flow, output of Model recommended by IRC:93 and developed Model 1 are compared and tabulated in Table 4.

Table 4 Comparison of observed saturation with output of the models

Sr. No. A	Width of Road (m) B	Observed saturation flow (PCU/hr) C	Saturation flow (PCU/hr) as per model suggested by IRC: 93 D	% Difference w.r.t. observed saturation flow E= (D-C)*100/C	Saturation flow determined using Model 1 (PCU/hr) F	% Difference w.r.t. Observed saturation flow G = (F-C)*100/C
1	4.5	6668	2363	-64	7539	13
2	7.3	7740	3833	-50	8321	7
3	8.5	8740	4463	-49	10913	24
4	8.85	12440	4646	-62	10172	-22
5	8.9	10440	4673	-55	11359	8
6	9	11400	4725	-58	10979	-4
7	9.3	12360	4883	-60	10615	-16

The difference between observed saturation flow and output of developed **Model 1** is less compared to model recommended by IRC:93. The difference between observed saturation flow and output of model recommended by IRC: 93 is in the range from -49% to -64%. The difference between observed flow and output of developed **Model 1** is less compared to IRC method.

VII. CONCLUSION

The signal should be designed such that it allows maximum vehicles to cross the traffic at intersection safely. Due to improper signalized intersection, congestion or delay increases at intersection, which results in driver discomfort, frustration, fuel consumption and increased travel time. Saturation flow, delay and signal timings are the important parameter in the analysis of signalized intersection. The accurate determination of saturation flow is necessary for calculating optimum cycle time. The saturation flow for each study approach was measured and linear regression model is developed. The regression model 1 is developed for saturation flow based on width of road and roughness of selected intersection of Ahmedabad city. It gives satisfactory results closer to the field observations. The selected urban road intersection is having less roughness. The effect of roughness is distinctive effort for estimation of saturation flow in addition to width of road. The developed model may be applied in other cities of India and checked for its usefulness. The developed model 1 is useful for estimating saturation flow. The developed model is statistically validated for significance level of 95%.

VIII. REFERENCES

[1] Agent K. R. and Crabtree J. D. (1982), "Analysis of Saturation Flow at Signalized Intersection", Technical Report - Lexington, 1-52.
[2] Anusha B. S., Verma Ashish and Kavitha G. (2013) "Effects of Two-Wheelers on Saturation Flow at Signalized Intersection in Developing Countries, Journal of Transportation Engineering, ASCE, 2013, 448-457.
[3] Chien Chang (1978), "Saturation Flow at Signal Controlled intersection in Bangkok" MSc Thesis, Asian Institute of Technology, Bangkok, Thailand.
[4] Mukwaya Richard and Mwesige Godfrey (2011), "Saturation Flow Rate for Through-Traffic at Signalized Junctions in Kampala", Second International Conference on Advances in Engineering and Technology, 464-470.
[5] Nikhil G. Raval, Dr. P. J. Gundaliya, 'Modifications of Webster's Delay Formula using Modified Saturation Flow Model for Non-Lane based Heterogeneous Traffic Condition", *Highway Research Journal, Page no – 41 – 48*, Volume – 5, No-1, Published in January – June-2012.
[6] Robert V. Stokes (1988), "Comparison of Saturation Flow Rates at Signalized Intersection", ITE Journal, 15-20.
[7] Yanming Guo, Quan Y, Yunlong Zhang and Jian Rong (2012), "Effect of Bicycles on the Saturation Flow Rate of Turning Vehicles at Signalized Intersections, Journal of Transportation Engineering, ASCE, 21-30.

