Analysis Of Signalised Urban Intersections Under Mixed Traffic Conditions

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Abstract: The performance estimation of a signal controlled crossroad mainly depends upon saturation flow rate. In urban areas, the multi-modal traffic surrounding affects the saturation flow rate. In the present study, the Indian urban traffic is grouped into two categories based on the degree of manoeuvrability namely Highly Manoeuvrable Vehicles (HMV) and others. Those vehicles which have a high measure of lateral and longitudinal mobility are called Highly Manoeuvrable Vehicles (HMV). Motorized wheelers and human-power driven bicycles are put into this category in the current study. Saturated green time studies are carried at certain signal controlled intersections of Srinagar city and the numbers collected are analysed for the saturation flow rates. The analysis concluded that the saturation flow rate depends not only on the width existing for the movement under deliberation but also on the share of HMV in the traffic. As a result of this study a statistical model was developed to explain the connection between the saturation flow rate in veh/hour and the two independent variables, the width available for movement and the amount of HMV which has admirable prediction competence for assessing saturation flow rate.

Introduction

General

The largely complex locations in urban road system are Signal controlled intersections. The overall effectiveness of the whole transportation network in cities overwhelmingly depends upon the operational situation of such intersections. With time the functional capability of urban roads gets reduced due to an increase in number of vehicles over the years. So to tackle this challenge a higher level of service, efficiently planned and a better effective scheme is indispensable to assure a comfortable ride on urban roads at any instant. to achieve this goal there needs to be an immediate assessment of current status and functionality of urban roads to manage the road network near perfection. Based on the assessment results various plans and strategies could be framed out and can lead to the judicious allocation and use of funds. There is ample number of examples like U.K, USA, Canada etc. where we find that researchers have used level of service and capacity flow of an intersection to assess the overall performance and efficacy of signalised intersection.

Since signals are normally used to counter capacity shortage on urban roads, so in order to predict the capacity of a signalised intersection it becomes necessary to employ an adequately precise method which could yield some realistic data. The signal design plays a significant role in reducing a lot of problems. If the signal is properly designed there would be less congestion, least fuel wastage, reduced delays, greater capacity of intersection and a very less amount of pollution. Therefore, it becomes necessary for a traffic engineer and signal designer to assess the traffic scenario very meticulously to design an apt optimum cycle time and corresponding phasing to suit the requirements of the traffic with a significant deliberation to the location physical features.

The design of a signal is majorly affected by Saturation Flow rate. Saturation flow rate can be defined as the maximum number of vehicles from a lane group that can traverse through an intersection during an uninterrupted green time for one hour under prevailing traffic scenario. The capacity of a signal controlled intersection and design of signal timing can be evaluated using saturation flow rate. According to the Highway Capacity Manual (HCM) saturation flow rate directly affects the capacity of a signal controlled. The capacity of the signal controlled intersection can be analysed accurately along with delay timing and the level of service; given the reasonable accuracy in estimation of the saturation flow rate.

Palpably the saturation flow rate is manipulated by the available width of approach over which the release takes place as well as the way the vehicles fork out laterally and longitudinally within the accessible space while getting released. So it is imperative to give due consideration to the width of approach in the assessment of capacity of signalised intersection.

Need for the proposed study

The assessment of the existing status and performance of signal controlled urban road intersections in urban traffic management is one of the significant responsibilities. Saturation flow rate is the main aspect in the functional assessment of signal controlled urban crossroad. So for the rational and realistic computation of saturation flow rates at signal controlled urban intersections the present study is a step in the same direction with due importance to traffic composition and the approach width. It is very significant to determine saturation flow rate more precisely only then signalised intersections can be designed more accurately, which otherwise results in huge congestions because both signal design and assessment of intersection capacity are dependent on it

Objectives of the Study

In the present study only signal controlled urban intersections, whose signal design is such that those allow synchronized release of straight and right flows from a given approach, were assessed. This is the generally implemented phase plan in Indian traffic situation.

The main objectives of the study are:

a) To compound a database on saturations flows under diverse signal plans and geometric conditions by performing field studies at particular signal controlled intersections in Srinagar city

b) To assess and estimate saturation flows based on traffic composition and geometrics of the approach for the development of a statistical model

c) To check and validate the developed model by means of data collected at comparable signal controlled intersections positioned in the study zone.

Methodology

Introduction

The methodology adopted for this study is represented in the form of a flow chart below (fig 1). The stand out steps are data collection, data processing and developing of MLR model. The flow chart demonstrating the comprehensive methodology for the present study is shown in fig. 1.

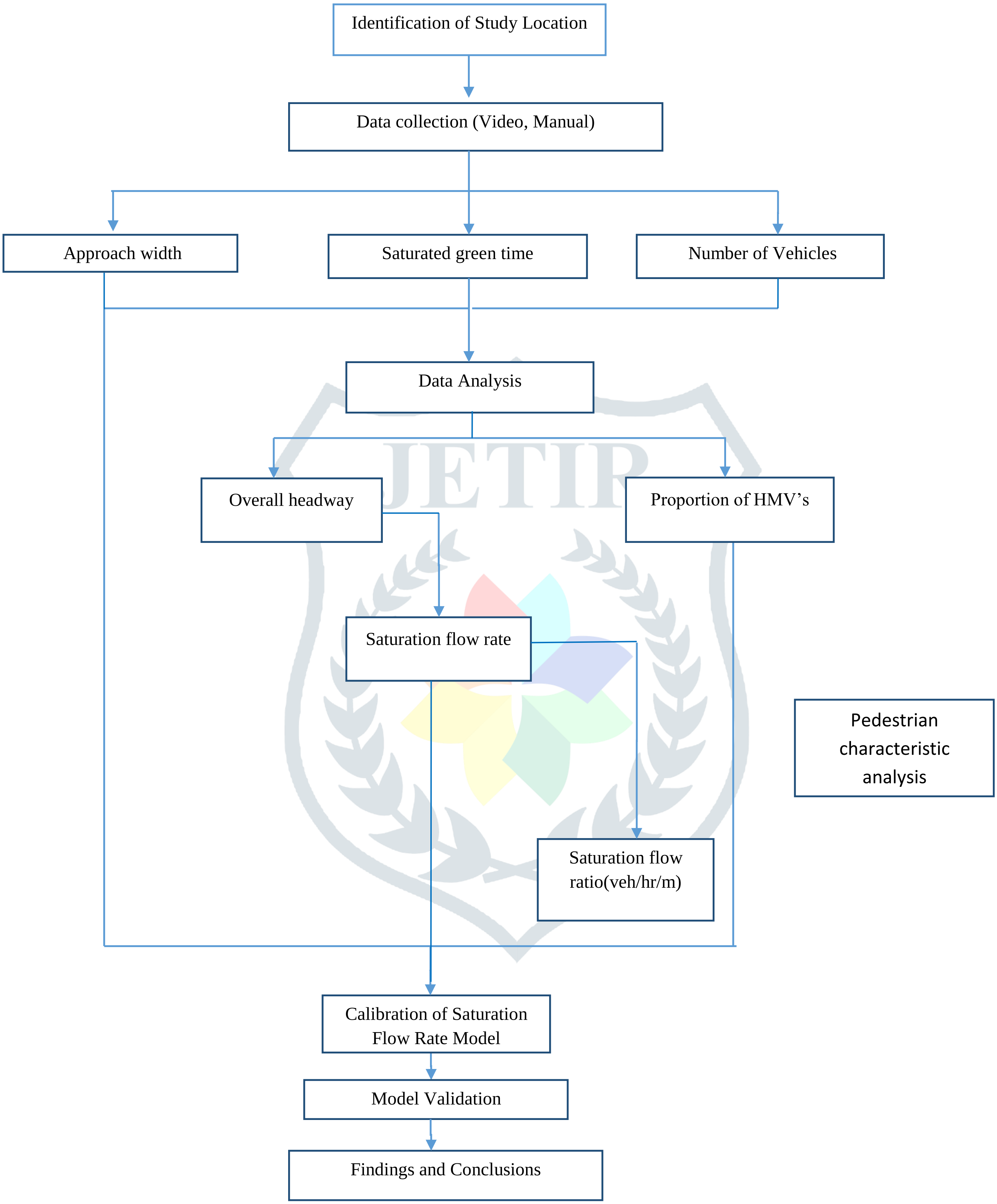


Fig 1 Methodology

Study sites

Two intersections in the city of Srinagar are chosen and four of their approaches are studied. The intersections with their corresponding approaches selected are as below. Both the intersections chosen are four-legged with a pre-timed signal controlling the traffic.

Table 1 showing Study Locations

Intersection	Approach
Sanat nagar	a)Nowgam b)Rangreth
Nowgam	a)sanant nagar b)chattergam

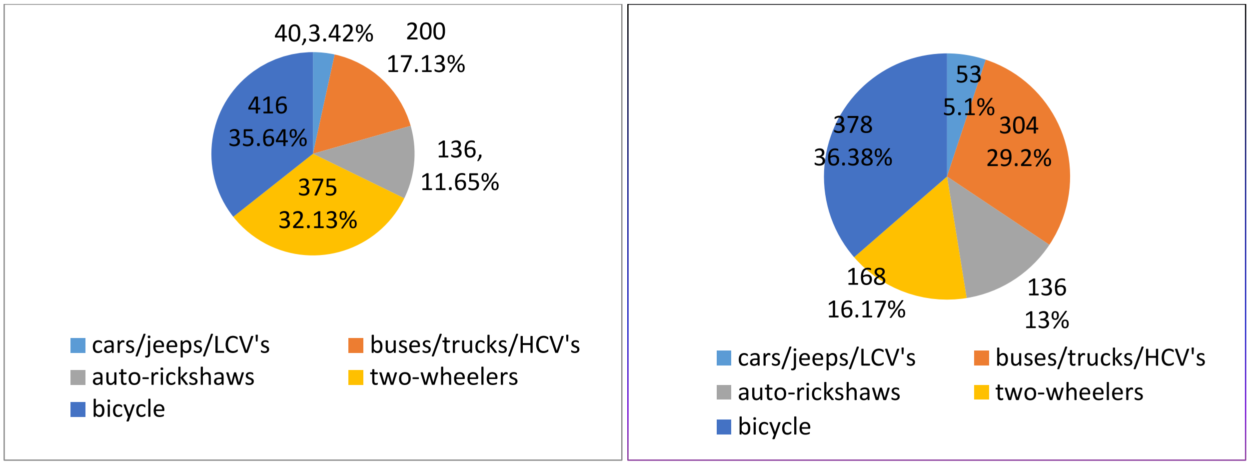
Sanatnagar Intersection

The geometrical details of this intersection are presented in Figure 2. The intersection is a four-legged intersection governed by a four phased pretimed signal with a cycle time of 145 seconds. The four approach roads are designated as lal chowk approach, hyderpora approach, rangreth approach and nowgam approach. Straight and right flows from a particular approach are released at the same time in each of the four phases. The left turns are allowed without any interruptions from all the approaches. The saturated green time study is carried at this location on two approaches that is Nowgam approach and rangreth approach.

Nowgam Intersection

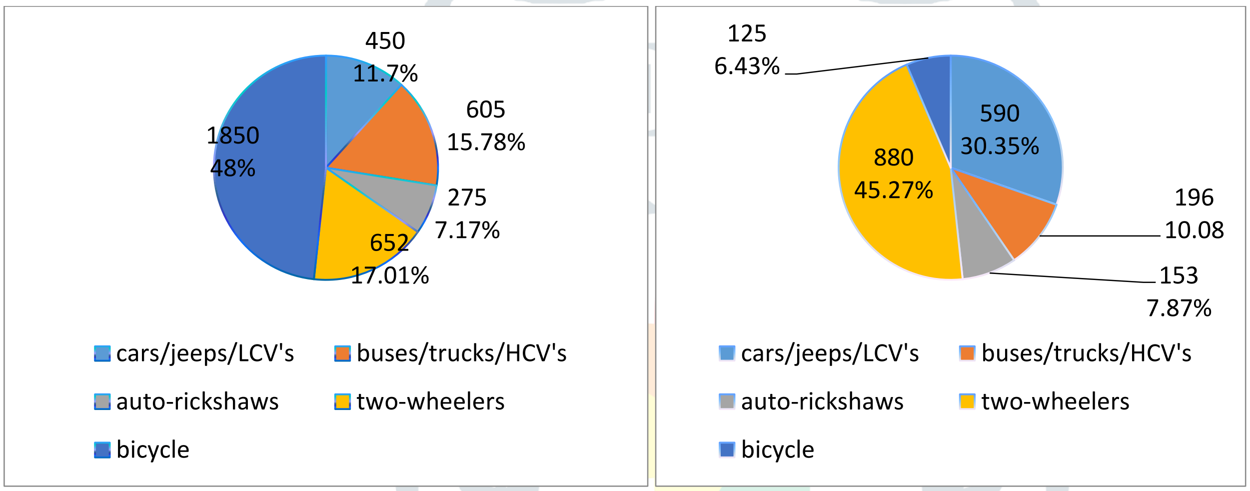
The geometrical information of this intersection is provided in Figure 3. The intersection is a four -legged intersection governed by a four phased pretimed signal with a cycle time of 140 seconds The four approaches are designated as Sanatnagar approach, chattergam Nowgam approach, Natipora approach and Panthachowk bypass approach. The saturated green time study is performed at this location on two approaches namely sanant nagar approach and chattergam approach.

While collecting data and analysing it for conclusions, the composition of vehicle types in the traffic stream needs to be calculated. The proportion of each vehicle type can be then represented in the form of a pie chart. Figures 4 and 5represent mode spilit for both the selected intersections on the selected approaches.



1)Nowgam intersection-chattergam approach 2)Nowgam intersection-sanant nagar approach

Fig.2 Modal Split at Nowgam Intersection



1)sanat nagar intersection-nowgam approach 2)sanat nagar intersection-rangreth approach

Fig.3 Modal Split at Sanant nagar Intersection

Data Analysis

The data collected in field is in raw form so after amassing field statistics it is essential to reduce these multitudinous amounts of data down to an understandable form through the exercise of various parameters. The data is reduced in such a manner it complies with the visioned objectives and also gives credible information about the traffic behaviour.

Sanatnagar Intersection-Nowgam Approach

This approach facilitates the straight and right movements on a combined width of 10.29m. The signal is operational with cycle duration of 145 sec and has allocated green time of 40 sec for this phase. The share of highly manoeuvrable vehicles (HMV) ranged from 0.35 to a maximum value of 0.79 with a mean value of 0.57. The saturated green time also was not consistent and varied from cycle to cycle in succession, within a range of 17 seconds to 39 seconds with an average of 28 seconds. The overall headway ranged from a minimum assessment of 0.36 sec to a maximum of 0.79 sec with a mean value of 0.55sec. The saturation flow rates with a mean of 4509 veh/hr varied from a highest of 6955 veh/hour to a lowest of 4105 veh/hr. The saturation flow ratio

(SFR) in terms of veh/hr/m varied from a bottom value of 399 to a maximum of 675 with a mean of 495. Some exciting conclusions were revealed after a close scrutiny of the data.

the figure 6 set up the general trend that if the proportion of smaller vehicles goes down in the traffic stream, they attempt to move freely thereby not utilizing every space gap accessible in the carriageway resulting in higher overall headway and smaller saturation flow rate and *vice versa*.

Sanatnagar intersection-Rangreth approach

This approach facilitates the straight and right movements on a combined width of 7.3m. The signal is operational with cycle duration of 145 sec and has allocated green time of 24 sec for this phase. The share of highly manoeuvrable vehicles (HMV) with a mean value of 0.72 ranged from 0.35 to a maximum value of 0.80. The saturated green time also was not consistent and varied from cycle to cycle in succession, within a range of 11 seconds to 25 seconds with an average of 18 seconds. The overall headway ranged from a minimum assessment of 0.39 sec to a maximum of 0.99 sec with a mean value of 0.68sec. The saturation flow rates with a mean of 5632 veh/hr varied from a highest of 6750 veh/hour to a lowest of 3457 veh/hr. figure 7 shows a correlation between proportion of HMV's and saturation flow ratio.

Nowgam Intersection- Sanant-nagar Approach

This approach offers a shared width of 12m for the straight and right manoeuvres. The signal is operational with a a green time of 28 seconds per phase and a total cycle length of 140 seconds. The share of highly manoeuvrable vehicles (HMV) with a mean assessment of 0.70 varied from 0.33 to 0.86. The overall headway with an average value of 0.47sec varied from a least value of 0.44 seconds to a maximum of 0.93 sec. The saturation flow rates with a mean of 5502 veh/hr ranged from a maximum of 6495veh/hr to a minimum of 3812 veh/hr,. The saturated green time with an average of 20.5 seconds ranged from cycle to cycle with a range of 12 seconds to 29 seconds. Figure 8 illustrates a constructive correlation between the saturation flow ratio (SFR) and the share of HMV. The coefficient of determination is 0.601.

Nowgam Intersection- Chattergam Approach

This approach facilitates the straight and right movements with a pooled width of 7.9m. The signal is in force with an assigned green time of 32 sec for a single green phase with a total cycle length of 140 sec. The share of highly manoeuvrable vehicles (HMV) with a mean value of 0.611 varied from 0.461 to a maximum value of 0.815. The overall headway with a mean value of 0.51sec varied from a least value of 0.29 sec to a maximum of 0.91 sec. The saturation flow rates , with an average of 4710 veh/hr ranged from a maximum of 5931 veh/hr to a minimum of 3762 veh/hr. The saturated green time with an average of 21.6 seconds also ranged from cycle to cycle within a range of 11.8 seconds to 27.5 seconds. Figure 9 confirms a correlation between the saturation flow ratio and the proportion of Highly Manoeuvrable Vehicles (HMV's). The coefficient of determination is 0.645.

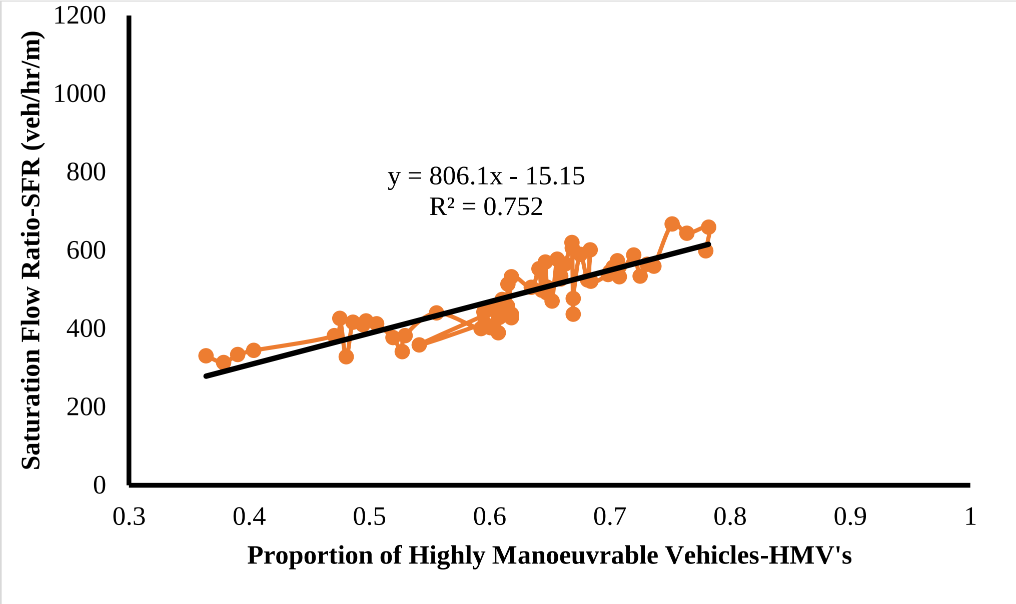


Fig 4 Saturation Flow Chart for Sanatnagar Intersection- Nowgam approach

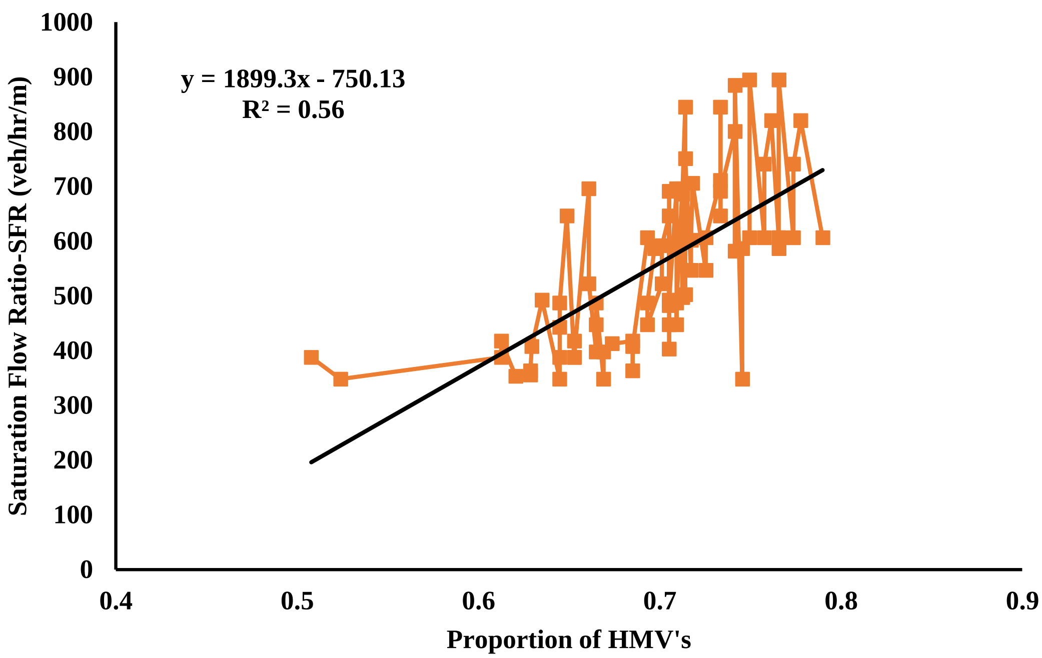


Fig 5 Saturation Flow Chart for Sanatnagar Intersection- Rangreth approach

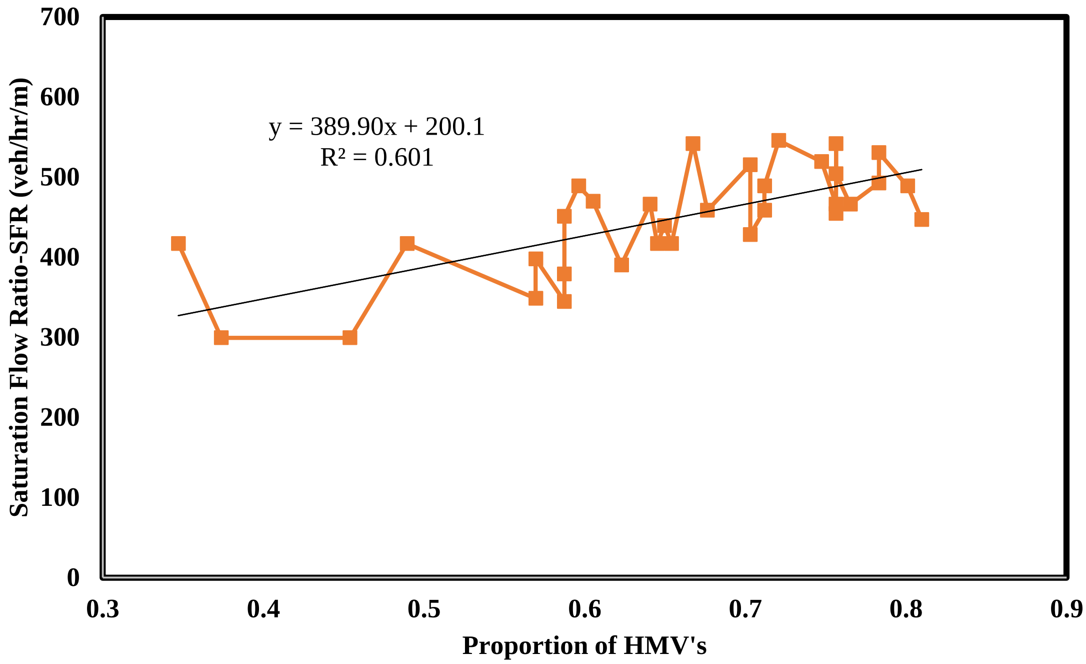


Fig 6 Saturation Flow Chart Nowgam Intersection- Sanat nagar approach

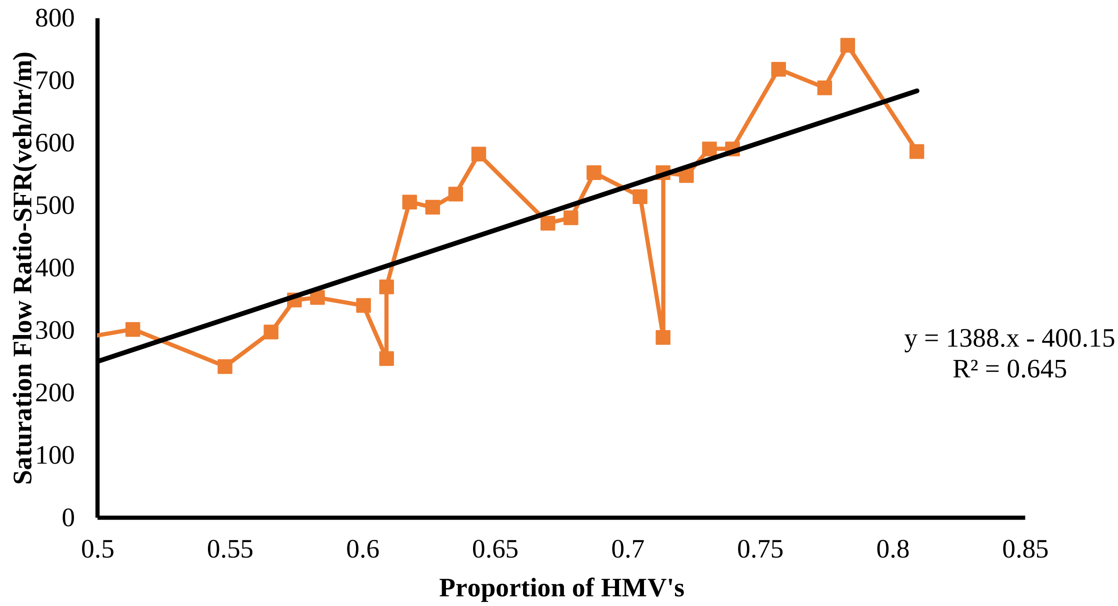


Fig 7 Saturation Flow Chart Nowgam Intersection- chatter gam approach

Estimation and Evaluation of Saturation Flow Rate

So far from the observations and analysis of traffic data it is evident that the saturation flow rate from cycle to cycle for a given approach is recorded for the unaltered width available for the lane group and only the share of the highly manoeuvrable vehicles (HMV's) is varying from cycle to cycle. It has been noticeably concluded that the saturation flow rate varies proportionally with the proportion of HMV's, the saturation flow rate increases with the rise in share of HMV's. For the intention to understand this aspect, the reduced data of all the approaches analysed is illustrated by means of Table 2. This table depicts the range of saturation flow rate and the saturation flow ratio both.

The greatest saturation flow rates recorded at each location are employed to compare their relationships with the width. The table below also depicts the saturation flow rate in terms of veh/hr/lane (vphpl, vehicles per hour per lane) taking 3.5m as the width of a single lane. The maximum values of saturation flow rate are utilized to work out the graphical relationship between the saturation flow rate and the width of carriageway offered. A graph plotted between the saturation flow ratio (SFR) and the width as depicted in Figure 10 approves the observation that the vehicles seek to adjust themselves over the accessible width. The saturation flow ratio (vphpm) is noted to vary inversely with the width insinuating that the vehicles travel nearer to each other when the overall accessible width is less and when generous width of road is available the vehicles aim to uphold more secure and comfortable lateral and longitudinal spacing.

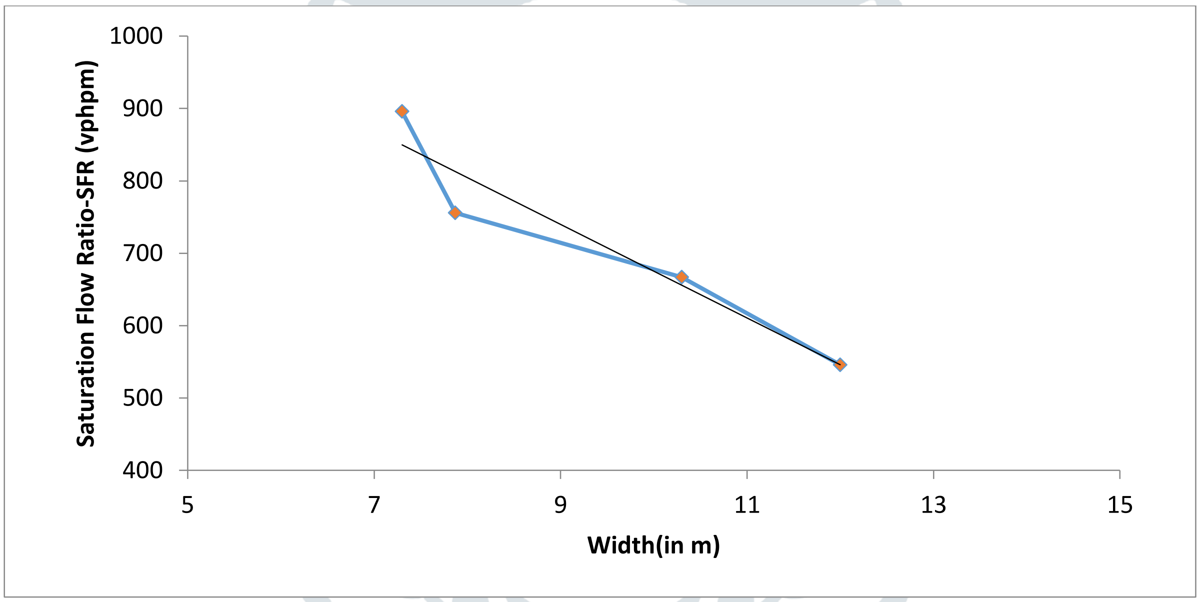


Fig.8 Saturation Flow Ratio Vs Width

Table 2 Consolidated Data on Saturation Flow

Width, m	Saturation Flow Rate vph (Max)	Saturation Flow Rate (vphpl)	Saturation Flow Ratio vphpm (Max)
7.3	6750	3236	925
7.87	5931	2638	754
10.3	6955	2363	675
12	6495	1894	541

Mathematical modelling of saturation flow rate using regression analysis

If a model has the competence to develop a close relationship between the input and output functions then the result are considered to be satisfactory. Well recognized mathematical model such as Multiple Linear Regression (MLR) and) is employed to analyze the saturation flow rate at signal controlled intersections in the present analysis.

Development of regression model

The mathematical model established elucidates the observed behaviour more intimately because of its reasonable validity as well as the statistical measures of appropriateness of the equation.

$$SF= -5298+8252P_{HMV}+490W$$

Where SF= Saturation Flow Rate, in vph;

P_{HMV} = Proportion of Highly Manoeuvrable vehicles; and

W =Width accessible for the combined straight and right manoeuvres from an approach, in m.

The equation has illustrated a significant R^2 value of 0.741 representing a judicious scale of correlation between the dependent variable and the independent variables. it is rational to assume that the model can yield unfailing results over the range of widths that are fed as inputs to the model i.e., from 7.3m to 12m. The p-values linked with the constant as well as the independent variables are pretty good demonstrating a high-quality of correlation with the dependent variable.

Table 3 showing p-values and R^2 value for statistical model

Parameter	Coefficient	p-value	t-value
Constant	-5298	$4.78E^{-13}$	6.91>1.96
P_{HMV}	8252	$1.29E^{-22}$	10.95>1.96
Width	490	$2.09E^{-28}$	13.35>1.96
R^2	0.741		

Here it is confirmed that the p values of the two variables and the constant is smaller than 0.05, which proves null hypothesis erroneous at 5% significance level. It also signifies a reasonable level of correlation with the dependent variable as the t-ratios linked with the constant as well as the independent variables is pretty good when contrasted to table values. The observed t-values and the table values at 5% significance level are tabulated above.

Validation of Multiple Linear Regression Model

Table 4.2 Validation of Multiple Linear Regression Model

Width (m)	Proportion of HMV	Saturation Flow Rate, vph	
		Observed Values	Predicted Values by MLR Regression Model
7.3	0.770	5107	4763.2740
7.3	0.769	4439	4590.1294
7.3	0.771	4599	4604.6124
7.3	0.781	4905	4688.2798
7.3	0.790	4312	4789.0819
7.8	0.741	4721	4595.2985
7.8	0.751	5710	5337.6778
7.8	0.765	5396	4997.5654
7.8	0.779	4700	4962.1632
7.8	0.810	5398	5178.5521
10.3	0.728	5732	5589.6842
10.3	0.707	5483	5498.9554
10.3	0.719	5588	5598.8194
10.3	0.725	5501	5648.7514
12	0.771	6412	6616.1435
12	0.759	6210	6524.6485
12	0.783	6550	6857.5625

Multiple linear regression model validation refers to the comparison of saturation flow rate estimated by model with the observed saturation flow rate in the field for given values of approach width and proportion of HMV. Table 4 above presents the validation of model outputs and the results are quite encouraging.

Conclusions

1. The Saturation Flow Rate from a particular approach banks on the available width of approach and the proportion of highly manoeuvrable vehicles in the traffic. The relationship given by multiple linear regression model is expressed as

$$SF= -5298+8252\ P_{HMV}+490\ W$$

Where S is the Saturation Flow Rate in veh/hr, P_{HMV} is the proportion of highly manoeuvrable vehicle group and w is the width available for the manoeuvre. The equation has displayed an R^2 value of 0.741. The p-values and the t- signify a rational level of correlation with the dependent variable.

2. A linear and positive relation between the saturation flow rate and the two independent variables i.e. proportion of HMV's and the available width for the movement exists. This illustrates if both width and proportion of HMV's rise, the saturation flow rate will also rise.

3. The model will furnish good results for P_{HMV} ranging from 0.35 to 0.85 and for width ranging from 7.3m to 12m. The model possibly will show discrepancy for other values of P_{HMV} and approach widths.

Future Scope of the Work

The present study is restricted to four legged signal controlled intersections only where the straight and right movements from an approach are released simultaneously. To develop a universal procedure for the performance evaluation of any signal controlled urban intersection under heterogeneous traffic conditions a broad study encompassing all the potential intersection lay outs and phase plans is indispensable.

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