Estimation of Saturation Flow at Signalized Intersections Under Heterogeneous Traffic Conditions

Rakesh Kulakarni, Akhilesh Chepuri, Shriniwas Arkatkar and Gaurang J. Joshi

Abstract This research aims to develop a simulation-based methodology in the estimation of saturation flow at signalized intersections under heterogeneous traffic conditions in India. Field surveys have been carried out particularly during peak periods at two signalized intersections, namely Vijay Char Rasta intersection situated in Ahmedabad and Rangila Park intersection situated in Surat. Videographic technique is employed to capture the data at macro- and microlevel. The videographic approach provides the queue building, moving, and queue dissipation at microlevel. The field data pertains to traffic volume, compositions, turning movements, headway, cycle time, and phasing at the approach. The survey also concentrates on noting the queue length of each approach. Apart from videographic survey, road inventory survey and spot speed surveys are also carried out in order to use this data in VISSIM 7.0 for the development of network and defining speed distributions. The present work mainly focused on the development of PCUs, dynamic saturation flows, VISSIM modeling and validation, regression modeling and validation, and sensitivity analysis. Passenger car unit for each vehicle category is calculated by two methods—headway method and optimization method. Saturation flow is estimated with the help of PCU values estimated by different methods, and these values are compared. TRL method is adopted in the estimation of saturation flow. A 5-s interval is considered in this method. Nearly, 8842 VPH is the saturation flow against to 5460 PCU of headway method and 5071 PCU of optimization method for 3 lane approach of Vijay Char Rasta intersection. Saturation flow is almost double in terms of mixed traffic. Therefore, saturation flow cannot be static in present study but is dynamic. Dynamic saturation flow values are provided for varied composition and approach widths.

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Base network is created in VISSIM 7.0. Model is calibrated as per Indian driving behavior for both Vijay Char Rasta and Rangila Park. Average queue length is considered for validating the model. Sensitivity analysis is carried out after validating the simulation model. It is observed that change in road width is having significant effect on saturation flow when compared to change in turning movements. Regression analysis is carried out for developing multilinear regression saturation flow model (MLR–SFM). The model is developed between saturation flow and proportion of 2W, 3W, small car, big car, and road width. 65–35 combination is observed to be best fitted combination in developing and validating the model. Similar to the observations in VISSIM modeling, it is observed that change in road width is having a significant effect on saturation flow when compared to change in traffic compositions.

Keywords Saturation flow · Signalized intersection · Heterogenous traffic · Micro simulation

1 Background

Urbanization is the physical growth of urban areas as a result of global economy. It is closely linked to modernization, industrialization, and the sociological process of rationalization. Urbanization is an index of transformation from traditional rural economies to modern industrial one. It is a long-term process. Urbanization is a natural expansion of an existing population, namely the proportion of total population or area in urban localities or areas (cities and towns), or the increase of this proportion over time. It can thus represent a level of urban population relative to total population of the area, or the rate at which the urban proportion is increasing. The urbanization impact has been felt in all urban sectors. It is more so in transportation sector. The transport demand growth in vehicle population and traffic has been observed in a significant way.

Most of the metropolitan cities in India possess diversified traffic characteristics. The characteristics of traffic flow include speed of vehicles, their concentration, and density of flow, and these are governed by a variety of factors attributable to road features, the vehicle performance characteristics, and road-user behavior. Most of the Indian cities comprise of heterogeneous traffic composition, with two-wheeler and four-wheeler as the leading percentages. Heterogeneity not only exists in terms of vehicles but also in case of road users and pedestrians. Deficiency in lanewise discipline is observed compared to the cities of western countries.

Intersections are an important part of an urban roadway network, and they have a significant effect on the operation and performance of the traffic system. Frequently intersecting urban road links lead to conflicts between opposite flow of traffic, thereby causing delay and accident. They are normally major bottlenecks to smooth flow of traffic and a major place for conflicts. Thus, operation of intersection is critical in Indian urban context where the heterogeneous traffic conditions prevail. Signalization of intersection is done to provide an effective movement of the vehicular traffic,

thereby enhancing higher safety to users as well as pedestrians. Signalized intersections are indispensable when due importance is to be given to vehicular flows of all approaches meeting at the intersection. The present research project focuses on mixed traffic behavior at the signalized urban intersection approaches.

Saturation flow is an important input parameter in the design of cycle time for traffic signals. It is the flow that can be accommodated by the lane group assuming that the green phase was displayed 100% of time. The characteristics of heterogeneous traffic are significantly different from homogeneous traffic in terms of lane discipline, driver behavior, and vehicle compositions. Due to heterogeneity of traffic, it is unlikely to use the HCM model directly because it has been developed for a homogeneous traffic conditions. Heterogeneous traffic has varying types of vehicles: two-wheelers, motorized and non-motorized three-wheelers, cars, buses, trucks, bicycles, and miscellaneous types; out of them, two-wheelers are the major mode of transportation in most of the developing countries like India. Due to these high compositions of two-wheelers, the urban traffic behavior is greatly different from developed nations. Minh and Sano [1] analyzed the effect of motorcycles on saturation flow rate in Hanoi and Bangkok. They suggested that the effect of motorcycles is significant and should be taken into account in geometry design and operation of signalized intersections. Anusha et al. [2] studied the effect of two-wheelers on saturation flow at signalized intersection in Bangalore, India. They modified HCM equation by introducing an adjustment factor for two-wheelers and concluded that the saturation flow estimated using calibrated HCM model is closer to field values. Arasan and Jagadeesh [3] estimated the PCU for different categories of vehicles using the multiple linear regression models considering the saturated green time against the number of each category of vehicles crossing the stop line, during the green time. Vien et al. [4] studied the effect of the motorcycles' travel behavior on saturation flow rates at signalized intersections in Malaysia. They divided motorcyclists traveling through an intersection into within the flow (follow a first-in-first-out rule, travel either in front of or behind other vehicles) and outside the flow (do not follow the first-in-first-out rule). They compared the saturation flow rates observed at sites based on motorcycle inside the flow and saturation flow rates estimated using the Malaysia Highway Capacity Manual (2006) based on total volume of motorcycle and concluded that motorcycles inside flow should be considered in the estimation of saturation flow rates.

The various factors like vehicle types, approach width, traffic mix, driver behavior, and roadside activity can influence traffic behavior and in turn the saturation flow rates. A number of studies have been done to model the effects of heterogeneous traffic on saturation flow at signalized intersection. The equation suggested by the Indian Roads Congress (IRC) to estimate saturation flow is $S = 525 * (w)$, PCUs per hour, where $w =$ width. It is valid for width from 5.5 to 18 m. Arasan and Vedagiri [5] studied the influence on saturation flow due to road width by using simulation technique. They found a positive effect on saturation flow with the width of an approach. Patil et al. [6] studied the influence of area type in the PCU values and estimated that the PCU for two-wheeler ranges from 0.09 to 1.23, three-wheeler from 0.23 to 6.14 and that of bus from 1.02 to 3.78. Praveen and Arasan [7] have

derived the vehicle equivalency factors for urban roads in India. It was found that under heterogeneous traffic conditions, for a given roadway and traffic composition, the PCU value of vehicles varies significantly with change in traffic volume. Mathew and Radhakrishnan [8] developed a saturation flow model per lane width using the different traffic parameters, by developing PCUs using optimization technique. They validated the proposed model with saturation flows collected from different locations in India.

Estimation of saturation flow requires a common platform, and this is accomplished by passenger car units. As the significant portion of the traffic in developed nations comprises of passenger cars, it has been taken as the vehicular traffic unit for the purpose of design and analysis which is widely known as "passenger car unit" (PCU). But, in the heterogeneous traffic conditions, drivers do not usually follow lane discipline and can occupy any lateral position on the road. Because of these significant differences in characteristics between the heterogeneous and homogeneous traffic, the research results based on the homogeneous situation are unlikely to give reliable results if applied in the heterogeneous traffic conditions.

2   Study Section and Methodology

Base signalized intersection is an intersection where saturation flow is measured in ideal conditions. So, selection of such intersection plays a vital role in estimating the base saturation flow rate (so), which is later applied for other intersections for finding saturation flow by considering other adjustment factors. Present study accompanied at two four-legged intersections, namely Vijay Char Rasta (VCR) intersection in Ahmedabad and Rangila Park intersection in Surat, western part of India. Both the intersections consist of a pre-timed signal (four-phase) with VCR total cycle time of 142 s in the morning and 167 s in the evening and RP total cycle time of 125 s which are operated during the peak hours.

The methodology in the present research study broadly includes the identification of relevant intersections, data collection and extraction of traffic composition, headway and turning movements, and microscopic simulation. Data extraction is carried out through the moviemaker software from the video-recorded files of traffic movement at the study intersection. Thus, extracted values are analyzed using the statistical and frequency distributions. Traffic composition, headway, and turning movements are analyzed to find PCU values and estimate saturation flow. This data is also used in developing regression model. Simulation technique is employed to analyze and compare the results by performing sensitivity analysis. The developed model is validated by using the queue length results. Regression model is developed in order to apply it to other intersection and know the effect of the developed model. The developed model is validated by comparing the observed and expected saturation flow results.

3 Data Collection

Data collection for the present study includes the collection of the data related to traffic volume, turning movements, headway, cycle time, phase, queue length, road geometry, and spot speed of vehicles. Videographic, road inventory, and spot speed surveys are carried out to capture the required traffic characteristics. A total of eight hours of videographic data was initially collected for one weekday covering both morning and evening peak hours. Videographic survey was done on March 20, 2015, for Rangila Park intersection, Surat city, on April 6, 2015, for Vijay Char Rasta, Ahmedabad city (Fig. 1). All the four cameras were placed on the high-raised buildings, each camera covering the respective major and minor approach traffic. Cameras were placed in such a way that they cover the complete queue length formed in each of the individual approach.

Road inventory survey has been carried out during the free flow conditions causing minimum obstruction to the traffic movement and reducing the risk for the surveyors. This data has been used in building a VISSIM 7.0 model and also in developing MLR model for estimation of saturation flow. Spot speed survey is performed using radar guns on all approaches of intersection in both the scenarios. This survey is carried out on same day simultaneously for the duration of one hour to capture the spot speeds of all types of vehicle categories for every 5-min interval.

Fig. 1 Aerial view of Vijay Char Rasta, Ahmedabad

Table 1 Statistics of traffic composition

Intersection	% TW	% 3W	% Small car	% Big car	% HGV
Vijay Char Rasta	60.63	14.88	16.50	7.25	0.56
Rangila Park	57.75	15.23	16.30	10.29	0.43

3.1 Data Extraction and Processing

Data extraction is carried out manually using moviemaker software from video file to evaluate the traffic flow characteristics like turning movements, vehicle composition, headway, and cycle time. Extracted data is processed using Excel and Statistical Practice for Social Science (SPSS) tools for calculating percentiles and frequencies of different variables involved in the present study. Stop line present in each approach is considered as the reference point in the data extraction. Headway is measured as the time gap between former and latter vehicle.

3.2 Analysis of the Extracted Data

3.2.1 Classified Vehicle Count

Classified vehicle count (CVC) is carried out by counting the vehicles for every 5-s interval of green time. Five vehicle classes two-wheeler, three-wheeler, small car, big car, and heavy goods vehicle (HGV) are considered and compositions are calculated (Table 1). Auto rickshaw and light commercial vehicle (LCV), are considered together as three-wheeler, bus, and truck, are considered together as HGV. Vehicles that are discharging from the queue and passing the stop line are taken into consideration in each interval. Flow between 0 and 5 s is considered in 5-s interval. Flow between 5 and 10 s is considered in 10-s interval and so on. This is done for morning one hour and evening one hour for VCR intersection and RP intersection. Extracted data is entered into the Microsoft excel simultaneously. This data is given as volume input in the VISSIM 7.0 model.

3.2.2 Turning Movement Count

Turning movement count (TMC) is carried out for every 5-s interval for all the three directions' traffic. TMC was done for one hour in the morning and evening both the intersections. Moviemaker and KM player tools were used in the extraction of TMC. This data is used in calculating the relative flows of each approach and are given as input in VISSIM 7.0 model (Fig. 2).
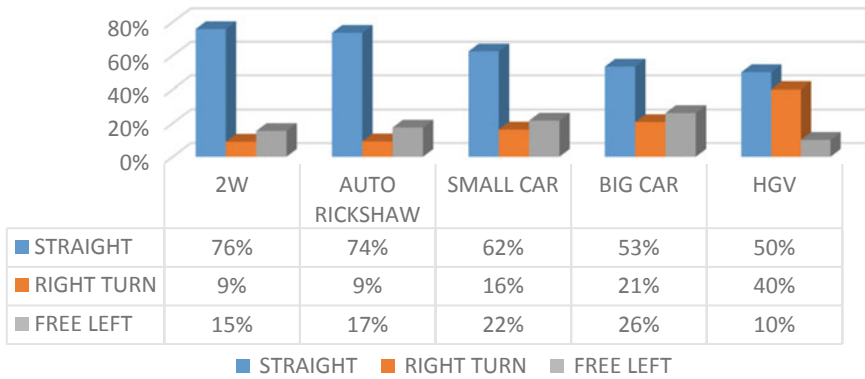
	2W	AUTO RICKSHAW	SMALL CAR	BIG CAR	HGV
■ STRAIGHT	76%	74%	62%	53%	50%
■ RIGHT TURN	9%	9%	16%	21%	40%
■ FREE LEFT	15%	17%	22%	26%	10%

■ STRAIGHT   ■ RIGHT TURN   ■ FREE LEFT

Fig. 2 Directional proportion for Vijay Char Rasta intersection

3.2.3 Spot Speed Data

The parameters like minimum, maximum, 15th, 50th, 85th, and 95th percentile speeds for each vehicular category are calculated. This data has been used further for developing the desired speed distributions in the VISSIM model for simulation purpose. These speed distributions are developed separately for each of the vehicular categories considered in the present study. It is observed that car has maximum speed followed by motorized two-wheelers.

3.2.4 Time Headway

Time taken by successive vehicles to cross the stop line is considered as time headway. Each vehicle category was assigned a number. The time at which each vehicle was crossing the stop line was noted down. Headway is measured as the time gap between former and latter vehicle.

4 Measurement of PCU and Saturation Flow

Flow is normally measured in PCU/h. So, estimation of PCU has more significance. Two methods are adopted in estimation of PCU, viz., headway method and optimization method.

4.1 Headway Method

This method is used for finding the PCUs for various vehicle categories such as two-wheeler, three-wheeler, small car, big car, and HGV. Each vehicular category was assigned a particular number like small car 1, big car 2, three-wheeler 3, and two-wheeler as 4. Time headway was calculated for one hour in the morning as well as evening for all the approaches of Vijay Char Rasta, Ahmedabad, and Rangila Park, Surat. Based on the obtained time headways, respective PCUs are estimated. Time headway is calculated as follows.

$$\text{Time Headway(h)} = \text{Tfollower} - \text{Tleader} \tag{1}$$

PCU values of different types of vehicle are determined by keeping small car as a standard vehicle. Width of the vehicles is also considered along with average time headway in calculation of PCU. Headway ratio and width ratio together comprises to area ratio. Following table shows the width considered in PCU estimation (Table 2).

$$\text{PCU} = \left(\frac{h_i}{h_c}\right) * \left(\frac{w_i}{w_c}\right) \tag{2}$$

where h_i = average time headway of ith vehicle, h_c = average time headway of standard vehicle (small car), w_i = width of the ith vehicle, w_c = width of the standard vehicle (small car).

The obtained average time headway and PCU values for all the intersections by headway method are represented in Table 3.

Table 2 Vehicular dimensions

Vehicle type	Overall dimension (m)		Area (m^2)
	Length	Width	
Motorized two-wheelers	1.87	0.64	1.20
Motorized three-wheelers	2.60	1.40	3.64
Small car	3.72	1.44	5.36
Big car	4.58	1.77	8.11
Buses	10.3	2.5	25.75
Light commercial vehicles	5.00	1.9	9.50
Truck	7.20	2.5	18.0

Table 3 Average headway and PCU values by headway method

Study section	Two-wheeler		Three-wheeler		Small car		Big car		HGV	
	Avg. headway	PCU	Avg. headway	PCU	Avg. headway	PCU	Avg. headway	PCU	Avg. headway	PCU
Vijay Char Rasta, Ahmedabad	0.38	0.39	0.45	0.86	0.51	1.00	0.50	1.19	0.65	1.98
Rangila Park, Surat	0.72	0.30	0.77	0.71	1.03	1.00	1.05	1.22	0.80	1.40

4.2 Optimization Technique

This is the method proposed by IIT-Bombay for field measurement of saturation flow. Analysis is carried out in three steps for measurement of saturation flow.

- **Determination of Saturation Green Time**

For measuring the saturation flow, discharge pattern of vehicles in each interval is considered in the analysis. It is observed that most of the times, discharge pattern in the first interval is having low flow values due to start up loss time. It is assumed that saturation flow starts from the second interval. This step determines the saturation period by comparing the flow values obtained in each interval. Analysis of saturation period is found using the ANOVA test. Mean and spread of flow values in consecutive interval are compared to find the flow values which are representing similar dataset. From the test, if samples are found to be statistically equivalent, it means that saturation flow is continuing. The test is carried over all the pairs and saturated green time is found. The saturation period may vary depending on the green time and flow at each approach.

- **Determination of PCU Value**

Initially for calculation of flow values, IRC-suggested PCU values are used. These PCU values are initial PCU values used for optimization. Now onwards, the flow values observed in saturation green time are only used for analysis. By using the appropriate PCU values, the spread of flow values can be reduced. PCU values are the decision variables, and sum of the standard deviations of flow values observed in the saturated green is objective function which is to be minimized. Constraints will be the minimum and maximum values of PCU values for different vehicle classes. These flow values are normalized before optimization using the standard score method to eliminate the effect of absolute value of flow on the sum of standard deviations of flow values in saturated green time.

$$\text{Normalized value} = \frac{X - \mu}{\sigma} \tag{3}$$

where

X Observed flow value using initial PCU
σ Standard deviation of all the flow values observed in saturated green time
μ Mean of all the flow values observed in saturated green time

These flow values are normalized before optimization using the standard score method to eliminate the effect of absolute value of flow on the sum of standard deviations of flow values in saturated green time. Evolutionary algorithm is used for optimization as the problem is nonlinear. Hence, flow values of heterogeneous traffic are adjusted to as homogeneous as possible by changing the PCU values. Table 4 represents the PCU values derived from optimization method.

- **Determination of Saturation Flow**

This step determines the saturation flow by minimizing the error between the assumed saturation flow and observed discharge in saturated green time. Optimization is used to minimize the average error, i.e., average difference between assumed saturation flow and observed flow values in saturated green time. To eliminate the outliers, data in the range of ±5 of assumed saturation flow is used to calculate average error. Optimization with evolutionary algorithm is used for the minimization of average error. Saturation flow is the decision variable and average error is the objective function which is to be minimized. Constraints will be kept minimum and maximum value a saturation flow can take will be the ouput of optimization. Saturation flow shall be greater than minimum flow observed in saturated period, and it shall be less than maximum flow observed in saturation period.

The following Table 5 shows the comparison of saturation flow using headway method and optimization method. From Table 5, it can be inferred that saturation flow values obtained by headway method are satisfactory for almost all the approaches

Table 4 PCU values from optimization method

Intersection	Two-wheeler	Three-wheeler	Small car	Big car	HGV
Vijay Char Rasta, Ahmedabad	0.39	1.01	1	1.40	1.40
Rangila Park, Surat	0.34	0.94	1	1.18	1.4

Table 5 Comparison of saturation flow using headway method and optimization method

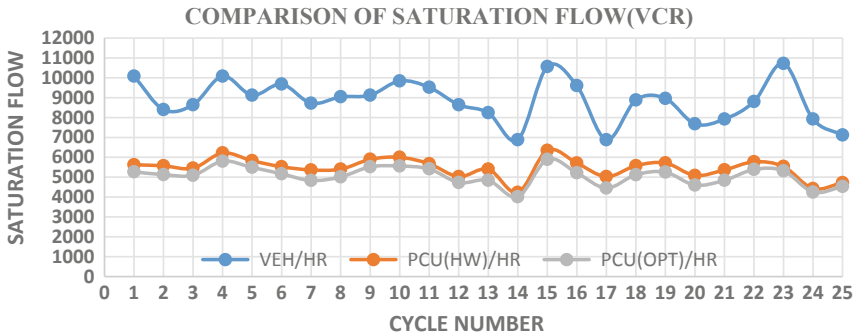| Intersection	Average saturation flow		Average saturation flow (headway)		Average saturation flow (optimization)	
	veh/h	veh/h/l	PCU/h	PCU/h/l	PCU/h	PCU/h/l
Vijay Char Rasta, Ahmedabad	8620	3434	5272	2105	5849	2310
Rangila Park, Surat	5550	2775	3792	1896	4094	2047

Fig. 3 Comparison of saturation flow

when compared to optimization method. Mathew and Radhakrishnan [8] suggested saturation flow for heterogeneous traffic as 1925 PCU/lane; Arasan and Vedagiri [5] suggested it as 2196 PCU/lane and obtained results for the present study are coinciding with the results of the various literature studies.

Saturation flow is estimated in PCU/h by using the PCU values obtained from two methods. These values are compared in the following Fig. 3.

5 Development of VISSIM Model and Saturation Flow Model

The model is developed based on the conditions related to signals in VISSIM 7.0. The simulation model is validated using the queue length for various approaches, which is a derived parameter. The saturation flow prediction model is developed for the primary data set using multilinear regression technique. The independent variables considered are width of the approach and proportion of vehicular categories. The developed model has been validated using the secondary data set.

5.1 VISSIM Modeling

The model is developed as per the existing network of Vijay Char Rasta as shown in Fig. 4. Traffic surveys which include volume count, turning movements, signal timing, and vehicular speeds are carried out at the specified location and are given as input for the base network file. Figure 5 shows the phasing details of Vijay Char Rasta.

Signal groups in the simulation model are designed and assigned to a particular turning movement according to the field conditions. Queue counters were placed just behind the signal heads to record the total number of vehicles present in the queue.
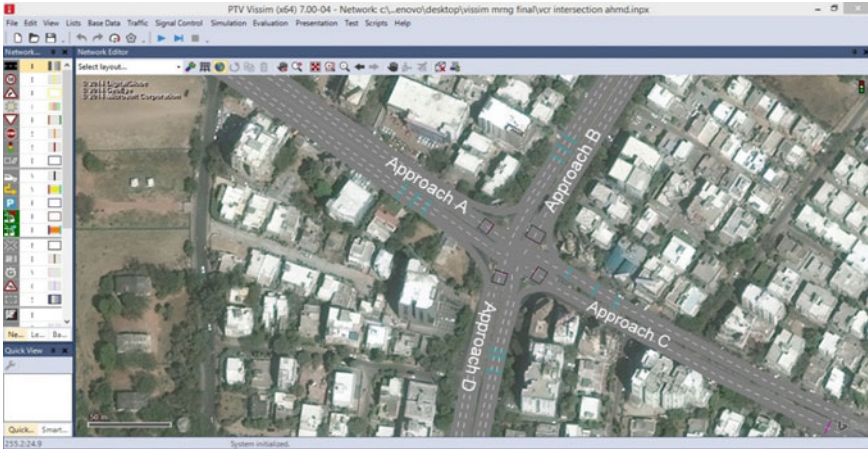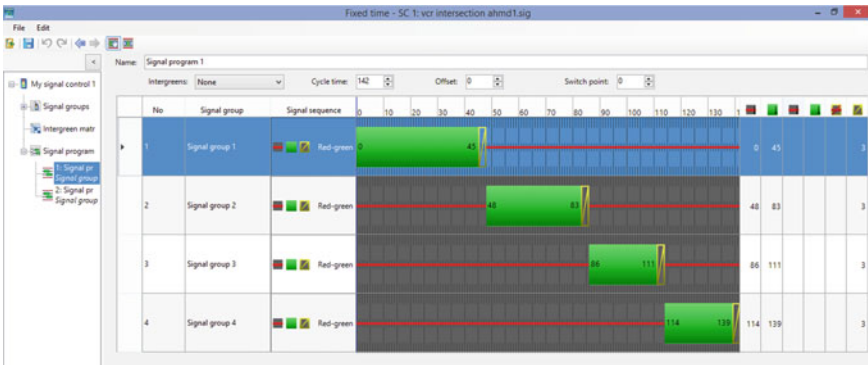
Fig. 4 Screenshot of VISSIM model

Fig. 5 Phasing details of Vijay Char Rasta

Average queue length is considered for validation. Individual nodes are placed for each approach in the model to obtain the results of headway and number vehicle released for each cycle. The Indian driving behavior is added in VISSIM 7.0 manually since it is heterogeneous in nature. Car following model of Wiedemann 74 is used in the analysis.

5.2 Calibration of VISSIM Model

The calibration process includes the modification of default vehicular geometrical and mechanical parameters. The default values are in accordance with the vehicular

Table 6 Validation results of Vijay Char Rasta

Approach	Queue counter	Average queue length (m) in field	Average queue length (m) in simulation	MAPE
A	1	147.64	260.42	9.13
B	2	57.12	52.59	7.93
C	3	38.84	42.70	9.94
D	4	32.44	29.70	8.45

characteristics in European countries. The 2D/3D models of the vehicular categories are collected from the various sources, and these models are used in the network. It also includes the modification of the default parameters of a car following model in VISSIM 7.0. It is basically a trial and error process and is carried out until the field conditions are observed to be simulated in the model. The conflict areas are defined at the intersection areas and are set according to the field observations. One-hour data is given as input for the base model. Model has been run for 4500 s, out of which first 900 s are considered as buffer time. Buffer time is provided in order to consider the effect of cumulative vehicles during the starting period of evaluation of results.

5.3 Validation of VISSIM Model

The simulation results are considered for the 3600 s of the run after the buffer time. The average queue length data collected for the different approaches has been used as validation parameter. Similar average queue length results for each approach are observed from the calibrated VISSIM model using the queue counters. Field and VISSIM simulated queue lengths for each approach are compared in an hour for minimum possible error. The trial and error method is carried until the errors of field measured, and simulated travel time is observed to be less than 10%. Sensitivity analysis has also been carried out. Table 6 shows the validation results.

5.4 Saturation Flow Prediction Model

The regression analysis is performed in order to develop saturation flow model (SFM). In this analysis, saturation flow in PCU/h is considered as dependent variable and proportion of vehicles and effective approach width are considered as independent variables. The data set corresponding to the first five seconds of each cycle is not considered for the development of the model. This is attributed to the reason that the start-up loss time is accounted in an indirect way. Data sets of both the locations are considered for developing regression model. Attempts are made to develop and validate the model with different combinations (80–20, 75–25, 70–30 and 65–35)

Table 7 Significance test of variables

	Coefficients	Standard error	t Stat	P-value
Intercept	0.00	#N/A	#N/A	#N/A
Two-wheeler	−4249.94	991.5655	−4.28609	3.47E−05
Three-wheeler	−2558.44	1186.739	−2.15586	0.032894
Small car	−3954.60	1408.325	−2.80801	0.005736
Big car	4921.98	1033.104	4.764259	4.89E−06
Width	905.24	81.54211	11.10148	1.14E−20

to develop regression model for saturation flow. 65–35 combination yielded good results, i.e., 65% of the total data is used for developing the SFM and 35% of the total data is used for validation. The SFM is developed by using the data obtained from headway method.

Normality test for the dependent variable (saturation flow) is performed. The significance of the various independent variables is also tested statistically. Following table shows the significance test of variables (Table 7).

From the table, it can be observed that all the independent variables are significant as the t statistic values are less than critical value (1.96) at 95% confidence interval and also the significance test is satisfied in the case of p test as the p statistic values are less than 0.05 at the 95% confidence interval. The following MLR model is obtained from the regression technique in MS excel.

$$S = -4249.94t_{\mathrm{w}} - 2558.44a - 3954.60\mathrm{sc} + 4921.98\mathrm{bc} + 905.24w \ \left(R^2 = 0.97\right)$$

where S = saturation flow in PCU/h, t_{w} = proportion of two-wheelers, a = proportion of three-wheelers, sc = proportion of small cars, bc = proportion of big cars, w = effective approach width.

The model developed has been validated using the 35% data set and satisfactory results are obtained. The mean absolute percentage error (MAPE) is observed as 12.45%. The above equation shows the negative relation between 2W, 3W, small car, and saturation flow, and it shows positive relation between big car, width, and saturation flow.

6 Summary and Conclusions

In the present study, PCU is estimated by two methods: headway method and optimization method. It is observed that PCU values which are estimated by headway method are yielding good results. TRL method is considered in the estimation of saturation flow. Saturation flow is estimated in PCU/h by using the PCU values obtained by above two methods. The obtained results are coinciding with the results of the various literature studies. For sensitivity analysis, microscopic simulation using VIS-

SIM 7.0 has been carried out. In validation of VISSIM model, average queue length from field is considered. It can be inferred from present study that change in width has more effect on saturation flow when compared to change in turning movements. Saturation flow model has been developed from multilinear regression analysis by considering the data sets of the intersections and validated for 65–35 combination.

Sensitivity analysis is carried out for SFM developed by regression analysis. In developing the model, proportion of 2W, 3W, small car, big car, and road width are considered along with saturation flow. The developed model shows negative relationship between 2W and saturation flow. Similar relation is observed in the case of 3W and small cars, whereas model shows positive relation of saturation flow with big car and road width. It is also observed that road width is very sensitive parameter in measurement of saturation flow. Hence, it can be inferred from present study that change in width has more effect on saturation flow in both the models.

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