

Microsimulation Modelling of Traffic Adaptive Signal Control for Unsaturated Flow at Signalized Intersection

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ABSTRACT: Bengaluru one of the biggest cities in India is facing alarming growth of private vehicles in recent years with over 1900 new vehicles getting registered of all category every day. Vehicle population has passed 72 lakh mark with over 50 lakh two-wheelers and 14 lakh cars, according to Transport Department data till December 2017. This has led to the necessity of the active transport control system. Traffic simulation models are used and accepted by traffic planners and researchers for the modelling of the traffic transit. Vehicle Actuated (VA) Signal Control is seen as the future for controlling the traffic across the urban cities at the major intersection. Testing of the VA signal control on the traffic simulation models helps to know how efficient our model will be with minimum resources invested. This study proposes a method to check and improve the efficiency of the intersection by using vehicle actuated signal controls. The intersection on a Raja Rajeshwari Nagar circle near Gopalan Arcade Mall, Bengaluru is selected and modelled in PTV VISSIM for Indian Traffic conditions. Model is calibrated manually and calibration errors for both vehicle flow and Travel time are within limits. Validation test is also well within the limits. The Capacity Estimations were carried out for both the intersections by the method prescribed in the INDO – HCM. One of the two signals was improved with VA signal system, the average delay per vehicles reduced by 48.3% and the following signal by 8.63%. Thus, Vehicle Actuated (VA) Signal Control proved to be more superior than the fixed control system.

KEYWORDS: Simulation Modelling, Vehicle Actuated SignalControl, Control Delay, Flow, Travel Time, Calibration, Validation, Intersection Capacity

I. INTRODUCTION

Bengaluru in the past two decades experienced a great rise in population due to the flourishing of the tech industry. the planners of the city didn't anticipate such a huge growth rate in population rise and thus the city was incapable to handle the traffic demand. The same situation is faced by many metropolitan cities across the globe. There is always an alarming need to tackle the situation. the solution of structural expansion has reached an impasse. There is a need for alternative strategies and tools which can combat the situation, and the researchers and enforcing communities are working tirelessly towards it. One of the tools is Vehicle Actuated (VA) Signal System, which has proved its efficiency in several developed countries. The field experiments are very difficult and expensive too and it's not practically possible to execute every trial on the field. This limitation is overcome by the microsimulation models which are indispensable instruments at the research and planning level which incorporated complex traffic conditions with real-life based behaviour pattern. These models are now widely used and acceptable all over the world.

In the large metropolitan like Bengaluru due its large area spread and high population density its always difficult for the traffic personnel to handle the traffic all over the city. Fixed time traffic signals are used which many a time causes undue controlled delay and reduce the level of service to the road user. Thus, vehicle actuated signal system can be a boon to the situation, and thus its feasibility could be analysed by the microsimulation modelling.

Traffic simulators used various algorithms and techniques such as differential equation numerical methods probability statistics etc. to visually represent the outcome based on the input parameters which are implanted in the model. It represents a visual environment and shows the real-time interaction with the vehicle, pedestrian other environmental aspect and the driving behaviour

A. PTV VISSIM

VISSIM is microscopic, behaviour-based, time-oriented simulation modelling software. It displays all road user elements and their interaction with each other for both rural and urban type of roads. The software was developed by the University of Karlsruhe, and the first version was introduced in 1994. It basically follows the Wiedemann's car model. It basically has two component Traffic Flow Model and Signal Control Model which Interact with each other.

B. LITERATURE REVIEW

Tom V. Mathew and Padmakumar Radhakrishnan, have published a paper on Calibration of Microsimulation Models for Nonlane-based heterogeneous traffic at Signalized Intersections. They have selected three intersections for their study, from two Indian cities in which they use the VISSIM software for nearby modelling of the intersection by inputting the vehicle type, composition, geometry of road, etc. the model was validated and calibrated from the data of different time period. Calibration was done on the proposed methodology of adopting GA to reduce the average delay on Both local and global validation was done and error was less than 15 % for local validation and less than 15% for global validation except one case.

Fang and Elefteriadou (2005), have published a paper on Guidelines for Selecting Microsimulation Models for Traffic Operational analysis. They tested various simulation software or packages like AIMSUN, CORSIM and VISSIM and laid guideline on how to select the various packages according to the need and requirement of work. As different package has different pros and cons related to different traffic plans so before choosing any particular package, we should first check whether the particular package has the capability to represent various geometric characteristics, simulate specific signalization plan etc. of the intersection.

Koh and Chin (2007), have published a paper on advantage and disadvantage of VISSIM with respect to network coding, data handling, calibration and validation. Author has given a high rating to visualization and modelling interface and low rating to calibration and validation, so overall considered the software difficult to handle.

Manjunatha, Pruthvi, have published a paper on advance traveller information system (AITS). Basically, AITS provide real-time information on traffic condition to a traveller in order to reduce travel time. This paper focuses on the methodology to provide real-time information to a traveller. from their study they came out with artificial neural networks which predicts the future traffic density from current density. It can also estimate traffic density by analysing the variation in speed. This type of technology is helpful in reducing traffic by cautioning the traveller against current traffic condition and mitigating the traffic to some other route.

Siddharth, S. M. P and Gitakrishnan Ramadurai, have published a paper on calibration using VISSIM software for heterogeneous traffic condition of India. The study was done in the Chennai and it was part of IT corridor. This paper focuses on the secondary sensitive parameters i.e. parameter which become important or sensitive after calibration. The preliminary and secondary sensitivity analysis of behaviour parameters were carried out using ANOVA test and Elementary Effects method.

Eidmar done microsimulation using VISSIM software and analytic modelling using CAPCAL software to model the intersection between vehicle and pedestrian surrounding the football stadium.

Buck and Vortisch calibrated VISSIM for analysis of delays at signalized intersection for four intersections, the vehicle record evaluation was used in conjunction with MATLAB to emulate the videography evaluation process for the simulator, the calibration process was based on the comparison of time taken to pass the intersection in field versus the simulation for one intersection, headways & arrival time distributions. The results are compared with the ones with default values which indicated large reduction in the RMSPE.

Swaminathan, Nithya, provide insight into the VISSIM traffic simulator by presenting a review on its typical applications & modelling principles, the traffic flow models with lateral and longitudinal movements between lanes are elucidated, social force modelling for pedestrians are described along with techniques for calibration of traffic flow models.

C. SCOPE AND MOTIVTION

The continuous increase in the number of vehicles on the road and fixed signal timing on the intersections leads to heavy traffic density and an increase in travelling time. Talking about Bengaluru city traffic jam causes a total loss of 60 cr working hour to this city. Bengaluru is home of more than 10 million people and a total of 90 lakhs of vehicle trip every day on the Bengaluru road. Since it is not possible to increase the geometry of the road with an increasing number of the vehicle, so the best way to reduce the congestion on the road is by the actuated signal control. Actuated signal control is the future of modern traffic. The Study scope involves Modelling two Intersections in series with all elements influencing the traffic & its characterization. The Signal Timing and phasing are gathered and programmed into the model. The necessary data such as Intersection geometry for development of the network is surveyed.

The objectives of the study are as follows:

To Develop a well calibrated and validated microsimulation model of two consecutive Signalized Intersections in VISSIM under heterogenous and non-lane-based traffic conditions. To Estimate the Capacity of the Signalized Intersections based on the method prescribed in the Indian – Highway Capacity Manual and characterize the nature of Traffic Flow. To Develop a Vehicle Actuated Signal Control Scenario for the Four-Legged Intersection in VISSIM and compare its effect on intersection delay in the network with existing Fixed Time Control scenario.

II. METHEDODOLOGY

Initially, the literature material and the thesis of the related topic was studied. By referring the manual and guidance provided by the mentors the hands-on knowledge of modeling software was familiarized. further prerequisite data, the quantity, and procedure to procure the data were determined.

The capacity estimates were obtained of the intersection to determine the nature of the flow of traffic according to the procedure given by INDO-HCM (2017). The data was obtained by video graphic method on the intersection obtained on one weekday and one weekend for a time period of one hour. The data extracted were turning volume counts for two hours. The geometries of the intersection and the signal timing and phasing were obtained by the field survey. The dimensions of the vehicles and the acceleration and deceleration were obtained by INDO-HCM (2017). Public transport frequency and the average halting time was observed on the field. all the other features on the field were incorporated in the model.

The data obtained is processed and documented for modeling, followed by the preparation of the basic model in the VISSIM. Vehicles were imported from the library. links and connector network were laid according to the geometry of the road obtained by the geometric survey. Vehicle input and the turning proportion is fed accordingly for all the three legs. The signal timing according to the field data was designed and the public transport route was defined, and the public transport was added. Other 3D elements like trees bus stand building trees were added.

Initially, the model is simulated with the default parameters and driving behaviour. The travel time and the flow information is extracted and is compared with the actual data. If the result fails, the error test than the driving behaviour lane change parameters are changed accordingly with respect to the Indian conditions by trial and error method. the changes are made till the actual value and simulated values are well within the error limit of 20%. this method is called calibration. The model is validated by giving inputs values for the different time frame, the performance should be within the limit of 15%.

For the Vehicle Actuated Signal System, the code is written in VISVAP and in inserted into the model. The effect of the enhanced signal system was observed for both the signals. The results were obtained and were analysed precisely and were compared with the results of the fixed signal system.

III. DATA COLLECTION

The area of study is a section consisting of three-legged intersection having a mall, Gopalan Arcade, on one of its corners. The intersection is on Mysore Road which is intercepted by road coming from Raja Rajeshwari Nagar. Section starts from 500m from RVCE side on Mysore Road. 500m on Raja Rajeshwari Metro station side and 500m on RR Nagar side. The section comprises single intersection. The traffic which was observed was heterogeneous in nature and was having minimum lane discipline. the average speed of vehicles was observed was 50kmph. RR Nagar Junction is a

three-legged intersection with three-phased fixed time signal program. A bus stop is present 50 meters away from the 3-legged junction.

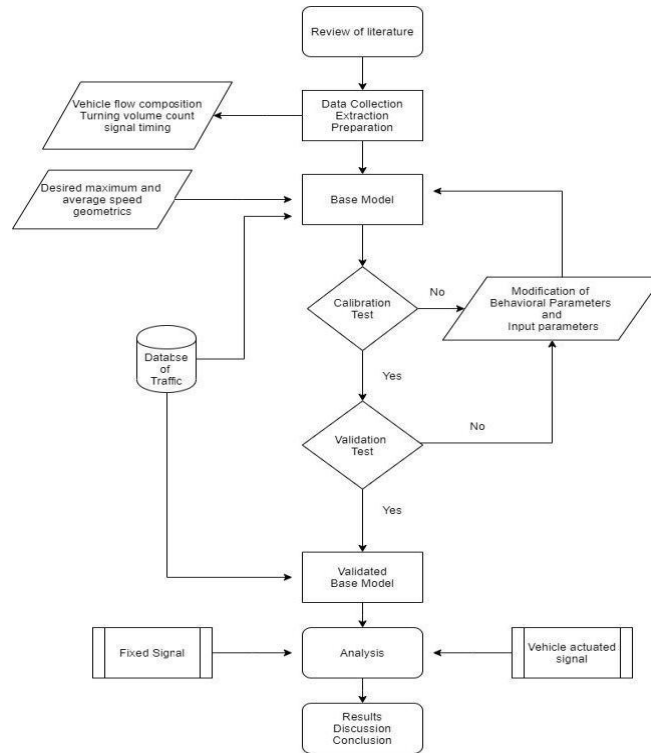


Figure 1 Methodology

A. Turning Volume Count

Turning volume count across the intersection was carried out for a period of two hour during the peak hours in the evening on Thursday and Sunday. data was extracted by playback for every five minutes interval and flow in veh/hr was determined. Thursday's data was used for modeling and calibration and was validated for the Sunday's data.



Figure 2 Site Location RR Junction



Traffic Volume- Wekday							
Vehicle	PCU	RVTOMAJESTIC	MAJESTICTORV	RVTORR	RRTORV	MAJESTICTORR	RRTOMAJESTIC
Car	1	1530		590	435	970	1375
Bus	3.5	840	840	0	3.5	297.5	178.5
Private	3.5	525	847	112	63	185.5	217
Auto	0.8	648	536	376	169.6	520	544
Bike	0.5	2467.5	2132.5	992.5	525	1625	2037.5
Total		6011	5496	2071	1197	3598	4352

Table 1

Traffic Volume- Weekend							
Vehicle	PCU	RVTOMAJESTIC	MAJESTICTORV	RVTORR	RRTORV	MAJESTICTORR	RRTOMAJESTIC
Car	1	1055	1115	430	407	1315	830
Bus	3.5	787.5	700	0	52.5	210	140
Private	3.5	595	1102.5	140	140	262.5	280
Auto	0.8	352	380	104	148	340	292
Bike	0.5	1222.5	1312.5	397.5	515	1312.5	1027.5
Total		4012	4610	1072	1263	3440	2570

Table 2

B. Travel time speed distance

The real-time measurements were obtained by traveling observer method with the help of GPS tracker using a smartphone. GPS Speedometer was used to record the speed continuously and record the time lapsed and the distance travelled.

C. Network Geometry

The geometries of the road network were surveyed using tape and Google Earth measuring tools. and the cross-sectional elements like carriageway width footpath medians approach width at bus stops and junctions were obtained.

D. Signal timing and phasing

Signal timing and phasing were obtained on the field at the time of video photography. The signal phasing and timing of both the sections were precisely obtained.

E. Vehicular Characteristic

The vehicle characteristics like dimensions, acceleration, deceleration was obtained by Indian Highway Capacity Manual. The Vehicle types adopted in this study are Two Wheelers (Bikes), Three Wheelers (Autos), Cars, Buses, LCV & HCV

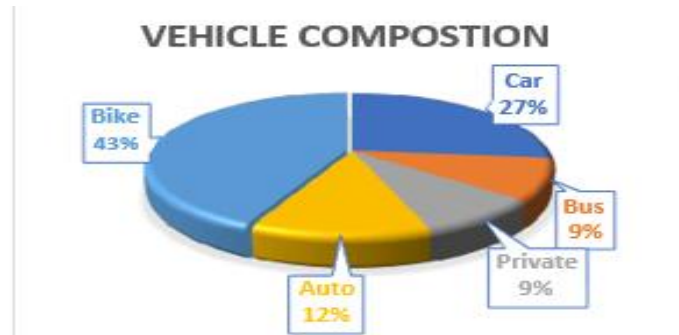


Figure 3 Vehicle Composition Day 1

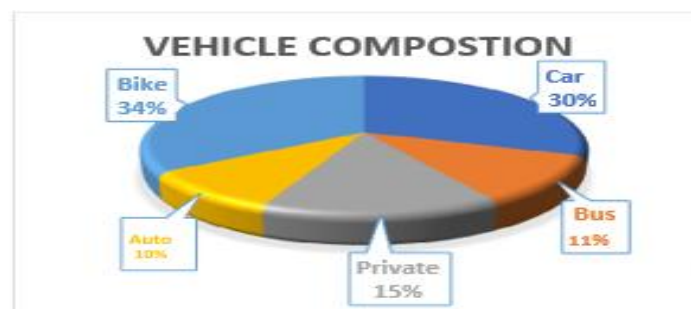


Figure 4 Vehicle Composition Day 2

IV. MICROSIMULATION MODELLING

Microsimulation is modelling of various individual vehicle movement and interaction with the different vehicle with their dynamic and stochastic behaviour. In microsimulation different vehicle move in a road network with different flow characteristics like speed, dimension, acceleration and deceleration, etc. and parallelly incorporating the driver behaviour such as lane changing car following, overtaking, etc. Therefore, the modelling of individual vehicular movements as a function of time, space & driver decisions is accomplished.

In microsimulation, there are car following model which consist of a set of the equation which governs the movement of a vehicle with respect to the neighbouring environment. Similarly, a Lane Changing model shall specify equations for compulsory, anticipatory or discretionary lane changing the behaviour of vehicles. For the study purpose time slices have been made which is a division of simulation period for analysis. In our study, one-hour time period is divided into 12 slices with every slice of 5 min each. The simulation is carried out in terms of small-time steps, i.e., the time interval between two consecutive computations of the vehicle. Shorter the time period better will be the result.

A. DATA INPUT DEMAND

VISSIM requires certain data to conduct the simulation of road traffic and these can be grouped as geometric input, traffic input, vehicular characteristics as input and signal control input.

B. GEOMETRIC INPUT

Road network in VISSIM can be developed either importing the background image of the intersection or using the built map in the VISSIM where one can do the sketching of the network. The road network can be drawn using network objects LINK - which is used to construct a single or multi-lane road. Various links are connected using CONNECTORS which is important for the continuous flow of traffic from one link to other. Representation of non-uniform width road is important for accurate simulation. Dividing the road into a number of lanes with equal width is quite complicated work. Footpaths and median are drawn using network object- AREA, POLYGON in the VISSIM. All the geometric input is static and doesn't change with time.

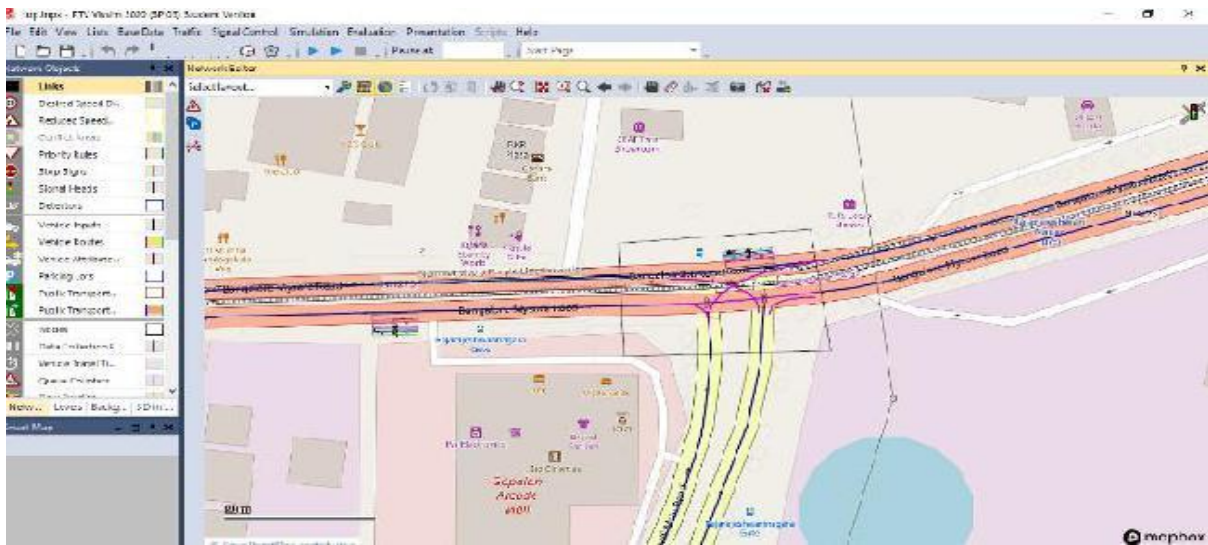


Figure 5 Screenshot of Network Diagram in VISSIM

C. TRAFFIC INPUT

Traffic inputs consist of Vehicle Inputs, Vehicular Composition & Relative Flows. At the beginning of each entrance number of the vehicle is assigned using the network object VEHICLE INPUT. The number of the vehicle in each entry is assigned from the data collected from the field survey by counting the number of vehicle/hours. Since we have divided the period into 12 slices with each equal to 5 min, so we had converted the number of vehicle/hours into vehicle/5 min for modelling purpose. Vehicle composition is characteristic of the intersection and must be defined and assigned at each input. Network object-VEHICLE ROUTES is used to define the relative flow of vehicle in a different direction i.e.- (fraction of vehicle going in a direction.)

D. VEHICLE CHARACTERISTICS

The Static attributes such as length, width, the rate of acceleration, deceleration & desired speed of the variety of vehicles are introduced here, There are various vehicle models present in the VISSIM but many a time it falls short of vehicle which usually runs on the road like a three-wheeler, bullock cart, etc. So, in order to make a correct simulation of the intersection, we have to define some different parameters to the existing vehicle model in the VISSIM in order to match with the characteristics of the vehicle on the intersection. All these parameters can be defined by going into the vehicle library and assigning the desired characteristics to a vehicle model.



Figure 6 Model in VISSIM

E. FIXED SIGNAL CONTROL

The signal timing and phasing extracted from the field must be programmed into the network and placing of Network Object – Signal Heads must be carried out and assigned to its respective lane groups. This section depicts the fixed time. The Fixed time signal program can be writing with the aid of the VISSIM control editor the interface built in the simulators, the total number of signal groups(phases) are present in the cycle are added, their signal type is selected as Red-Green-Amber, the cycle time for each program is fed into the controller, the phase editing can be carried out by click-dragging the phase or by punching the numbers into the matrix.

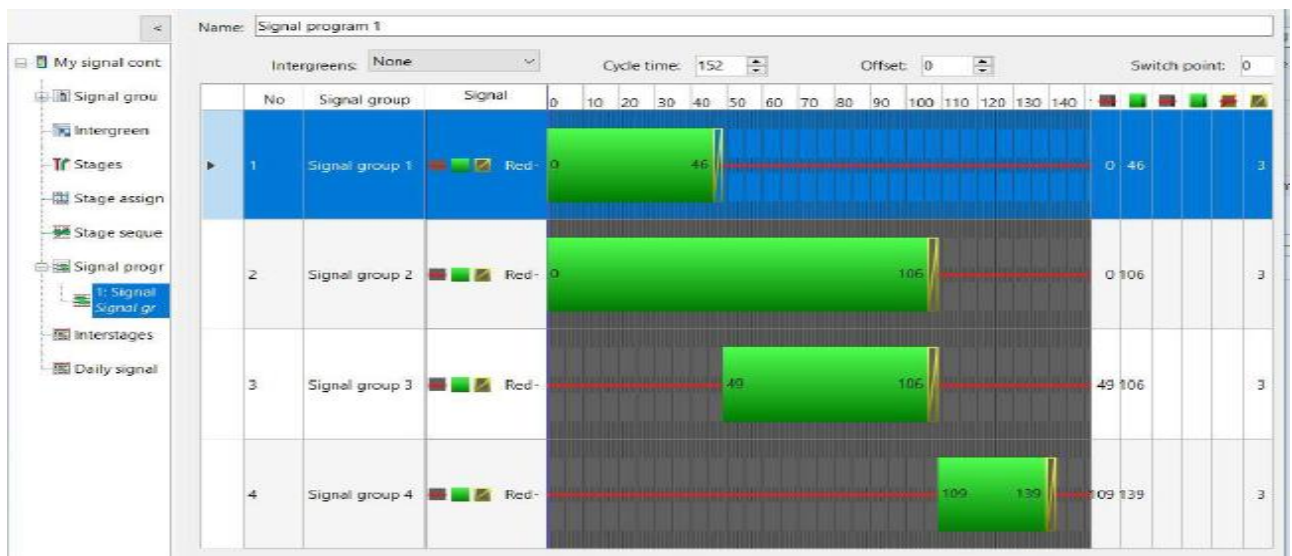


Figure 7 Signal Phasing in VISSIM



V. CALIBRATION AND VALIDATION

The simulation runs for 3600 sec in which first 3600 seconds is considered a warm-up period and last 300 sec are considered as a cooling period. The data of these two periods is not taken for study purpose and data from between these two intervals is used for the study. Every simulation consists of three trial and average of these three trials is be taken. [6] The random seeds are varied within these three multi runs, using the random seed increment function within the simulator, this can be any arbitrary value, for this study, the value was set as 3. The Validation of the model was carried out using the independent data set from other day.

CALIBRATION TRAVEL TIME COMPARISON

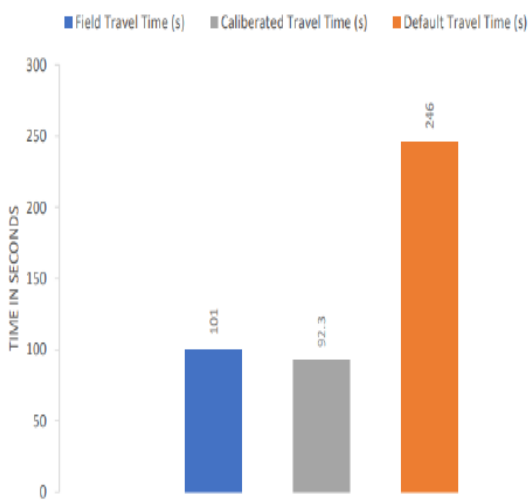


Figure 8 Travel Time Calibration

VALIDATION TRAVEL TIME COMPARISON

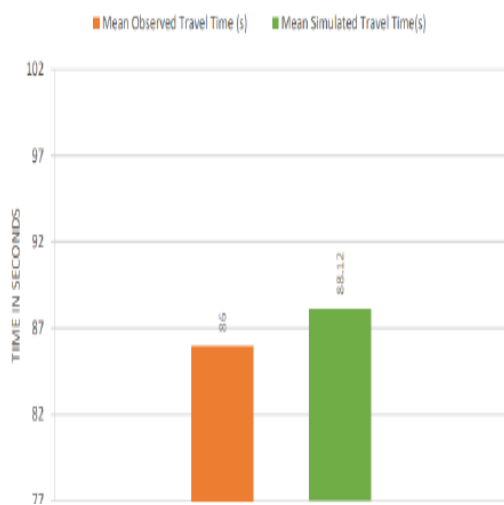


Figure 9 Validation Time Travel



A Driving behaviour parameters			
Look ahead distance (m)			
1	Minimum	0	50
2	Maximum	250	250
3	Number of observed vehicles	4	7
Look back distance (m)			
4	Minimum	0	50
5	Maximum	150	150
B Wiedemann 74 car following model			
6	Average standstill distance (m)	2	0.4
7	Additive part of safety distance	3	0.15
8	Multiplicative part of safety distance	3	0.2
C Lane change			
9	Waiting time before diffusion (s)	60	60
10	Advanced Merging	No	Yes
11	Minimum headway (m)	0.5	0.1
12	Consider Subsequent Static Routing Decision	No	Yes
13	Co-operative Lane Change	No	Yes
14	Lateral correction of Rear end position	No	Yes
D Lateral behaviour			
15	Desired position at free flow	Middle	Any
16	Keep lateral distance to vehicles on next lane	No	Yes
17	Diamond shaped queuing	No	Yes
18	Overtake on same lane	No	On left

Figure 10 Parameters

VI. CONCLUSION

The primary objective of the study was to develop a well calibrated and validated model if the area under study in PTV VISSIM. The model was within the permissible error limit and it closely represents the actual traffic condition of the location. The model is well calibrated by changing parameters according to the actual condition. The model is validated on other day and there also the average travel time is near to the observed time with considerate error. Each parameter was changed, and the model’s travel time was brought near to the actual travel time observed on field. The average Travel Time of vehicles reduced by 48.3% and the following signal by 8.63%. Thus, Vehicle Actuated (VA) Signal Control proved to be more superior than the fixed control system.

However, there is an error of 23 percent in number of cars, 22 percent in bike, 26 percent in buses, 21 percent in private vehicle and 26 percent in auto in our simulation model from the on-field data collected.

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