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Optimization of Heterogeneous Non Lane Based Traffic at Signalized Intersection using VISSIM

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Abstract

Asian countries show a diverse heterogeneous traffic behavior resulting in a very complex condition. Bengaluru's has a 4500 kms of road length with a 330 signalized intersections and road network is primarily radial and converging at the center leading to unwarranted entry of traffic to the center. The public modes of transport, mainly the buses, are vying for road space and have to compete with other modes of vehicles like autos, two wheelers, and cars. With litter addition to the infrastructure, it is becoming more & more challenging to manage the congestion levels. The problems may include lack of lane discipline, varying composition, diverse vehicle conditions which are inclined to worsen day by day. Micro simulation modeling is suitable for such dynamic traffic conditions. Calibration or modification is done to the default driver behavior characteristics to efficiently simulate the heterogeneous traffic scenarios where factors such as traffic compositions and static dynamic features are considered. In this study a methodology adopted for representing non lane based driver behavior, calibration and signal optimization for heterogeneous traffic at signalized intersection. Calibration was done to minimize the error between field control delay calculated by quick estimation method and simulated. VISSIM (Verkerhr in Staedten Simulation) a psychophysical car following model is used. Shoolay junction of Richmond road located in Bengaluru is considered for the case study.

Keywords: *Control delay, Simulation, Calibration, Validation; Signal optimization*

I. INTRODUCTION

Demand for traffic flow management is getting bigger and bigger day by day which leads congestion of traffic. Which leads to grow number of urban economic, social and environmental problems. Every day we face rush hour, road traffic accidents, atmospheric pollution and driver pressure.Congestion creates major dynamic problems. Composed of numerous compound processes and contains many components that interact with each other. In such a composite issue, the simulator can be extremely productive tool for assessing different traffic states. Helps decision-makers comprehend and inspect traffic, assess current issues, and suggest sensible solutions. Traffic simulation supports planning of traffic and management decisions as well as constructive remedial actions. New results and technologies can be tested effectively in a "virtual reality" domain in a comfortable office without interrupting traffic or abandoning field testing. Simulation can be described as a vital depiction of a part of the existent world, attained through the construction of a computer model and the passage of time.

One of the first successful attempts to use a computer simulation for traffic management was due to D.L. Gerlough (1956) for highway traffic simulation at the University of California computer. Another important early contribution to traffic modeling was Kallberg (1971). There are many types of simulation systems. Some basic categories are divided as microscopic, mesoscopic and macroscopic. Two basic categories are: a macro model that describes the traffic flow represented by scalar values of flow, density, and velocity, and a microscopic model that takes into account all vehicles with its properties. Traffic simulation models are usually random because they contain probability distributions to describe road traffic.

The objectives of the study to develop a valid micro simulation model using VISSIM. To optimize the intersection, thus reducing the delay. To calibrate the simulation model and address the variability of driver and vehicular behavior. To suggest viable alternative solutions to ease the traffic, optimize signal and improvements in geometry.

Comparison studies of current and the proposed alternatives.

Micro-simulations are frequently used to inspect traffic conditions, evaluate the class of traffic management and assess possible traffic measures. Simulation programs used to compare different traffic management measures and as evaluation criteria to select and further optimize the best. VISSIM a microscopic, time-based, behavioral-based simulation tool for simulating urban and rural traffic and pedestrian mobility. In addition to Private Transport (PrT), Public Transport (PuT) can be created based on roads and highways.

Traffic flows are simulated under various restrictions on lane distribution, vehicle composition, signal control, and PrT and PuT vehicle records. VISSIM has the ability to simulate the interaction between various modes of transport and vehicle traffic, the ability to randomly generate vehicles, and the flexibility to model complex geometries (Moen, Fitts, Carter, & Ouyang, 2000). VISSIM is better in terms of ease of use and does not require cumbersome coding (Rat rout & Rahman, 2008).

The calibration default parameter value is changed until the error between the actual and analog measurements is less than the desired threshold. In the calibration, adjust the parameters so that the model output is similar to the observed data (Hollander & Liu 2008). The various parameters that can be calibrated in VISSIM are acceleration, desired speed and gap distance (Asunder, Zulu, & Heilmann, 2011), emergency stop distance, latency before diffusion, lane switching distance, stop distance, minimum lane distance (Park & Schneeberger, 2002) and other Wiedemann parameters (Wu, Sun, & Yang, 2005).

In Mathew and Radhakrishnan (2010), after the VISSIM model was created, sensitive parameters were found by increasing the value of each parameter by 10% while keeping other parameter values unchanged. Delay obtained from the simulation is compared to the default parameters. If you change the default parameter value to affect the delay, it is treated as an important parameter and selects these parameters for calibration.

In Park and Qi (2010), ANOVA was used to find sensitive parameters from a set of eight parameters to be calibrated. The Latin hypercube experiment was designed to generate 200 sample ets for eight parameters. The VISSIM model of 200 sample sets was simulated and the travel time was used as a measure of the effectiveness of one-way ANOVA. The required velocity distribution and minimum clearance are found to be sensitive parameters.

Yang Yayang and Gannanpu (2016) established the VISSIM traffic model by collecting pedestrian and vehicle traffic data at the intersection of Songjiang University's urban transport hub. The simulation results show the main traffic congestion problems in the Meiji side (east-west) section, and the main traffic barriers and lane change modes are also observed. Late optimization is completed, including signal timing, by adding straight and left-turn lanes between the collision area and the section movement. As a result, lead to optimal traffic management.

Khaled Shaaban 2015) focused on the comparison between two-lane and three-lane modeling, taking into account traffic flow, left-turn movement and truck proportions, resulting in statistically significant differences in simulation tools. However, in the case of high traffic, VISSIM shows a higher average delay compared to low flow SIM card traffic.Mei Pingyun and Jingji (2013) proposed on the basis of delay analysis, using VISSIM software to complete the difference between the parking sign intersection, and use VISSIM to verify the traffic flow performance.

The average vehicle delay under volume change is analyzed under the parking sign and the production mark.

The minimum delay is considered to be the optimal target, and the key traffic volume is set to set the parking sign and the revenue flag. Manjunatha (2012) developed a calibration model for hybrid traffic using VISSIM. The driver behavior is observed in mixed traffic conditions and the simulation model is shown. Multi-parameter sensitivity analysis is used to identify calibration parameters, mainly using genetic algorithms to minimize the error between analog and field data. The Mumbai signal crossing is considered a case study.

Li (2011) describe which traffic characteristics can be simulated using VISSIM. Saturated flow distribution, intersection characteristics, speed acceleration characteristics and other parameters. Due to the limitation of the flow characteristics, not all parameters can be used in simulation modeling.From the above review calibration of heterogeneous traffic in simulation model is not given much importance. The efficiency of the heterogeneous traffic simulation model can be improved by setting parameters for the calibration using Weidmann 74 model. And signal optimization is carried out.

2. METHODOLOGY

To calibrate heterogeneous business simulation models special procedures are required to address the unique factors of this process. Thus a method has been proposed that includes heterogeneous traffic representation and propagation, sensitive parameter identification, setting of heuristic range and parameter value determination by optimization of the model. This method applies to the context of the signalized intersection, which is considered to be the calibration and verification of performance measurements. Heterogeneous traffic is designed to solve different combinations of vehicles and geometric problems, such as uneven road width. Identifying sensitive parameters and setting ranges is a proposed heuristic program that reduces computational power to find the best setting. By the optimization of the model the parameter settings are determined which reduces the simulation error. The hierarchy of the simulation methodology is shown in Figure.

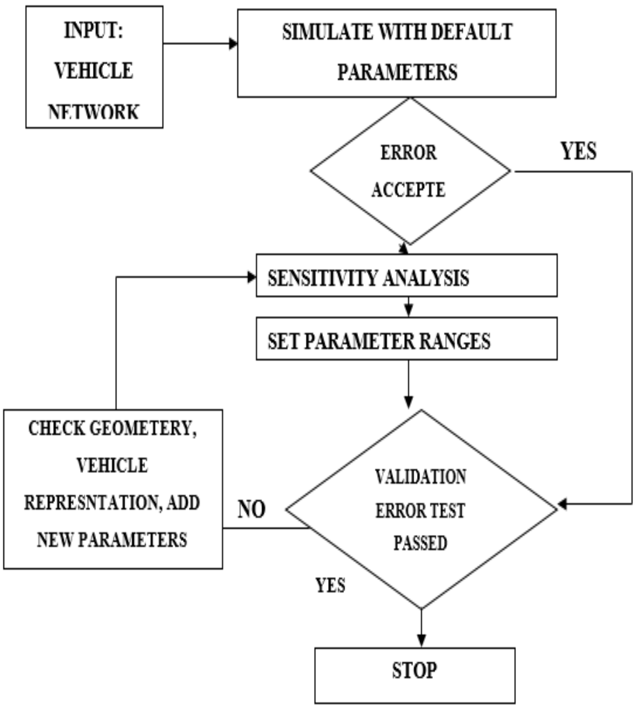

Figure1: Flowchart of simulation methodology

2.1 Information requirements

The data required for the proposed method are Vehicle representation, Vehicle composition, Traffic volume studies, Intersection representation, Determine the signal timing, Determine Critical Intersection Volume-to-Capacity Ratio, Determine Control Delay, Parameter selection and Validation.

3. Study area description and data collection

Shoolay intersection located in Bengaluru city was selected for this study. Satellite image of the intersection is shown in the figure. Shoolay circle is one of the junctions present in Richmond road. It is one of the heavily congested roads in Bangalore with volume to capacity ratio of 2.26. Due to number of schools and shopping malls present in this area the traffic volume increases to a very great extent during peak hour of weekdays and weekends. To determine the feasibility of the proposed methodology four legged intersection in Bengaluru city was taken into consideration which doesn't have fixed or pre-timed signal timing. Micro simulation Car following model, VISSIM was considered for the study (PTV 9). The turning movement, desired speed ranges were obtained using video data. The control delay was calculated using quick estimation method recommended by the HCM (TRB 2010)

Figure 2: Study area - Shoolay circle

Intersection model development

To develop an intersection model, vehicle representation, geometrics, driver behavior and signal are taken into consideration.

Vehicle representation

The vehicles are represented in VISSIM by changing the static and dynamic characteristics of the vehicle up to the nearest match. The new dimensions are used in the model. The table 1 shows the details of the intersection, vehicle dimensions, speeds, vehicular flow and composition.

Signal design

The Shoolay intersection doesn't have a pre-timed signal for weekdays, thereby adopting a HCM quick estimation method to determine the signal timing. The weekends show a pre-timed signals shown in the Table 2.

Table 1 Vehicular and Geometrical characteristics of the intersection

Vehicle type	Length(m)	Width(m)	Desired Speed (km/h)	% Vehicular composition
HCV	10.21	2.5	20	0.527653
LCV	6.1	2.2	25	1.082335
Car/jeep	4.4	2.5	30	33.03766
Two wheeler	1.8	1.5	40	49.37514
Three wheeler	3.2	1.4	25	13.08676
Bicycle	1.9	0.5	5	0.430917
Bus	11.54	2.5	20	1.928941
Flow (vehicles /hour)				10147.25

Table 2 Signal timings of the intersection

Routes		Green timing (sec)	Red timing(sec)	Amber timing (sec)	Cycle length (sec)		Green timing (sec)	Red timing (sec)	Amber timing (sec)	Cycle length (sec)		Green timing (sec)	Red timing (sec)	Amber timing (sec)	Cycle length (sec)
Theresa road toward Richmond circle	Monday morning	110	64	3	180	Monday evening	267	187	3	460	Sunday	67	37	3	110
Brigade road to Hosur road		64	110	3	180		187	267	3	460		37	67	3	110
Hosur road to Brigade road		64	110	3	180		187	267	3	460		37	67	3	110

3.1.3 Sensitive parameter identification

Weidmann 74 car following model was used for the case study. The parameters are as follows ax_average (average standstill distance), bx_add and bx_mult (additive and multiplicative factors).Simulations were done using the default values and comparison was carried out with respect to the field conditions. Table 3 shows the delay observed using the default values.

Table 3 Simulated and Observed delay comparison for Shoolay junction using Wiedemann 7

Serial no	Model used	Models	Simulated delay(s)	Observed delay (s)	Absolute error
1	Wiedemann 74	Monday morning	101	89	12
2	Wiedemann 74	Monday evening	140	145	5
3	Wiedemann 74	Sunday morning	69	76	7
4	Wiedemann 74	Sunday evening	31	76	45

3.1.4 Calibration of the parameters

Optimization can be carried out in two ways reducing the absolute error from the individual models and reducing the absolute error sums for all the models

The optimized Wiedmann 74 parameter model and absolute error values are shown in the table. The absolute error obtained for Monday morning and Sunday morning is 1second (<1%), Monday evening is 2 seconds (<1%) and Sunday evening is 4 seconds (5%). The error for calibration is within acceptable limit of 15% for all the models.

4. MODEL VALIDATION

The calibrated parameters and the traffic data are validated for all the models form different time period. The individual intersection models and the calibrated parameters are validated. The results of the validations show an error of 15% as shown in the Table 4. The validation results are thus accepted and confirm the studies. Thus, the methodology of calibration in the study is able to optimize and model the intersection for all the models of the heterogeneous traffic reasonably.

Table 4 Calibrated Weidmann 74 parameters

Parameter	**Monday morning**	**Monday evening**	**Sunday morning**	**Sunday evening**	**Default values**
AX_AVERAGE	1	2	0.5	5	2
BX_ADD	1	2	1	6	2
BX_MULT	0.75	3	2	5	3
Delay in seconds (VISSIM)	90	143	77	72	
Delay in seconds (field)	89	145	76	76	
Absolute error	1	2	1	4	

Optimization of signal design

Optimization is a process of finding an alternative with most cost effective and a better performance under the given constraints by maximizing desired factors andminimizing undesired ones. Optimization of the Shoolay junction can be carried out once the model is calibrated and validated within minimal error. Signal design is one such optimization which can be implemented at the junction decreases the traffic delay to an extent and improves the level of service. Using VISSIM the green time and red time can be calibrated through trial and error for the respective models to minimize the delay. Table 5 and 6 shows the optimized signal of Monday and Sunday.

Table 5 Optimized Monday signal timings

Routes		Green Timing (Sec)	Red Timing(Sec)	Amber Timing(Sec)	Cycle Length(Sec)		Green Timing (Sec)	Red Timing (Sec)	Amber Timing (Sec)	Cycle Length (Sec)
Theresa road toward Richmond circle	Monday Morning	67	27	3	100	Monday Evening	77	37	3	120
Brigade road to Hosur road		27	67	3	100		37	77	3	120
Hosur road to Brigade road		27	67	3	100		37	77	3	120

Table 6 Optimized Sunday signal timings

Routes		Green Timing (Sec)	Red Timing(Sec)	Amber Timing(Sec)	Cycle Length(Sec)		Green Timing (Sec)	Red Timing (Sec)	Amber Timing (Sec)	Cycle Length (Sec)
Theresa road toward Richmond circle	Sunday Morning	47	17	3	70	Sunday Evening	25	19	3	50
Brigade road to Hosur road		17	47	3	70		19	25	3	50
Hosur road to Brigade road		17	47	3	70		19	25	3	50

Optimized delay

Once the signal optimization was carried out there was a reduction in delay, where Monday morning had an optimized delay of 68 seconds when compared to the observed delay of 89 seconds, Monday evening had an optimized delay of 64 seconds whereas the observed was 145 seconds, Sunday morning optimized delay was 68 seconds and observed delay was 76 seconds, whereas Sunday evening had an optimized delay of 54 seconds in comparison to the observed delay of 76 seconds as shown in the Table 7.

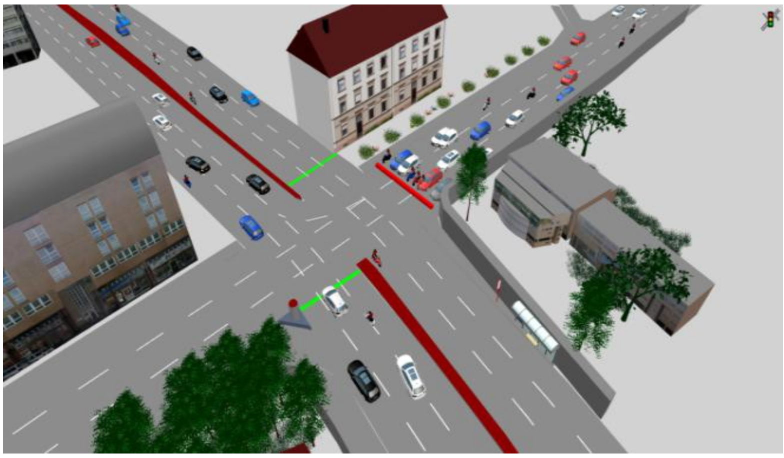

Figure 3 Simulation model VISSIM

Table 7 Optimized delay

DAY	OBSERVED DELAY	(AFTER OPTIMIZATION) DELAY	DECRESE IN DELAY(SEC)
MONDAY MORNING	89	68	21
MONDAY MORNING	145	64	81
SUNDAY MORNING	76	68	8
SUNDAY EVENING	76	54	22

5. SUMMARY

The study was carried out at Shoolay junction of Bengaluru city. For this study turning traffic volume, static and dynamic features of the vehicles, intersection geometric data were collected. Cycle time and control delay was calculated according to the quick estimation method prescribed in HCM 2010 by TRB. In this study, simulation model was constructed using the traffic and intersection representation data in PTV VISSIM. Tuning of the Driving behavior parameters of Weidman 74 model was done to calibrate the model and the model was successfully validated to a confidence level with error less than 5 %. We made an attempt to improve the performance of the junction by varying the signal timing.

CONCLUSIONS

Based on the study conducted, the conclusions can be drawn:

1) During the peak hours of Monday morning the delay was reduced by 21 seconds by varying the cycle length to 100 seconds.

2) Monday evening which had highest delay was optimized by varying the cycle length to 120 seconds thus reducing the delay by 81 seconds.

3) Sunday evening delay was reduced by 22 seconds by improving the cycle length to 50 seconds.

4) Sunday morning delay reduced by 8 seconds by varying the cycle length by 70 seconds.

5) Ambiguity is vested on the scope of study as it is restricted to a nodal level, which can be annulled only when the whole network is considered for analysis.

Scope for future works

1) VISWALK is an add-on requirement with VISSIM imitates the pedestrians and their effect in the network, which was not considered due to non-availability presenting it as further scope.

2) Network level studies which further presents a full picture of the behavior of traffic.

3) The real time field data of the performance parameter in the consideration is to be measured and use for the calibration which gives more confidence to the model.

4) Also various other elements can be changed or introduced into the network such as traffic actuators or refined intersection geometrics, regulations etc and compared for improvement in performance.

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