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Calibration of Car Following Parameters in VISSIM for Traffic in Kathmandu

By

Anmol Chhetri

A THESIS

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Calibration of Car Following Parameters in VISSIM for Traffic in Kathmandu"** submitted by Anmol Chhetri in partial fulfillment of the requirements for the degree of Master of Science in Transportation Engineering.

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ABSTRACT

Traffic simulation is widely used to perform analysis of traffic operations. Traffic in Nepal is non-lane based, heterogeneous and mixed while car-following models are developed for lane based and homogeneous traffic condition. Traffic simulation software needs to be calibrated to represent local conditions. The main objective of this study was to calibrate Car-following parameters in VISSIM. The parameters for calibration were selected based on past studies on VISSIM calibration in heterogeneous traffic condition. Eleven parameters were selected for analysis. Latin hypercube sampling technique was used to create the sample set of parameters for simulation. One-way ANOVA was used to determine the sensitive parameters. Linear equations were developed using sample set prepared by Latin hypercube sampling technique. Multi objective Genetic algorithm tool available in MATLAB was used to perform optimization of linear equations to minimize the difference between field delay and simulated delay. Three car-following parameters of Widemann-74 model were found sensitive which were calibrated using genetic algorithm to obtain optimal values. For further study, it is recommended that more than one intersection can be studied to generate a range of values, and more than one measure of effectiveness can be selected for robust calibration and validation.

Keywords: VISSIM, Genetic algorithm, LHS, ANOVA

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AX_still	Average Standstill Distance
BX_add	Additive part of Safety Distance
BX_mult	Multiplicative part of Safety Distance
GA	Genetic Algorithm
HCM	Highway Capacity Manual
LHS	Latin Hypercube Sampling
LAD_min	Look ahead Distance(min)
LAD_max	Look ahead Distance(max)
Lat_0	Minimum Lateral Distance Standing
Lat_50	Minimum Lateral Distance Driving
LBD_min	Look back Distance(min)
LBD_max	Look back Distance(max)
Min_clc	Minimum Clearance Front and Rear
NRS	Nepal Road Standard
ODelay	Observed Delay
SDelay	Simulated Delay
SDRF	Safety Distance Reduction Factor
PTV	Planning Transport Verkehr
VISSIM	Verkehr in Stadten – SIMulation Model

CHAPTER 1: INTRODUCTION

1.1 Background

Microscopic simulation model provides a quicker, cheaper, and safer environment for conducting studies than field installation and testing, so it is extensively utilized in both transportation operations and management analysis (Park & Schneeberger, 2003). The use of microscopic traffic simulation tools enables the introduction and assessment of various situations without affecting the flow of traffic on the road. These traffic simulation tools are based on different theories of microscopic traffic behavior, such as car following and lane changing (Panwai & Dia, 2005).

The traffic in Nepal is non-lane based, heterogeneous, and mixed while car following models are developed for lane based and homogeneous traffic environment. Analytical modeling of non-lane based and mixed traffic is in developing stage. For the purpose of analyzing and modeling heterogeneous traffic, microscopic simulation is preferred (Mathew & Radhakrishnan, 2010).

Previous studies suggest that microscopic simulation model need to be calibrated to represent the local traffic. This can be accomplished through model calibration, which is a process of choosing the optimal set of model input parameters by changing or fine-tuning their default values to accurately reflect the field-measured and simulated local traffic conditions (Park & Schneeberger, 2003).

PTV VISSIM was used as micro simulation framework. The car following parameters in VISSIM was calibrated according to the local traffic in this study.

1.2 Problem Statement

Simulation modeling for study of traffic has gained recognition as an effective approach for quantifying traffic operations. Different traffic simulation packages like VISSIM, CORSIM, PARAMICS, MITSIM, AIMSUN, etc. are used for analyzing traffic. These traffic simulation models run on different principles, and there is little information on the most appropriate application of these models for specific traffic study.

These models have different parameters that govern the simulation, the user manuals provide little information about the appropriateness of the default parameters. They do not provide any guidance on how to modify these parameters for different traffic conditions. Hence, the user has to make appropriate changes on the parameters to comply with the present traffic.

Any of the model can be used to perform traffic simulation, to use any of these models we need to test its applicability for the local traffic conditions. There are different parameters that represent the driving behavior and traffic conditions which are based on the country where the model was originally introduced. Therefore, there is an obvious need for calibration and validation of these models to represent the present traffic.

Calibration is the process in which the model parameters of the simulation are optimized to the extent possible for obtaining a close match between the simulated and the actual traffic measurements. In this study, VISSIM a German microscopic simulation framework was selected for calibration. It is a comprehensive microscopic simulator covering wide range of traffic situations including traffic and transit on urban roads and motorways.

1.3 Research Objectives

The main objective of this study was to calibrate the car-following parameters in VISSIM.

The specific objectives are:

i. To perform sensitivity analysis of driving behavior parameters in VISSIM
ii. To calibrate sensitive car-following parameters using genetic algorithm

1.4 Scope and Limitations of study

The present study is focused to calibrate the car-following parameters in VISSIM for the local traffic in Kathmandu. This study has some limitations

i. Pedestrian interaction with the traffic is not considered.
ii. Only one intersection was used for calibration of the car-following parameters.

1.5 Organization of Report

This report has been organized into five chapters as described below;

CHAPTER 1: INTRODUCTION

This chapter contains a general introduction of the topic of the thesis. It consists of background, research objectives, limitation of study and organization of thesis.

CHAPTER 2: LITERATURE REVIEW

This chapter consists of the previous studies done on VISSIM calibration and final takeaway from those studies.

CHAPTER 3: METHODOLOGY

This chapter comprises of framework to carry out the research work.

CHAPTER 4: DATA ANALYSIS

This chapter includes processing the data extracted from the video graphic survey. The calibration of VISSIM and its validation.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

This final chapter summarizes the works and outcome of the study and provides recommendation for further study.

CHAPTER 2: LITERATURE REVIEW

2.1 Car-following Model in VISSIM

The car-following model in VISSIM is based on the psychophysical models introduced by Wiedemann. The basic assumption in these models is that a driver can be in one of four driving modes. These four modes as a whole form the car-following model.

- Free-driving mode, where no influence is exerted from leading vehicles. In this mode, the driver attempts to reach and maintain a desired speed.
- Approaching mode, when the driver of the follower vehicle consciously observes that s/he is approaching a slower vehicle in front.
- Following mode, where the headway for a pair of vehicles is between the maximum following headway and the safe headway. In this mode, the follower vehicle is able to accelerate or decelerate in accordance with the vehicle in front.
- Braking mode, when the headway between vehicles drops below a desired safety distance (*PTV Vissim 2023 Manual*).

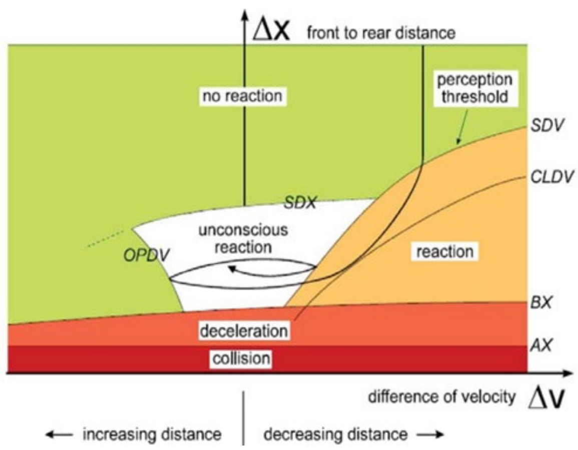

Figure 2- 1 Wiedemann Car-Following model

Where,

AX-Desired distance between the front sides of two successive vehicles in a standing queue.

BX-Desired minimum following distance, which is a function of AX, a safety distance, and speed.

SDV-Action point when a driver consciously observes approaching a slower vehicle. SDV increases with increasing speed differences.

OPDV-Action point when drivers of follower vehicles notice that they are traveling slower than the leading vehicles and start to accelerate again.

SDX-Perception threshold to model the maximum following distance, which is about 1.5–2.5 times BX.

VISSIM has two car following models Wiedemann-74 and Wiedemann-99. The parameters of Wiedemann74 and Wiedemann99 are shown in Table 2- 1 and Table 2-2 below:

Table 2- 1 Wiedemann-74 Parameters

Parameter	Description
Average standstill distance	(ax): "Base value for average desired distance between two stationary cars. The tolerance lies within a range of –1.0 m to +1.0 m which is normally distributed at around 0.0 m, with a standard deviation of 0.3 m. This leads to "stochastic smearing" of ax. Default 2.0 m".
Additive part of safety distance	(bxadd): "Value used for the computation of the desired safety distance d. Allows to adjust the time requirement values. Default 2.0 m".
Multiplicative part of safety distance	(bxmult): "Value used for the computation of the desired safety distance d. Allows to adjust the time requirement values. Greater value = greater distribution (standard deviation) of safety distance Default 3.0 m".

Source: PTV VISSIM manual (2023).

Table 2- 2 Wiedemann – 99 Parameters.

Parameter	Description
CC0	It is the average desired standstill distance between two vehicles. It has no variation.
CC1	It is the distance in seconds which a driver wants to maintain at a certain speed. The higher the value, the more cautious the driver is.
CC2	It restricts the distance difference (longitudinal oscillation) or how much more distance than the desired safety distance a driver allows before he intentionally moves closer to the car in front.
CC3	It controls the start of the deceleration process, i.e., the number of seconds before reaching the safety distance. At this stage the driver recognizes a preceding slower vehicle.
CC4	It defines negative speed difference during the following process.
CC5	It defines positive speed difference during the following process.
CC6	Influence of distance on speed oscillation while in following process.
CC7	Oscillation during acceleration
CC8	Desired acceleration when starting from stand still.
CC9	Desired acceleration at 80 Kmph.

Source: PTV VISSIM manual (2023).

2.2 Mean Absolute Percentage Error (MAPE)

Mean absolute percentage error (MAPE), is a frequently used metric to assess the accuracy of model predictions. The average absolute percentage difference between expected and actual values is known as MAPE. The equation is:

$$MAPE = \frac{\sum \frac{|\text{Actual} - Forecast\ |}{Actual} * 100\%}{N} \tag{2.5}$$

Where,

N = total number of observations.

2.3 Previous Related Studies

Park and Schneeberger proposed a nine step method to calibrate VISSIM, a micro-simulation software. A linear equation was developed and optimized by excel solver to match the field travel time value (Park & Schneeberger, 2003).

Park and Qi devised a methodology where calibration of VISSIM was done by selecting a measure of effectiveness(MOE) as performance measure for calibration. Travel time of south bound approach of intersection located in Virginia, U.S.A was used as measure of effectiveness. The parameters which were significant to the study was found by ANOVA test. The sampling plan for ANOVA test was created by Latin Hypercube Sampling (LHS) technique. Genetic Algorithm was used as optimization technique to calibrate 8 sensitive parameters (Park & Qi, 2005).

Mathew and Radhakrishnan studied three intersections in India to calibrate VISSIM in heterogeneous traffic condition. Delay was used as the MOE for calibration. Field delay was measured by procedure recommended by HCM (*The Highway Capacity Manual*, 2010). The sensitive parameters were identified utilizing trial and error approach in which each parameter was increased and decreased by 10% individually. The sensitive parameters were then calibrated by using GA, the minimization of difference between field delay and simulated delay was used as tuning parameter for GA. Seven parameters were calibrated which included three Widemann-74 and four Widemann-99 parameters (Mathew & Radhakrishnan, 2010).

Siddhartha and Ramadurai used flow as MOE to calibrate VISSIM, LHS was used for sampling plan and first level sensitivity analysis was done by ANOVA, second level sensitivity analysis was done by elementary effects method on parameters which were not found significant from ANOVA test. Genetic algorithm was used to find the optimal values of sensitive parameters during calibration. A total of nine parameters were calibrated which included minimum headway, Average standstill distance, Additive part of safety distance, multiplicative part of safety distance, minimum lateral distance of bike at 0 kmph, look ahead distance minimum, Look back distance minimum, desired acceleration for bike and HMV at 0 kmph (Siddharth & Ramadurai, 2013).

Maheshwary et al. used travel time as MOE to calibrate VISSIM, initial sensitivity analysis was done by individually varying each parameter by 10 % and measuring its effects. Further LHS was used to create sampling plan and ANOVA was used to find significant parameters. The LHS was used to develop regression equations; travel time was used as dependent variable and sensitive parameters as independent variables. The regression equations were input to genetic algorithm mechanism to obtain the optimal values of the parameters. The genetic algorithm toolbox in MATLAB was utilized for the optimization of the obtained sensitive car-following parameters for each vehicle class (Maheshwary et al., 2020).

Gunarathne et al. selected a three legged intersection to calibrate VISSIM in Srilanka. Queue length was selected as MoE. Initially ten parameters were selected by reviewing past studies. The sensitive parameters for calibration was determined by trial and error method in which each parameter was altered individually without changing other parameters. Six parameters were found sensitive which was optimized using genetic algorithm. Genetic algorithm optimization tool available in the optimization toolbox of the MATLAB was used as genetic algorithm framework for optimization. Mean absolute percentage error (MAPE) between observed and simulated queue length obtained below acceptable range was used to obtain optimal value of parameters (Gunarathne et al., 2023).

Acharya and Marsani altered driving behavior parameters so as to match the traffic volumes obtained from VISSIM with the field data (Acharya & Marsani, 2020).

Shrestha and Pradhananga used volume as key performance measure and queue length as additional calibration measure, the parameters used for calibration was based on review of literature related to VISSIM calibration under heterogeneous and non-lane-based traffic, trial and error method was used to find the optimal values of the parameters (Shrestha & Pradhananga, 2023).

Considering the literatures above VISSIM is used by many researchers for simulation (Acharya & Marsani, 2020; Gunarathne et al., 2023; Maheshwary et al., 2020; Mathew & Radhakrishnan, 2010; Park & Qi, 2005; Shrestha & Pradhananga, 2023; Siddharth & Ramadurai, 2013). The preferred MOE used for calibration are delay, flow, travel time, and queue length. For sensitivity analysis ANOVA and for sampling plan LHS were frequently used. Finally GA was used as optimization algorithm

(Gunarathne et al., 2023; Mathew & Radhakrishnan, 2010; Park & Qi, 2005; Siddharth & Ramadurai, 2013). Previous research shows that travel time is frequently used as MOE. Travel time was used considering whole lane of intersection, for study of particular intersection delay has been by Mathew and Radhakrishnan (Mathew & Radhakrishnan, 2010). Hence, for this study a particular intersection was used and field delay was used as MOE, ANOVA was used for sensitivity analysis, LHS was used to create sampling plan and GA was used for optimization.

CHAPTER 3: METHODOLOGY

The framework of methodology is shown in Figure 3- 1. The methodology involves selection of site. A video graphic survey was performed to get traffic data. The required input was fed to PTV VISSIM 2023 (SP 08), a microsimulation software. LHS was used to prepare a sampling plan. ANOVA was used to perform sensitivity analysis. The sensitive parameters were then subjected to a genetic algorithm process using optimization toolbox available in MATLAB to optimize the parameters.

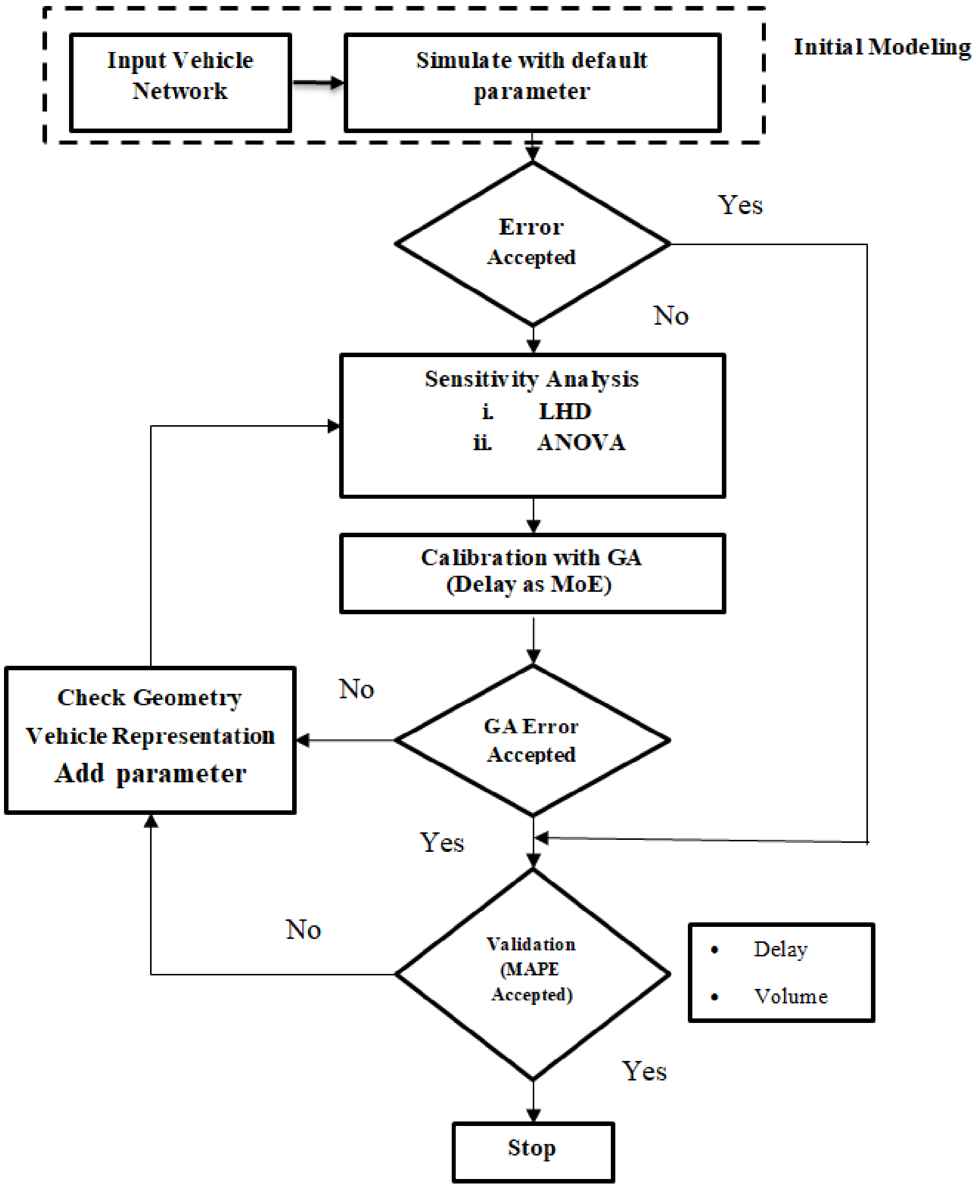

Figure 3- 1 Framework of Methodology

3.1 Initial Modelling

In this, selection of study site is done. Collecting and processing of the data from the field, network coding, vehicle representation, and once simulation model is set up simulation run with default parameter is done. The observed values are compared with field values.

3.1.1 Study Site

A map of Kathmandu was analyzed to find the suitable network for simulation in VISSIM. The considered criteria for site selection were that the site should have simple geometry, a wide range of vehicle composition, and should be signalized. The Putalisadak intersection was selected for this study as it met all the criteria for site selection. The intersection had simple geometry with wide range of vehicle composition and it was a signalized intersection. The Figure 3- 2 and Figure 3- 3 shows the general layout and geometry of Putalisadak intersection.

Figure 3- 2 General Layout of Putalisadak Intersection

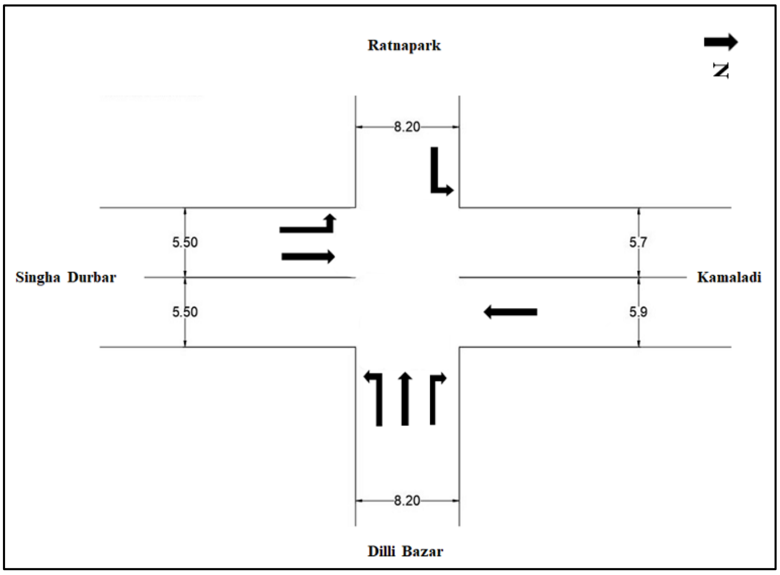

Figure 3- 3 Geometrical Layout of Putalisadak Intersection (Sketch not in scale)

3.1.2 Data Collection and Extraction

The geometric data of the intersection was obtained by direct measurement of the lane width in the field with the use of a measuring tape. A video graphic survey was performed to obtain the traffic characteristics of the intersection. One video camera was installed to obtain the required videos for the study. The video was taken from 26-07-2021 to 28-07-2021 (Monday to Wednesday). A video of one hour was recorded at non-peak hour from 01:00 p.m. to 02:00 p.m. for first two days (Monday and Tuesday) which was used for calibration and a video of one hour was recorded at evening peak hour form 05:00 p.m. to 06:00 p.m. (Wednesday) which was used for validation.

Data extraction was done by playing the video several times. The classified count of the vehicles was done according to the vehicle types mentioned in Table 4-1 of Nepal Road Standard 2070 (*Nepal Road Standard 2070.*, 2013).

Non-motorized carts, tractor, rickshaw, auto rickshaw, and, bicycle were not considered in classified count as their volume was negligible. The directional movement, signal timing and phasing was also obtained from the video.

3.1.2.1 Field Delay Measurement

Field delay measurement method has been recommended in Highway capacity manual (*The Highway Capacity Manual*, 2010). The delay is calculated based on vehicle-in-queue at frequent intervals. The measurement of queued vehicle is started at the beginning of the red phase of the considered lane. Previous green phase should not have an overflow queue when counting is started. An interval for counting of queued vehicle is selected between 10 secs to 20 seconds. The selected interval should be integral divisor of the cycle length. The vehicle in queue are vehicles which has joined the queue and not exited the intersection. The vehicle is considered to exit the intersection when rear wheel of the vehicle exits stop line of the intersection. All the vehicle that had entered in the queue within the survey period are counted until they exit the intersection in the last cycle. A separate count is kept of stopping vehicle in the intersection during survey period. Stopping vehicle is counted only once even if it stops more than once (*The Highway Capacity Manual*, 2010). Following calculations are made then:

$$T_Q = (I_s * \sum V_{iq} / V_T) * 0.9 \quad (2.1)$$

Where,

T_Q = average time-in-queue, s/veh

I_s = time interval between time-in-queue counts, sec

$\sum V_{iq}$ = sum of all vehicle-in-queue counts

V_T = total number of vehicles arriving during the study period, vehs

0.9 = empirical adjustment factor

$$V_{SLC} = V_{stop} / (N_c * N_L) \quad (2.2)$$

Where,

V_{SLC} = number of vehicles stopping per lane, per cycle

V_{stop} = total count of stopping vehicles

N_c = number of cycles included in the survey

N_L= number of lanes in the survey lane group

$$FVS = V_{stop} / V_T \quad (2.3)$$

Where, FVS = fraction of vehicles stopping

$$Delay = T_Q + (FVS * CF) \quad (2.4)$$

Where, CF = correction factor based on the free flow speed and vehicles stopping per lane per cycle.

3.1.3 Network coding and simulation run

The obtained geometric, traffic and signal timing data are fed to VISSIM 2023 (SP 08) to model the intersection. Figure 3- 4 shows the network and lane composition respectively.

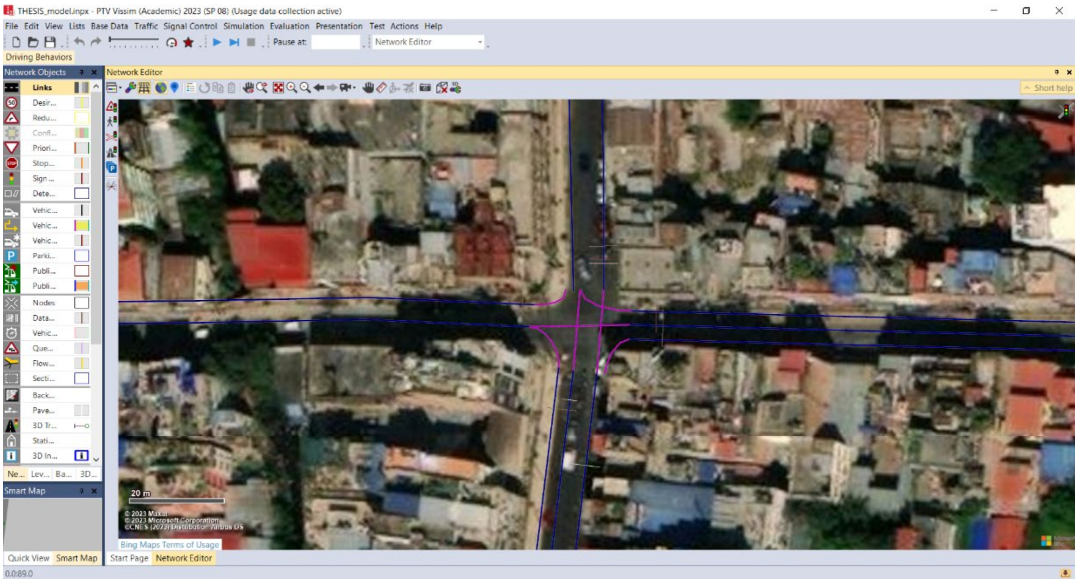

Figure 3- 4 Network and lane composition in VISSIM

The Dillibazar lane is a one-way lane, and the traffic from there disperses in three different directions. The traffic in the field seemed to move in three virtual lanes, so in VISSIM, a single lane is divided into three lanes with equal width, as shown in Figure 3- 4.

In Singhadurbar lane the left turning vehicle travelling towards Ratnapark blocked the through vehicle travelling towards Kamaladi. To avoid this problem, the Singhadurbar lane was split into two separate lanes.

After network coding, the model was run with default parameters, and the delay obtained from the simulation was compared with the field value.

3.2 Selection of Parameters

After simulation with default parameters, if simulation output is not within the acceptable range than calibration of model is required. VISSIM consists of a number of parameters which influence the output of the simulation. In this study, the parameters which affected the simulation was selected based on previous research done to calibrate VISSIM in heterogeneous traffic condition which is explained in section 4.7.

3.3 Sensitivity Analysis

Sensitivity analysis is performed to determine the significant variables that affect the outcome. It helps to substantially reduce the process of calibration by reducing the number of variables. LHS was used to prepare a sampling plan. One-way ANOVA was used to identify the sensitive variables. LHS was then used to develop multiple linear equations for sensitive variables. The developed equations were used for optimization using genetic algorithm.

3.3.1 Latin Hypercube Sampling

Latin hypercube sampling (LHS) is a statistical method for generating a random sample of parameter values. Latin Hypercube sampling is a method which generates random samples that effectively cover the sample space without having to generate as many samples as would be required by a truly random sampling process.

In the context of statistical sampling, a square grid containing sample positions is a Latin if (and only if) there is only one sample in each row and each column. A Latin hypercube is the generalization of this concept to ‘n’ number of dimensions, whereby each sample is the only one in each axis-aligned hyperplane containing it. In this each variable's range is divided into smaller ranges of values and then one sample is chosen for each combination of variables and ranges. An example of a Latin Hypercube sample for two variables (A and B) with four ranges of values each is shown in Figure 3- 5.

For this study, 50 samples were developed for selected parameters which is explained in section 4.8.

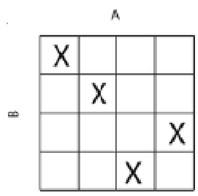

Figure 3- 5 Illustration of a Latin Hypercube Sample

3.3.2 Analysis of Variance (ANOVA)

ANOVA is a technique that is used to obtain inferences about population means when different factors affect mean values. For identifying whether a specific factor affects the response variable, one-way ANOVA is effective. This makes it an appropriate method to perform sensitivity analysis. For this study, SPSS (2020) was used to perform ANOVA. One-way ANOVA was performed with 95 % confidence interval.

3.4 Calibration

Calibration of a model is done to represent the local conditions. Calibration of VISSIM was done by using genetic algorithm as an optimization process and delay was used as a measure of effectiveness. Non-peak hour data from 01:00 p.m. to 02:00 p.m. recorded for first two days (Monday and Tuesday) was used for calibration of model.

3.4.1 Genetic Algorithm

The genetic algorithm is an optimization and search technique. It is based on the principles of genetics and natural selection. Haupt and Haupt stated that, "A GA allows a population composed of many individuals to evolve under specific selection rules to a that maximizes the "fitness" (i.e. minimizes the cost function)" (Haupt & Haupt, 2003). A GA process generally has three basic operator selection, crossover and mutation. The steps involved in GA process are:

i. Initialization: An initial population of chromosomes are created to begin the GA.
ii. Selection: The population of chromosomes are evaluated and most fit chromosomes are selected to create offspring in next step. The cost function associated with each chromosome are obtained and most fit chromosomes are selected by applying one of the different method of selection like tournament, ranked, Russian roulette, etc.
iii. Crossover: After selection the obtained chromosomes are subjected to mating process to create offspring. The generally used method of crossover are one point, two-point crossover, etc.
iv. Mutation: It helps to introduce randomness in the process and avoid local optimum.

MATLAB software was used to perform genetic algorithm. Multi objective genetic algorithm tool available in the optimization toolbox in MATLAB was utilized to perform optimization. Following setting was used, the number of generation was kept at 1000, population size was kept at 25, three-point tournament method was used for selection, crossover fraction was kept at 0.9 and mutation fraction was kept at 0.05.

3.5 Validation

Validation is done to determine how the calibrated model is performing under different set of data other than that used for calibration. For validation third day evening peak hour data from 5:00 PM to 6:00 PM was used for validation. Mean absolute percentage error (MAPE) was used for validation of calibrated model. MAPE is used to compare the forecasted value with the observed value. Simulation output values are also forecasted, so MAPE fits for this study to be used as a validation mechanism. Brockfeld et al. stated that, "the acceptable range for the

MAPE is 15% - 22% or lesser error such that the model would be considered as a calibrated model" (Brockfeld et al., 2005). For this study, the MAPE range from 0% to 15 % was selected for calibration and validation. MAPE in this study is calculated using equation 3.1. Delay was used as a measure for validation and volume was used as an additional measure for validation.

$$\mathrm{MAPE} = \frac{\frac{|\ \mathrm{ODelay} - \mathrm{SDelay}\ |}{\mathrm{ODelay}} * 100\%}{\mathrm{N}} \tag{3.1}$$

Where,

ODelay – Observed delay in field,

SDelay – Simulated delay,

N – fitted points.

CHAPTER 4: DATA ANALYSIS AND RESULTS

4.1 Traffic Volume at Intersection

Traffic count was carried out on the videos obtained from the video graphic survey which showed that the traffic volume of the intersection on Monday from 1:00 Pm to 2:00 Pm is 5420.5 PCU/hr and the traffic volume from Singhadurbar, Kamaladi, Ratnapark, and Dillibazar is 1844.5, 1494.5, 450, 1631.5 PCU/hr respectively. The intersection volume on different days is shown in Table 4- 2.

4.2 Traffic composition

The traffic at Putalisadak intersection is comprised of motorbikes, cars, pickups, and tempo. Cycles were not included in the study, while tractors and trucks were not included due to their negligible volume. The Table 4- 1 shows that volume of motorcycle comprises of higher percentage at intersection followed by car.

Table 4- 1 Total Traffic volume (Monday)

Time	13:00-13:15	13:15-13:30	13:30-13:45	13:45-14:00	Total	Percentage	PCU/hr
Motorcycle	1489	1833	1688	1635	6645	78.28%	3322.5
Car	358	412	349	388	1507	17.75%	1507
Bus	28	31	35	33	127	1.50%	381
Pickup	37	60	39	30	166	1.96%	166
Tempo	10	13	10	11	44	0.52%	44
Truck	0	0	0	0	0	0.00%	0
					8489		5420.5

Table 4- 2 Total Traffic volume at PutaliSadak Intersection

Day	Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck	Total
Monday	13:00-14:00	6645	1507	127	166	44	0	8489
Tuesday	13:00-14:00	6768	1615	105	146	46	0	8680
Wednesday	17:00-18:00	6059	1365	132	23	43	0	7622

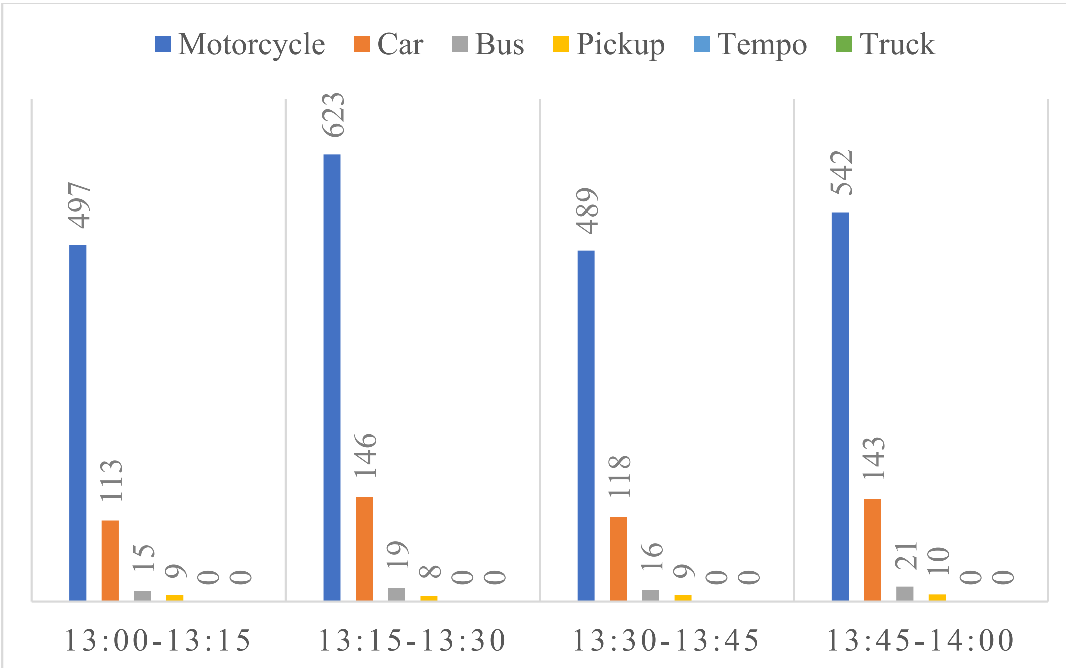

Figure 4- 1 Traffic from Singhadurbar (Monday)

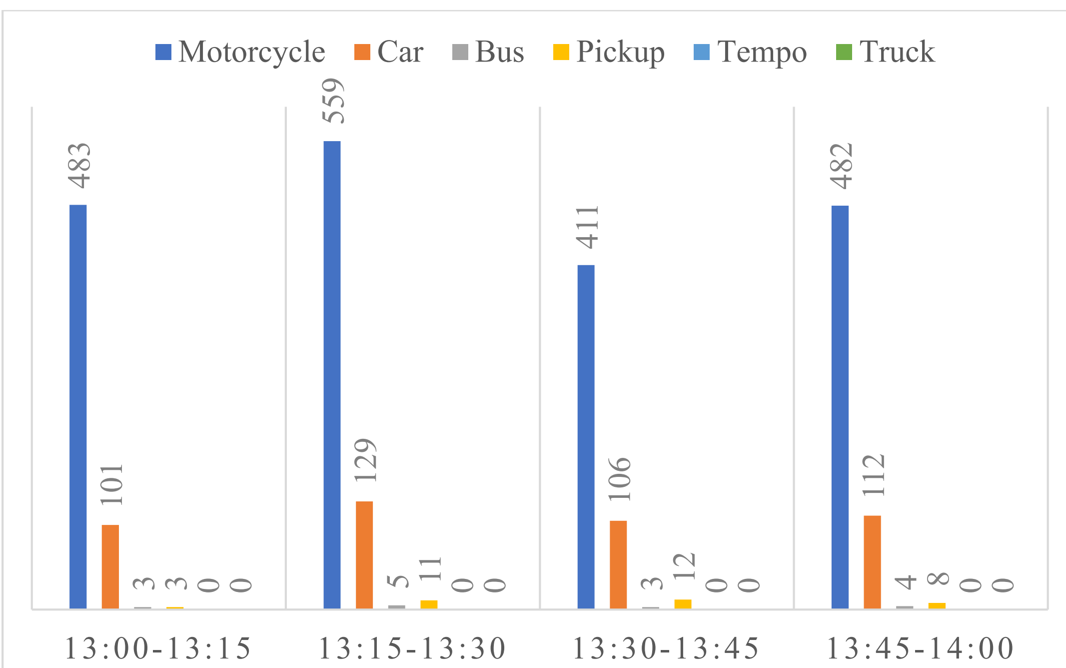

Figure 4- 2 Traffic from Kamaladi (Monday)

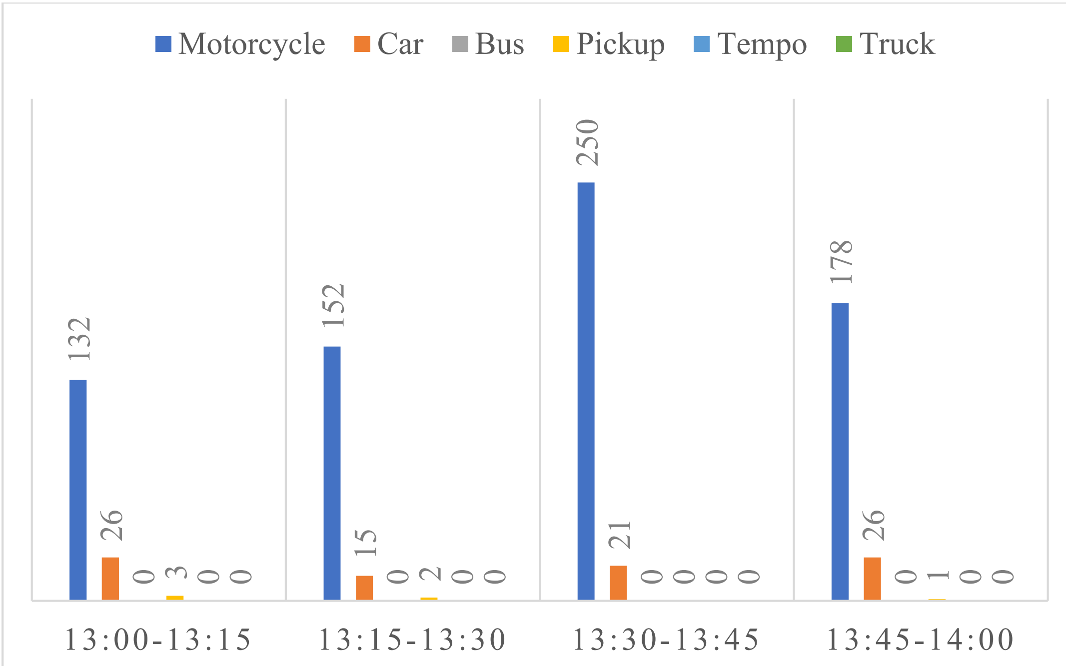

Figure 4- 3 Traffic from Ratnapark (Monday)

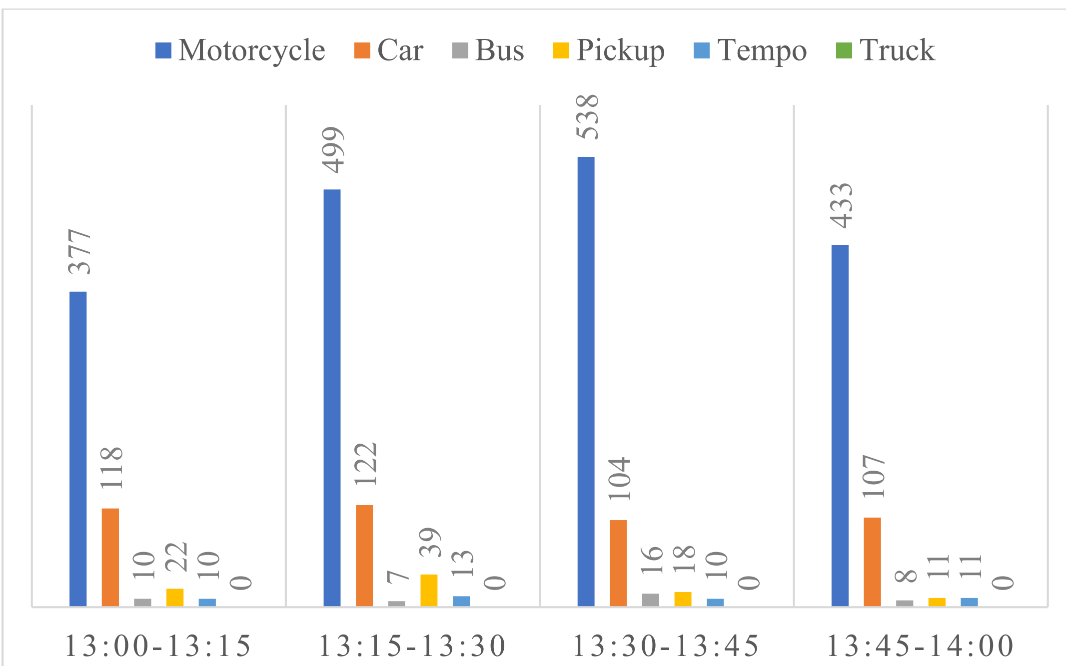

Figure 4- 4 Traffic from DilliBazar (Monday)

4.3 Relative Flow

The through and turning traffic towards respective lanes was obtained from the video. The Traffic from Singhadurbar was split into through traffic towards Kamaladi and turning towards Ratnapark. The traffic from Dillibazar was split into through traffic towards Ratnapark and turning traffic towards Singhadurbar and Kamaladi. In Singhdurbar lane to avoid turning traffic blocking the through traffic the two lanes were split into turning lane and through lane. In Dillibazar lane the single lane was split into three lanes as explained in section 3.1.3. The traffic form Kamaladi lane had only through traffic. The traffic from Ratnapark lane has only left turning traffic towards Kamaladi. The traffic volume for each split lane was determined and relative flow value of unity was used.

4.4 Signal Timing Data

The signal timing data was obtained from the video. The intersection had two phase signal. The signal cycle was different in afternoon off-peak hour from evening peak hour. Cycle length for off-peak hour was 197 seconds and for peak hour was 155 seconds. The traffic signal controlled the traffic from Singhadurbar lane, Kamaladi lane and Dillibazar lane. The traffic from Ratnapark lane was not governed by any signal and had free left turning movement. The traffic signal showed red signal simultaneously for traffic from Singhadurbar lane, Kamaladi lane and Dillibazar lane for pedestrian crossing which was 21 seconds and 20 seconds for off-peak hour and peak hour respectively. The signal time detail has been included in Appendix D.

4.5 Calculation of Field Delay

Field delay was used as measures of effectiveness for calibration. The delay for through traffic from Singhadurbar lane towards Kamaladi lane was used for calibration. The delay obtained for though traffic is shown in Table 4- 3. The detail calculation of the field delay is shown in Appendix F.

Table 4- 3 Field Delay for though traffic from Singhadurbar lane

S.N.	Day	Observed Delay (sec/veh)
1	Monday	37.33
2	Tuesday	37.69
3	Wednesday	18.28

4.6 Initial Simulation Run and Comparison

The model was run with default parameters with five different random seeds and the average value of simulated delay was compared with field delay. The Table 4- 4 shows that MAPE was 106% which is well above the acceptable range. This confirms that calibration of VISSIM is necessary.

Table 4- 4 Comparison of field Delay for through traffic from Singhdurbar lane

S.N.	Avg. Field Delay (Sec/veh)	Simulated Delay (Sec/veh)	MAPE
1	37.51	77.43	106%

4.7 Identification and Selection of Driving Behavior Parameters

VISSIM provides a number of driving behavior parameters majority of which include driving behavior parameters includes car-following, lane changing and lateral movement parameters. The identification and selection of driving behavior parameters and their range for this study was selected, based on previous studies done in heterogeneous mixed traffic conditions. Considering the previous studies (Acharya & Marsani, 2020; Gunarathne et al., 2023; Maheshwary et al., 2020; Mathew & Radhakrishnan, 2010; Shrestha & Pradhananga, 2023; Siddharth & Ramadurai, 2013) 11 parameters were selected for this study. The selected parameters were those which were repeatedly used in the previous studies and affected the simulation outcome. Table 4- 5 shows the parameters and their range which were selected for this study.

Table 4- 5 Selected Parameters and their Range for calibration

S.N.	Parameters	Range
1	Look ahead Distance(min) (LAD_min)	10-30
2	Look ahead Distance(man) (LAD_max)	100-140
3	Look back Distance(min) (LBD_min)	6-24
4	Look back Distance(max) (LBD_max)	80-120
5	Average Standstill Distance (AX_still)	0-2.5
6	Additive part of Safety Distance (BX_add)	0-2.5
7	Multiplicative part of Safety Distance (BX_mult)	0-4
8	Minimum Clearance Front and Rear (Min_clc)	0.25-0.8
9	Safety Distance Reduction Factor (SDRF)	0.3-0.7
10	Minimum Lateral Distance Standing (Lat_0)	0-1
11	Minimum Lateral Distance Driving (Lat_50)	0-1

4.8 Sensitivity Analysis

Sensitivity analysis is done to determine which parameters has significant impact on the output. It helps to select only those parameters for calibration which has significant impact on the model reducing the time in calibration process. For this study, sensitivity analysis was performed on the selected 11 parameters to find out which parameters were significant. One-way ANOVA was used for the sensitivity analysis. Latin hypercube sampling (LHS) was used to prepare a sampling plan of 50 samples. ANOVA and LHS is explained previously. Appendix E shows a sample of sampling plan used for this study.

Simulation was run with each parameter value obtained from LHS by keeping other parameter values as default. Simulated delay of Singhadurbar through lane was noted for each parameter value.

Table 4- 6 ANOVA Results

S.N.	Parameters	p-value
1	Look ahead Distance(min) (LAD_min)	1.000
2	Look ahead Distance(man) (LAD_max)	.102
3	Look back Distance(min) (LBD_min)	.987
4	Look back Distance(max) (LBD_max)	1.000
5	Average Standstill Distance (AX_still)	.000
6	Additive part of Safety Distance (BX_add)	.000
7	Multiplicative part of Safety Distance (BX_mult)	.000
8	Minimum Clearance Front and Rear (Min_clc)	1.000
9	Safety Distance Reduction Factor (SDRF)	.999
10	Minimum Lateral Distance Standing (Lat_0)	.261
11	Minimum Lateral Distance Driving (Lat_50)	.990

The simulated delay was input to SPSS to perform one-way ANOVA with confidence interval of 95%. Table 4- 6 shows the result of ANOVA. Three Wiedemann-74 car-following parameters were significant and had p-values less than 0.05. The three significant parameters were average standstill distance, additive part of safety distance, and multiplicative part of safety distance. These significant parameters were used for calibration of VISSIM.

4.9 Multiple Linear Regression

From the sampling plan of LHS and delay value obtained from VISSIM for each parameter value by keeping other values as default linear equations were developed. The sample size was determined by using the formula proposed by Khamis and Kepler as n = 20+5k where k is no. of predictors, n is no. of sample (Khamis & Kepler, 2010). For three predictors sample size with the formula given by Khamis and Kepler is 35, in this study 50 samples were taken to create a regression equation. The linear equations obtained are specific to this particular intersection only.

$$Delay = 94.964 - 9.66 * AX\_Still \qquad (4.1)$$

$$Delay = 62.653 + 6.030 * BX\_add \qquad (4.2)$$

$$Delay = 66.367 + 2.746 * BX\_mult \qquad (4.3)$$

4.10 Calibration with GA

Genetic algorithm was used to perform multiobjective optimization. Multiobjective optimization means optimizing more than one objective simultaneously. It can be performed using MATLAB software. The optimization of linear equations was performed by using the multi-objective genetic algorithm optimization tool available in the optimization toolbox of MATLAB. The number of generations was set to 1000 with a population size of 25 in optimization program. For selection, the 3-point tournament method was used; the crossover fraction was kept at 0.90 for reproduction, and a 0.05 value was used for mutation. Different driving behavior parameter values were obtained from each optimization. The parameter values obtained from each optimization trial were input into the VISSIM software's corresponding parameter. The model was run, and MAPE was calculated based on results from VISSIM. The MAPE obtained was compared with the aforementioned acceptable range. The values of the parameters in the trail with the most suitable MAPE were considered calibrated values.

4.10.1 Calibration results

Table 4- 7 shows the results of the optimization performed. The values of sensitive parameters obtained after each trial were provided as input into the VISSIM software to calculate MAPE. Trail No. 27 reduced MAPE from 76.02% initially to 9.7%. The obtained MAPE is less than 15%, which is within the acceptable range. The values obtained from trial 27 were considered calibrated values for driving behavior parameters at the Putalisadak intersection.

4.11 Validation

The validation was done with a different set of data from the same intersection. Evening peak hour data from 05:00 p.m. to 06:00 p.m. of date 28-7-2021 was used to validate the calibrated parameters. Validation was done using delay and volume in the intersection. The model was run 5 times with different random seed to obtain the delay and volume values. Table 4- 8 and Table 4- 9 shows the MAPE between simulated and field values. Figure 4- 5 shows comparison of observed and calibrated volume. The MAPE for delay and volume is 3.56 % and 2.07 % respectively which are within acceptable range. Hence, the model is successfully validated.

Table 4- 7 Optimized Set of Parameters with their respective MAPE

Trial	AX_Still (m)	BX_add	BX_mult	Delay (Sec/Veh)	MAPE
1	2.50	2.32	0.74	66.02668	76.02%
2	2.50	0.33	0.03	49.41345	31.73%
3	2.50	2.37	0.03	64.95724	73.17%
4	2.50	0.01	1.03	48.70235	29.84%
5	2.50	0.98	0.00	52.46716	39.88%
6	2.50	0.00	0.00	52.29695	39.42%
7	2.49	0.00	0.28	45.57137	21.49%
8	2.45	0.00	0.00	52.72835	40.57%
9	2.45	0.52	3.98	65.59007	74.86%
10	2.37	0.05	0.00	53.07381	41.49%
11	2.25	1.10	1.47	65.06923	73.47%
12	1.96	0.01	2.12	54.90056	46.36%
13	1.94	2.47	0.04	69.81201	86.12%
14	1.93	2.50	0.01	69.67575	85.75%
15	1.92	1.42	0.00	59.15173	57.70%
16	1.85	0.61	0.00	44.91631	19.74%
17	1.82	0.02	0.71	44.5622	18.80%
18	1.78	0.45	0.00	43.27198	15.36%
19	1.77	0.08	0.20	43.64372	16.35%
20	1.74	1.48	0.00	61.59063	64.20%
21	1.59	0.66	0.11	44.23435	17.93%
22	1.51	0.41	0.83	48.43145	29.12%
23	1.43	0.42	0.11	41.50503	10.65%
24	1.32	0.35	0.02	41.30607	10.12%
25	1.26	0.70	0.63	46.16281	23.07%
26	1.21	0.55	0.45	42.318	12.82%
27	1.15	0.40	0.35	41.1476	9.70%

Table 4- 8 Comparison of Calibrated delay with observed delay

SN	Avg Field Delay (Sec/veh)	Avg Calibrated Delay (Sec/veh)	MAPE
1	18.28	17.63	3.56%

Table 4- 9 Comparison of Calibrated Volume with observed Volume

Time Period (Sec)	Actual Volume	Simulated Volume	Percentage Error	MAPE
0-900	1748	1671	4.41%	2.07 %
900-1800	1841	1858	0.92%	
1800-2700	2133	2084	2.30%	
2700-3600	1872	1884	0.64%	

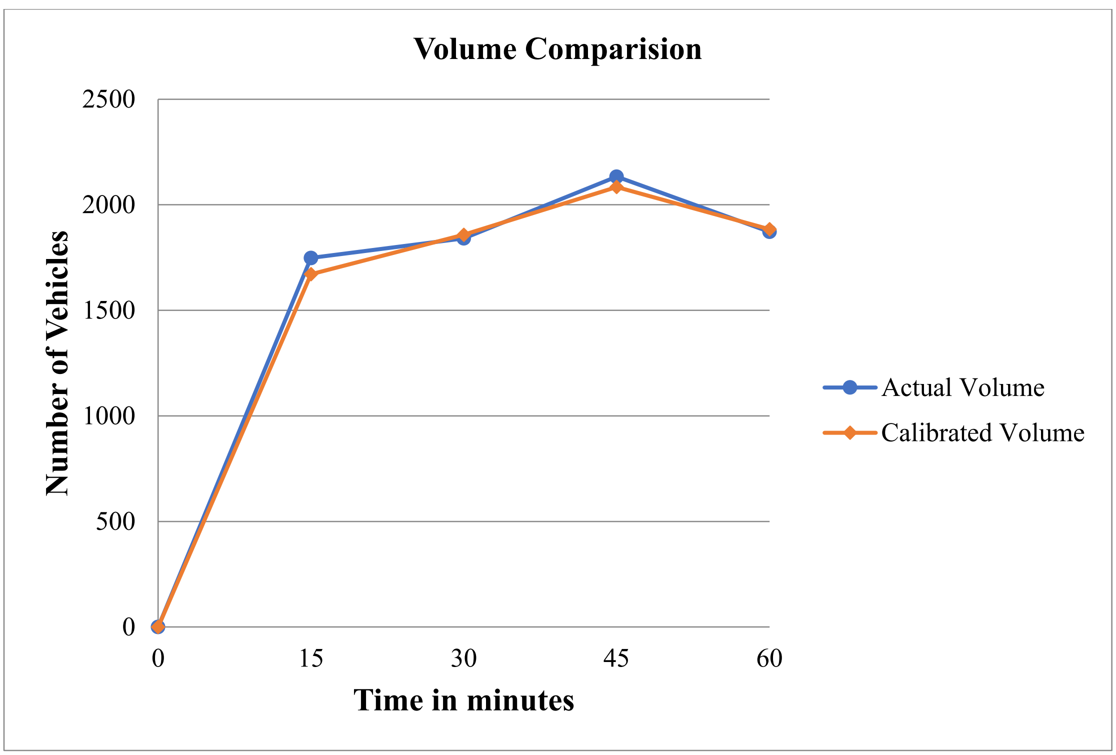

Figure 4- 5 Comparison of Field Volume with Calibrated Volume

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Following conclusion can be drawn from this study:

1. From this study it is observed that genetic algorithm can be used to calibrate car-following parameters in VISSIM to lower the error in simulation.
2. Off-peak traffic data recorded for an hour for two days was used to calibrate the model and peak traffic data recorded for an hour for one day was used to validate the model. Off-peak data can be used to calibrate the model.
3. Genetic algorithm provided optimal values for parameters quickly, however manual method was adopted for calibration which resulted to be time consuming.
4. Linear equation obtained for each parameter are intersection specific and can differ for other intersection.
5. The optimal values of widemann-74 car-following parameters average stand still distance (AX_still), additive part of safety distance(BX_add) and multiplicative part of safety distance(BX_mult) for Putalisadak intersection is 1.15 m, 0.4 and 0.35 respectively.

5.2 Recommendation

Following recommendations are put forward for further studies:

- Pedestrian Interaction with traffic is not considered in this study, which can be done for further study.
- One intersection is considered in this study; more intersection can be considered to obtain range of calibrated values.

- Automation can be done for optimization of parameters unlike manual method used in this study
- More MoEs can be considered for calibration of parameters.

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APPENDICES

APPENDIX A Classified Volume Count

Wednesday

Singhadurbar to Kamaladi

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck
17:00-17:15	349	104	10	1	0	0
17:15-17:30	386	101	7	1	0	0
17:30-17:45	469	115	9	1	0	0
17:45-18:00	336	87	9	1	0	0

Singhadurbar to Ratnapark

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck
17:00-17:15	62	12	3	1	0	0
17:15-17:30	65	10	5	1	0	0
17:30-17:45	69	9	3	1	0	0
17:45-18:00	61	19	4	1	0	0

Kamaladi to Singhadurbar

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck
17:00-17:15	400	114	2	0	0	0
17:15-17:30	441	95	3	1	0	0
17:30-17:45	565	110	3	5	0	0
17:45-18:00	398	76	2	0	0	0

Ratnapark to Kamaladi

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck
17:00-17:15	145	31	0	0	0	0
17:15-17:30	170	35	0	0	0	0
17:30-17:45	177	26	0	0	0	0
17:45-18:00	170	26	0	0	0	0

Dillibazar to Singhadurbar

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck
17:00-17:15	174	42	0	0	9	0
17:15-17:30	185	50	0	0	11	0
17:30-17:45	207	44	0	0	8	0
17:45-18:00	195	52	0	0	9	0

Dillibazar to Ratnapark

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck
17:00-17:15	128	24	16	0	1	0
17:15-17:30	125	22	12	0	0	0
17:30-17:45	124	21	11	0	2	0
17:45-18:00	172	24	13	0	4	0

Dillibazar to Kamaladi

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck
17:00-17:15	96	27	4	1	1	0
17:15-17:30	89	23	6	2	1	0
17:30-17:45	123	26	6	2	0	0
17:45-18:00	178	40	4	2	0	0

APPENDIX B Total Volume Count

Singhadurbar (Wednesday)

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck	PCU/hr
17:00-17:15	411	116	13	3	0	0	363.5
17:15-17:30	451	111	12	3	0	0	375.5
17:30-17:45	538	124	12	3	0	0	432
17:45-18:00	397	106	13	1	0	0	344.5
Total	**1797**	**457**	**50**	**10**	**0**	**0**	**1515.5**

Kamaladi (Wednesday)

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck	PCU/hr
17:00-17:15	400	114	2	0	0	0	320
17:15-17:30	441	95	3	1	0	0	325.5
17:30-17:45	565	110	3	5	0	0	406.5
17:45-18:00	398	76	2	0	0	0	281
Total	**1804**	**395**	**10**	**6**	**0**	**0**	**1333**

Ratnapark (Wednesday)

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck	PCU/hr
17:00-17:15	145	31	0	0	0	0	103.5
17:15-17:30	170	35	0	0	0	0	120
17:30-17:45	177	26	0	0	0	0	114.5
17:45-18:00	170	26	0	0	0	0	111
Total	**662**	**118**	**0**	**0**	**0**	**0**	**449**

Dillibazar (Wednesday)

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck	PCU/hr
17:00-17:15	398	93	20	1	11	0	364
17:15-17:30	399	95	18	2	12	0	362.5
17:30-17:45	454	91	17	2	10	0	381
17:45-18:00	545	116	17	2	10	0	451.5
Total	**1796**	**395**	**72**	**7**	**43**	**0**	**1559**

APPENDIX C Vehicle Composition

Total Traffic Volume of Intersection and their Percentage share (Monday)

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck	Total
01:00-01:15	1489	358	28	37	10	0	1922
01:15-01:30	1833	412	31	60	13	0	2349
01:30-01:45	1688	349	35	39	10	0	2121
01:45-02:00	1635	388	33	30	11	0	2097
Total	**6645**	**1507**	**127**	**166**	**44**	**0**	**8489**
Percentage	**78.28%**	**17.75%**	**1.50%**	**1.96%**	**0.52%**	**0.00%**	**100.00%**

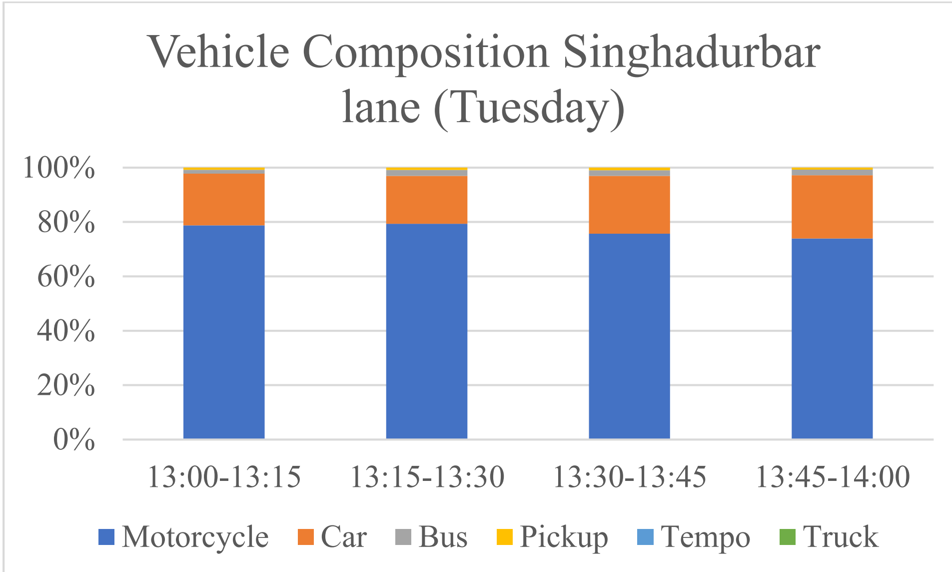
Total Traffic Volume of Intersection and their Percentage share (Tuesday)

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck	Total
01:00-01:15	1624	386	21	38	11	0	2080
01:15-01:30	1912	434	32	41	13	0	2432
01:30-01:45	1649	396	30	40	10	0	2125
01:45-02:00	1583	399	22	27	12	0	2043
Total	**6768**	**1615**	**105**	**146**	**46**	**0**	**8680**
Percentage	**77.97%**	**18.61%**	**1.21%**	**1.68%**	**0.53%**	**0.00%**	**100.00%**

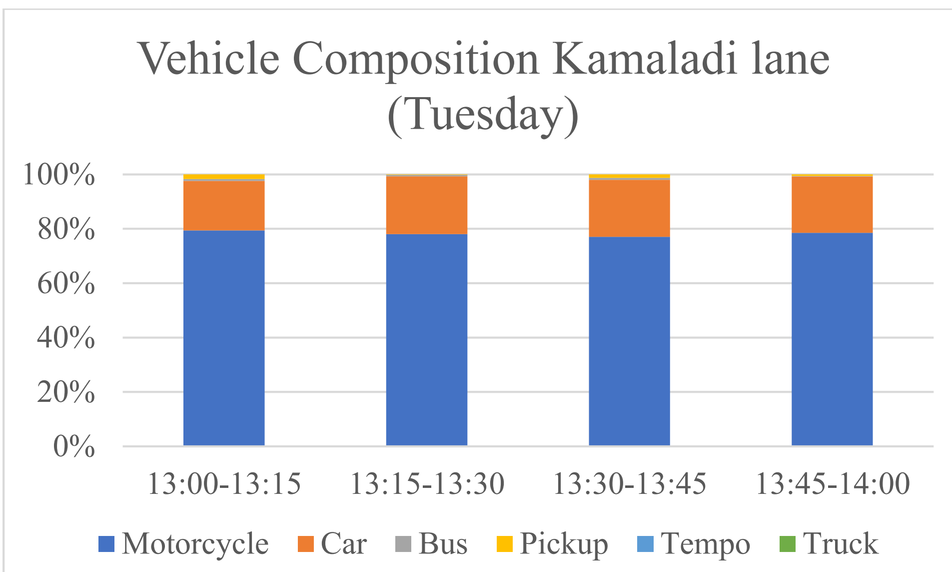
Total Traffic Volume of Intersection and their Percentage share (Wednesday)

Time	Motorcycle	Car	Bus	Pickup	Tempo	Truck	Total
01:00-01:15	1354	354	35	4	11	0	1758
01:15-01:30	1461	336	33	6	12	0	1848
01:30-01:45	1734	351	32	10	10	0	2137
01:45-02:00	1510	324	32	3	10	0	1879
Total	**6059**	**1365**	**132**	**23**	**43**	**0**	**7622**
Percentage	**79.49%**	**17.91%**	**1.73%**	**0.30%**	**0.56%**	**0.00%**	**100.00%**

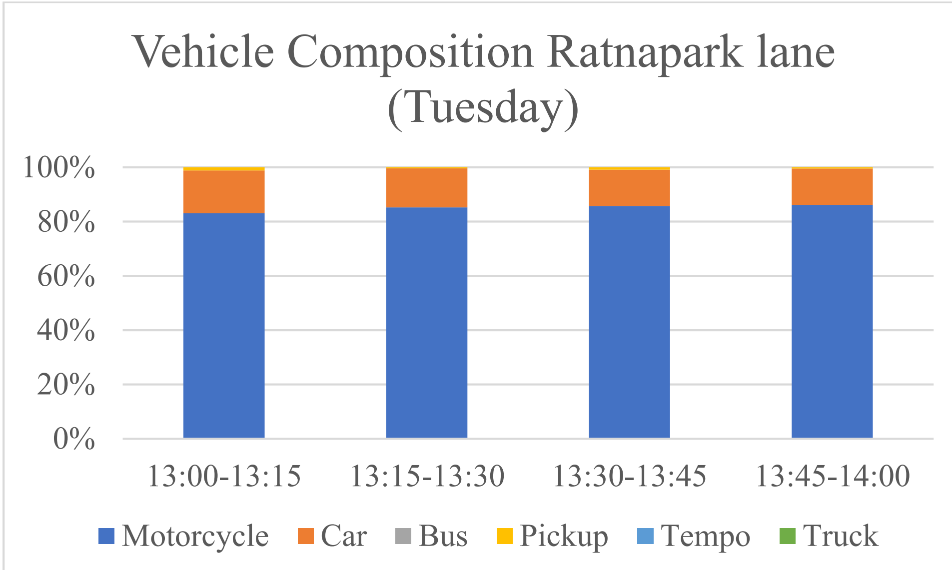
Vehicle Composition from Singhadurbar lane (Tuesday)



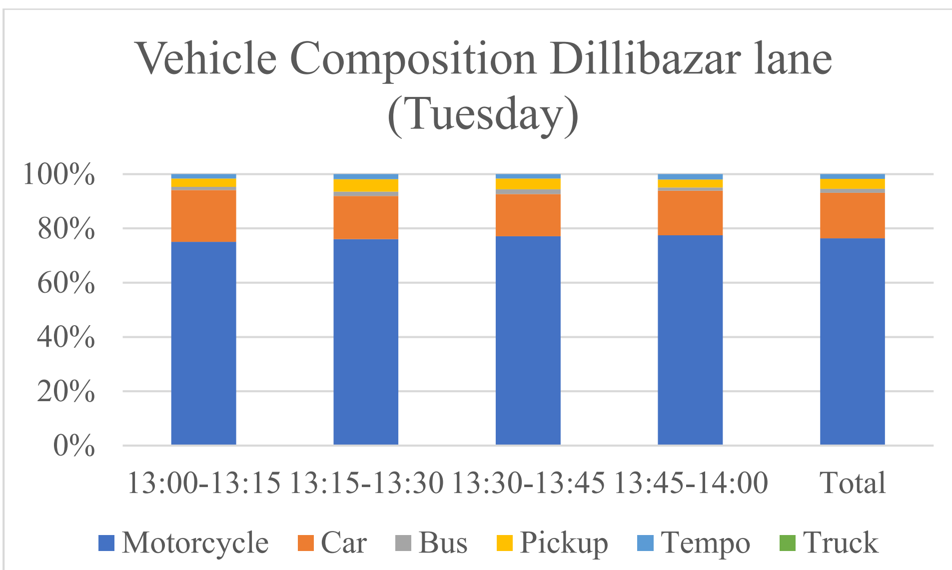
Vehicle Composition from Kamaladi lane (Tuesday)



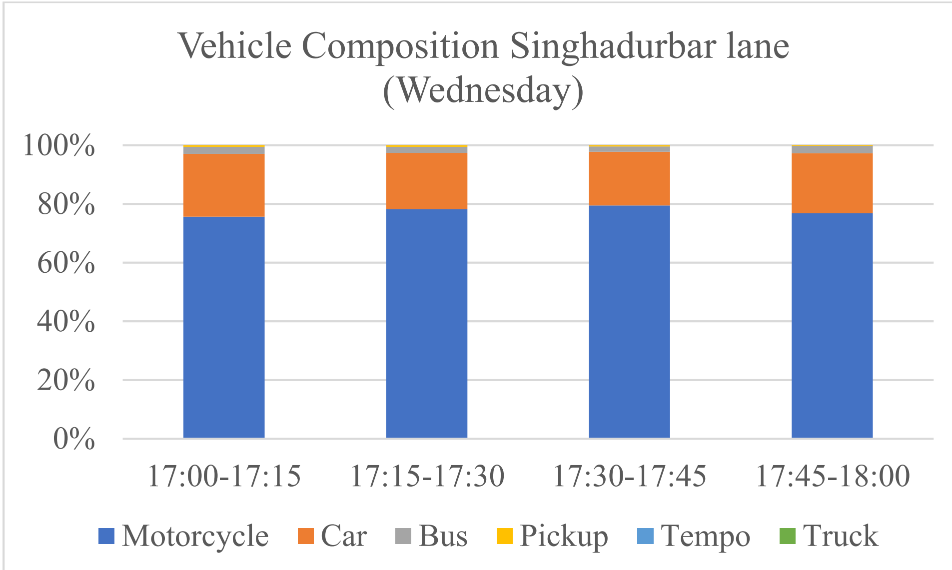
Vehicle Composition from Ratnapark lane (Tuesday)



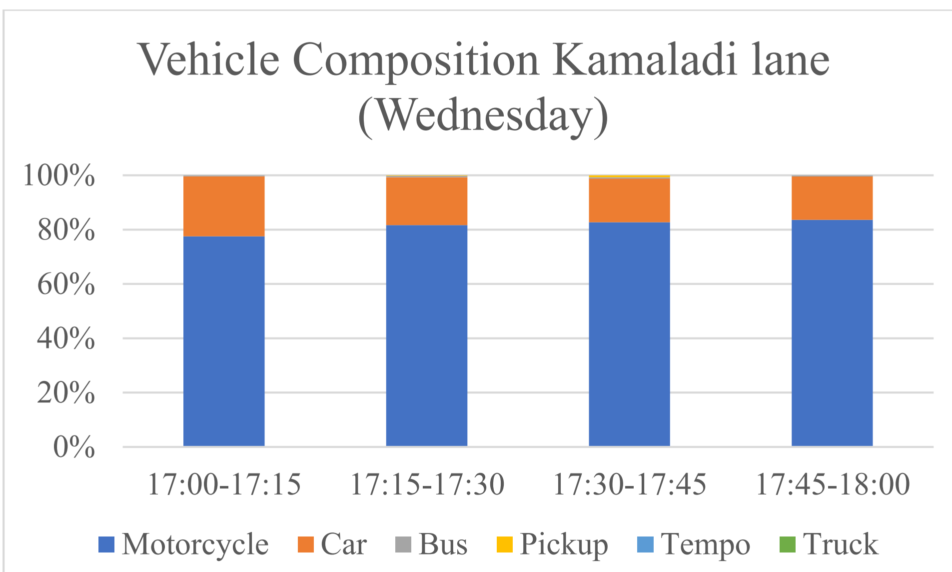
Vehicle Composition from Dillibazar lane (Tuesday)



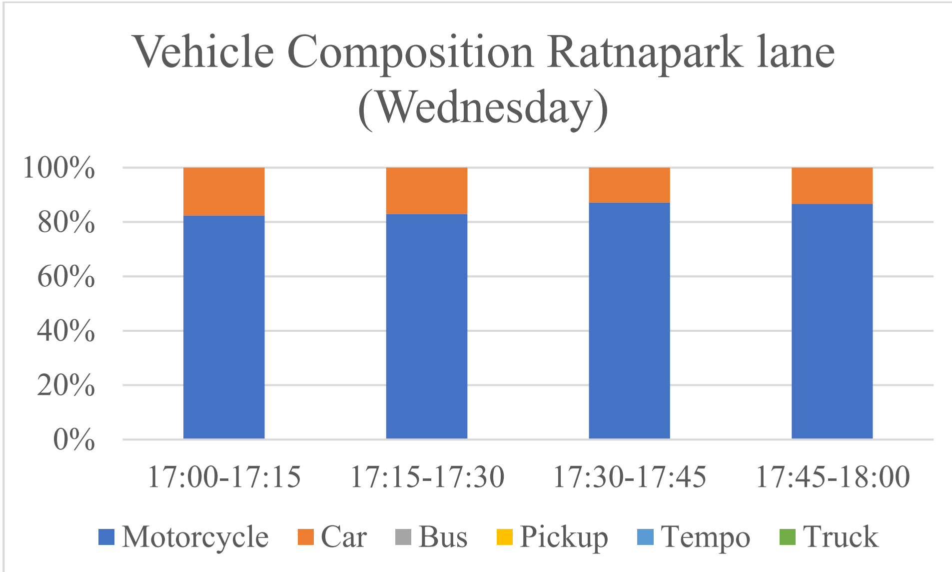
Vehicle Composition from Singhadurbar lane (Wednesday)



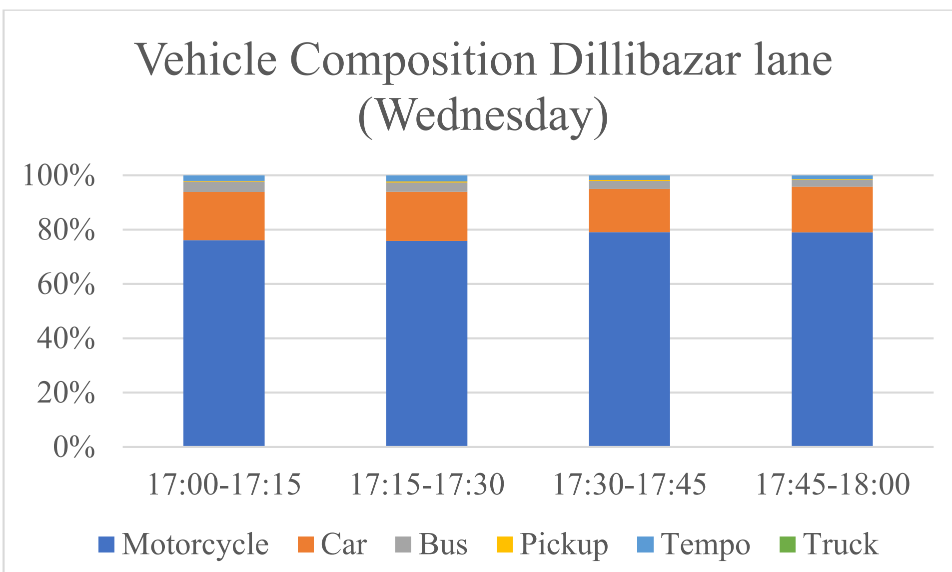
Vehicle Composition from Kamaladi lane (Wednesday)



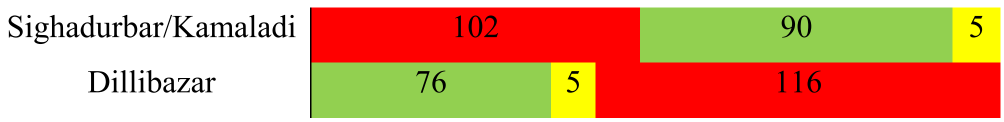
Vehicle Composition from Ratnapark lane (Wednesday)



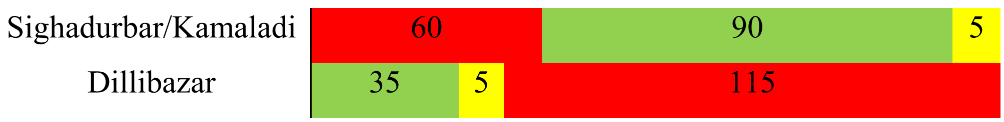
Vehicle Composition from Dillibazar lane (Wednesday)



APPENDIX D Signal Timing



For Monday and Tuesday (13:00 to 14:00)



For Wednesday (17:00 to 18:00)

APPENDIX E Latin Hypercube Sampling Plan

Latin Hypercube Sampling Plan (Sample)

S.N.	Look ahead distance (m)		Look Back distance (m)		Average Standstill distance (m)	Additive part of safety distance	Multiplicative part of safety distance	Min clearance front/rear (m)	Safety distance Reduction factor	Min lateral distance (m)	
	min	max	min	max						at 0 kmph	at 50 Kmph
1	10.21	111.61	6.72	117.05	1.96	2.38	3.22	0.73	0.34	0.66	0.49
2	26.04	124.40	21.32	103.71	0.53	0.93	2.73	0.39	0.52	0.13	0.57
3	19.23	106.45	18.45	118.41	0.29	0.75	2.36	0.70	0.68	0.59	0.04
4	22.47	132.49	19.24	89.53	2.04	1.21	1.02	0.62	0.44	0.34	0.69
5	13.72	130.31	16.73	85.40	1.51	0.73	2.94	0.70	0.63	0.32	0.94
6	19.70	137.41	14.34	93.75	0.05	2.50	1.30	0.76	0.55	0.09	0.10
7	23.24	119.45	11.86	98.33	2.42	1.16	2.48	0.34	0.60	0.11	0.42
8	29.97	127.33	18.05	101.17	1.27	0.67	3.65	0.44	0.62	0.54	0.31
9	17.87	134.42	7.50	95.36	1.31	1.10	3.14	0.80	0.33	0.19	1.00
10	11.60	122.23	8.34	109.81	1.45	1.79	3.75	0.58	0.41	0.49	0.67
11	10.47	114.59	6.16	83.89	1.93	0.85	3.87	0.75	0.56	0.84	0.24
12	21.00	139.53	23.56	98.85	2.24	0.38	3.09	0.49	0.50	0.67	0.18
13	25.45	102.88	23.79	93.32	0.96	2.25	0.02	0.28	0.70	0.60	0.60
14	22.31	116.39	8.11	94.82	0.21	1.50	0.14	0.56	0.58	0.89	0.75
15	16.99	138.80	13.18	84.33	1.83	0.84	0.55	0.37	0.53	0.72	0.81
16	29.08	118.68	17.63	108.68	0.85	0.56	0.76	0.50	0.43	0.53	0.78
17	19.17	115.41	11.18	90.48	2.12	0.53	0.19	0.63	0.40	0.87	0.18
18	29.57	109.36	19.96	87.49	0.89	1.32	1.51	0.54	0.65	0.04	0.60
19	11.17	136.73	15.21	80.67	2.07	1.13	1.24	0.52	0.49	0.17	0.90
20	13.44	109.74	12.61	91.55	0.48	1.95	2.43	0.48	0.63	0.97	0.12

APPENDIX F Delay Calculations

Cycle Number	Number of Vehicles in queue (Monday)													
	Count Interval													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	11	20	34	57	59	62	63	49	48	12	14	18	10	0
2	3	8	11	36	44	49	53	48	4	5	11	5	1	0
3	5	9	1	23	23	30	23	21	6	5	6	2	0	0
4	7	9	16	46	47	50	56	62	51	6	11	10	2	1
5	14	22	32	55	59	48	30	27	24	1	2	2	2	4
6	12	19	27	52	56	60	65	58	50	24	29	13	2	1
7	25	31	34	61	66	71	73	60	42	20	16	4	0	3
8	5	14	28	54	61	65	70	58	40	16	13	13	7	0
9	10	19	30	54	58	62	66	60	50	29	12	9	4	1
10	5	7	15	43	56	65	70	62	48	18	15	7	2	2
11	5	12	17	40	46	49	53	40	15	7	13	4	0	1
12	10	16	19	42	42	47	48	34	35	2	3	0	5	3
13	8	14	19	43	47	52	56	57	47	26	21	18	2	0
14	12	29	36	62	62	64	67	54	15	13	7	3	1	4
15	14	19	26	50	55	58	62	48	46	22	20	10	4	3
16	8	18	20	42	43	46	50	56	42	12	9	4	2	2
17	8	12	17	44	49	52	54	47	12	13	8	2	0	0
18	7	13	22	52	55	60	64	56	43	12	2	0	0	0
Sum	169	291	404	856	928	990	1023	897	618	243	212	124	44	25

Cycle Number	Number of Vehicles Stopped (Monday)													
	Count Interval													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	11	9	14	23	2	3	4	4	0	0	0	0	0	0
2	3	5	3	25	8	5	4	2	0	0	0	0	0	0
3	5	4	0	22	0	7	0	3	0	0	0	0	0	0
4	7	2	7	30	1	3	6	2	0	0	0	0	0	0
5	14	8	10	23	4	0	0	2	0	0	0	0	0	0
6	12	7	8	25	4	4	5	4	0	0	0	0	0	0
7	25	6	3	27	5	5	2	2	0	0	0	0	0	0
8	5	9	14	26	7	4	5	4	0	0	0	0	0	0
9	10	9	11	24	4	4	4	2	0	0	0	0	0	0
10	5	2	8	28	13	9	5	3	0	0	0	0	0	0
11	5	7	5	23	6	3	4	2	0	0	0	0	0	0
12	10	6	3	23	0	5	1	4	0	0	0	0	0	0
13	8	6	5	24	4	5	4	2	0	0	0	0	0	0
14	12	17	7	26	0	2	3	4	0	0	0	0	0	0
15	14	5	7	24	5	3	4	3	0	0	0	0	0	0
16	8	10	2	22	1	3	4	2	0	0	0	0	0	0
17	8	4	5	27	5	3	2	3	0	0	0	0	0	0
18	7	6	9	30	3	5	4	4	0	0	0	0	0	0
Sum	169	122	121	452	72	73	61	52	0	0	0	0	0	0

Total Vehicle in queue = 6824

Total vehicle travelling through = 2273

Total Vehicle stopped = 1122

Number of cycle = 18

Number of lane = 1

Interval = 14 secs

T_Q = 37.827

V_{SLC} = 62.33

FVS = 0.49362

Factor = -1 from table

Delay = T_{iq} + FVS*factor = 37.827 +0.49362*(-1) = 37.33 veh/sec

Cycle Number	Number of Vehicles in queue (Tuesday)													
	Count Interval													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	13	23	26	51	55	60	64	54	19	9	7	0	0	1
2	6	8	15	40	47	48	56	50	33	18	2	0	0	1
3	6	10	14	42	47	58	62	53	35	19	12	9	0	0
4	17	24	34	60	64	67	70	64	44	31	14	2	0	0
5	8	13	20	42	44	48	54	55	28	11	5	2	0	0
6	4	6	9	36	46	57	62	70	45	28	28	22	11	0
7	8	13	19	45	54	57	68	60	38	18	9	0	0	0
8	7	14	21	43	50	55	58	47	27	3	1	0	0	0
9	4	7	13	35	41	48	51	49	30	14	8	0	0	0
10	3	16	22	52	57	67	72	64	42	23	17	12	8	0
11	17	26	32	57	59	64	65	57	28	1	10	3	1	0
12	8	15	24	47	50	54	60	55	45	35	19	14	2	5
13	7	11	17	42	46	51	54	54	36	22	20	18	2	0
14	10	28	35	61	60	63	65	53	24	12	4	3	1	4
15	12	17	25	47	53	54	60	46	35	21	17	10	4	3
16	5	15	16	40	42	44	49	52	31	11	8	4	2	2
17	4	10	16	40	46	51	52	46	26	12	7	2	0	0
18	6	10	19	51	52	59	62	54	29	8	2	0	0	0
Sum	145	266	377	831	913	1005	1084	983	595	296	190	101	31	16

Cycle Number	Number of Vehicles Stopped(Tuesday)													
	Count Interval													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	13	10	3	25	4	5	4	4	0	0	0	0	0	1
2	6	2	7	25	7	1	8	9	0	0	0	0	0	1
3	6	4	4	28	5	11	4	4	0	4	0	0	0	0
4	17	7	10	26	4	3	3	2	0	0	0	0	0	0
5	8	5	7	22	2	4	6	2	0	0	0	0	0	0
6	4	2	3	27	10	11	5	8	6	0	0	0	0	0
7	8	5	6	26	9	3	11	0	0	0	0	0	0	0
8	7	7	7	22	7	5	3	0	0	0	0	0	0	0
9	4	3	6	22	6	7	3	3	0	0	0	0	0	0
10	3	13	6	30	5	10	5	3	0	0	0	1	0	0
11	17	9	6	25	2	5	1	2	0	0	3	0	1	0
12	8	7	9	23	3	4	6	2	0	0	0	0	2	0
13	7	4	6	25	4	5	3	1	0	0	0	0	0	0
14	10	18	7	26	0	3	2	3	0	0	0	0	0	0
15	12	5	8	22	6	1	6	2	0	0	0	0	0	0
16	5	10	1	24	2	2	5	2	0	0	0	0	0	0
17	4	6	6	24	6	5	1	3	0	0	0	0	0	0
18	6	4	9	32	1	7	3	3	0	0	0	0	0	0
Sum	145	121	111	454	83	92	79	53	6	4	3	1	3	2

Total Vehicle in queue = 6833

Total vehicle travelling through = 2255

Total Vehicle stopped = 1157

Number of cycle = 18

Number of lane = 1

Interval = 14 secs

$T_Q = 38.18$

$V_{SLC} = 64.2778$

FVS = 0.51308

Factor = -1 from table

Delay = T_Q + FVS*factor = 38.18 +0.51308*(-1) = 37.6669 veh/sec

Cycle Number	Number of Vehicles in queue (Wednesday)										
	Count Interval										
	1	2	3	4	5	6	7	8	9	10	11
1	7	8	12	13	16	5	0	0	3	4	0
2	8	13	15	20	20	7	3	0	0	2	2
3	7	15	21	25	22	6	8	2	1	0	1
4	8	12	22	29	32	18	4	0	0	0	2
5	18	21	29	33	35	19	6	1	2	5	3
6	12	20	22	25	22	13	1	2	0	0	0
7	2	4	6	14	16	4	1	3	2	0	1
8	11	12	12	13	13	3	3	0	0	0	0
9	3	15	26	31	25	14	5	2	0	0	0
10	21	31	38	46	39	19	12	4	0	0	0
11	8	19	31	37	27	19	17	12	0	0	0
12	7	28	38	47	38	29	15	6	1	0	1
13	14	25	33	38	21	8	4	0	2	2	0
14	5	17	18	22	13	2	0	0	0	1	0
15	16	21	22	30	21	8	1	3	0	0	0
16	6	12	24	38	23	13	6	1	0	2	0
17	9	14	21	31	20	1	0	0	0	0	0
18	5	10	30	46	27	15	2	0	0	0	0
19	10	20	37	48	29	12	8	0	0	0	0
20	11	16	33	42	31	20	2	0	0	0	0
21	4	12	31	35	28	13	5	0	0	0	0
22	9	18	33	47	32	16	4	0	1	1	0
23	3	13	32	42	25	10	0	0	0	1	0
Sum	204	376	586	752	575	274	107	36	12	18	10

Cycle Number	Number of Vehicles Stopped (Wednesday)										
	Count Interval										
	1	2	3	4	5	6	7	8	9	10	11
1	7	1	4	1	3	0	0	0	0	2	0
2	8	5	2	5	2	0	0	0	0	0	1
3	7	8	6	4	6	0	0	0	0	0	1
4	8	4	10	7	3	0	0	0	0	0	2
5	18	3	7	4	2	0	0	0	0	0	2
6	12	8	2	3	1	0	0	0	0	0	0
7	2	2	2	8	3	0	0	0	0	0	1
8	11	1	0	1	0	0	2	0	0	0	0
9	3	12	11	5	4	2	0	2	0	0	0
10	21	10	7	8	4	0	0	0	0	0	0
11	8	11	12	6	3	2	0	0	0	0	0
12	7	21	10	9	4	0	0	0	0	0	1
13	14	11	8	5	5	0	0	0	0	0	0
14	5	12	1	4	1	0	0	0	0	0	0
15	16	5	1	6	0	2	0	0	0	0	0
16	6	6	12	14	8	3	0	0	0	2	0
17	9	5	7	10	2	0	0	0	0	0	0
18	5	5	20	16	4	1	0	0	0	0	0
19	10	10	17	11	3	0	0	0	0	0	0
20	11	5	17	9	5	3	0	0	0	0	0
21	4	8	19	4	4	0	0	0	0	0	0
22	9	9	15	14	6	0	0	0	0	0	0
23	3	10	19	10	5	0	0	0	0	0	0
Sum	204	172	209	164	78	13	2	2	0	4	8

Total Vehicle in queue = 2950

Total vehicle travelling through = 1986

Total Vehicle stopped = 856

Number of cycle = 23

Number of lane = 1

Interval = 14 secs

T_Q = 18.72

V_{SLC} = 37.22

FVS = 0.43

Factor = -1 from table

Delay = T_Q + FVS*factor = 18.72 + 0.43*(-1) = 18.28 veh/sec

APPENDIX G MATLAB Code for LHS

```
function [X_scaled,X_normalized]=lhsdesign_modified(n,min_ranges_p,max_ranges_p)

p=length(min_ranges_p);

[M,N]=size(min_ranges_p);

if M<N

   min_ranges_p=min_ranges_p';

end

[M,N]=size(max_ranges_p);

if M<N

   max_ranges_p=max_ranges_p';

end

slope=max_ranges_p-min_ranges_p;

offset=min_ranges_p;

SLOPE=ones(n,p);

OFFSET=ones(n,p);

for i=1:p

   SLOPE(:,i)=ones(n,1).*slope(i);

   OFFSET(:,i)=ones(n,1).*offset(i);

end

X_normalized = lhsdesign(n,p);


X_scaled=SLOPE.*X_normalized+OFFSET;
```

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Date: November 26, 2023

To Whom It May Concern:

This is to certify that the paper titled "***Calibration of Car-following Parameters in VISSIM for Traffic in Kathmandu***" (Submission# **745**) submitted by **Anmol Chhetri** as the first author has been accepted after the peer-review process for presentation in the 14th IOE Graduate Conference being held during Nov 29 to Dec 1, 2023. Kindly note that the publication of the conference proceedings is still underway and hence inclusion of the accepted manuscript in the conference proceedings is contingent upon the author's presence for presentation during the conference and timely response to further edits during the publication process.

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