PAPER • OPEN ACCESS

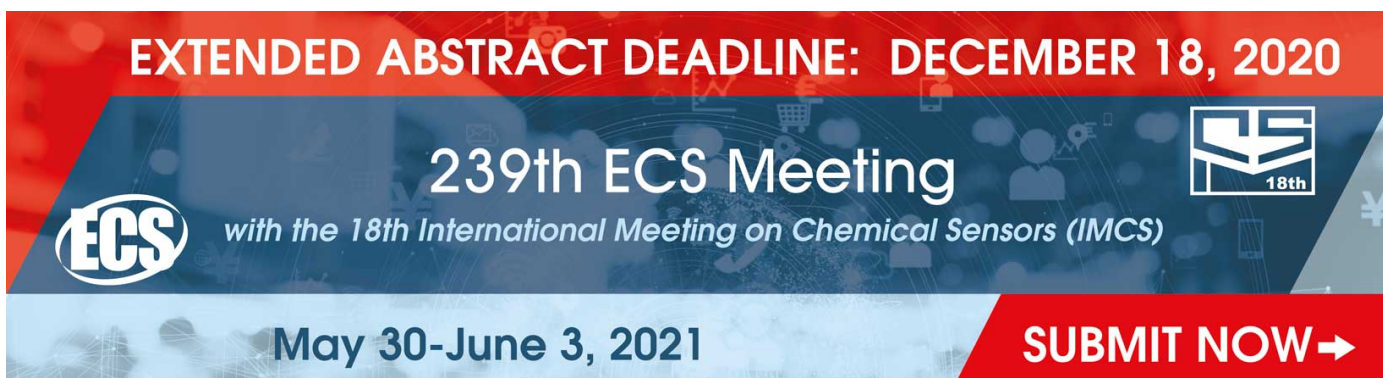# Calibration of microsimulation model for tight urban diamond interchange under heterogeneous traffic

To cite this article: M. Azam *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **527** 012077

View the article online for updates and enhancements.

Calibration of microsimulation model for tight urban diamond interchange under heterogeneous traffic

M. Azam[1], O. C. Puan*[1], S. A. Hassan[1], and N. Mashros[1]

[1]School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor Bahru, Johor, Malaysia

*Corresponding author e-mail: othmancp@utm.my

Abstract. Traffic simulation models have been widely used to evaluate design alternatives and to help decision-makers to select best design option for prevailing traffic conditions. This study focuses on application of microsimulation model to the performance assessment of Tight Urban Diamond Interchange (TUDI) located in a congested urban setting with population more than 9 million and current transport demand up to 13.5 million daily motorized trips. Geometric and operational data was collected by conducting multiple site visits. Traffic volume data showed the heterogeneous nature of traffic. Microsimulation model; VISSIM was applied and appropriateness of this model and the proposed methodology was assessed based on maximum queue length as Measure of Effectiveness (MOE). Calibration of model was done in two stages: system calibration and operational calibration. System calibration was done by reflecting the actual geometric and control conditions in model. While operational calibration was done by conducting Sensitivity Analysis (SA). MOE values from calibrated model were compared with the field values of maximum queue length. This study revealed that SA helps in selecting the most appropriate parameters and their values. Results from VISSIM show the cumulative difference of 32 % from the field observed values.

1. Introduction

Roads Simulation modelling is becoming an effective tool to analyse various transportation problems in an economical manner [1]. A traffic simulation model is any model which attempts to represent or mirror actual traffic behaviour [2]. Traffic simulation models have been widely used by the stakeholders and professionals to evaluate the design alternatives of different facilities including intersections, interchanges and corridors. The main reason of their frequent use is that with simulations one can get results faster, safer, and in an economical manner than actual ground field implementation and testing [3].

Evaluation of different simulation packages and their ability to adequately simulate various test networks and transportation system configurations started in the 1990s [4]. Traffic simulators have been frequently used for planning and designing transportation networks. With wider applications, it is necessary that the model reflects the actual field conditions. A traffic simulator can describe the actual field conditions if it is supported by a valid traffic model, and it is appropriately calibrated [5].

VISSIM, a microscopic, time step and behaviour-based simulation model developed by PTV AG from Germany has widespread applications in analysing urban and inter-urban traffic and also capable of modelling public transport and pedestrians [6]. Due to wider applications, the software has been upgraded to cater for various traffic networks, control types and driving behaviours. This advancement

has given rise to complexity in calibration process due to increase in parameters. To efficiently calibrate the model, several innovate techniques has been tested. Sensitivity analysis (SA) is one of the approaches that have been widely used for calibrating simulation models.

SA describes the dependency of analysis outcome on the parameter assumption by investigating the relationship between parameters and outputs of a simulation model [7]. Microsimulation models usually offer large number of calibration parameters and due to limitation of temporal, human and financial resources, all the parameters cannot be calibrated. To formulate that which parameter should be calibrated is difficult due to unavailability of formal procedure. Few examples on the application of SA in VISSIM calibration are in literature. Lownes and Machemehl [8] applied One-At-a-Time (OAT) method and investigated the impact of individual parameter on simulation capacity of stretch of highway. Ciuffo and Lima Azevedo [9] introduced multistep global SA in which they grouped the calibrated parameters following the same sub-models or same physical and conducting SA based on groups rather than individual parameter.

Several studies conducted to evaluate the suitability of certain traffic simulation model for specific geometric and control conditions. Shafiee *et al.* [10] indicated that microscopic traffic simulators such as AIMSUM, PARAMICS and VISSIM have been widely used as an analysis tool in transportation design as well as assessment. Kaseko [11] used three simulation tools including CORSIM, VISSIM and SIMTRAFFIC for arterial simulations and concluded that network development process is more complex with VISSIM than other two tools. They found that all three software can perform well for various operational conditions. In another study conducted by Sun *et al.* [12] simulation performance of VISSIM and CORSIM on urban street network were compared and it was found that for large intersections and high throughput traffic VISSIM is more appropriate than CORSIM but for network editing and signal configuration CORSIM is preferable.

SA has been adopted for various geometric conditions and under different control and traffic mix. This study focuses on checking applicability of SA procedure for TUDI under heterogeneous traffic and fixed signal control.

Diamond interchange is one out of the structures which are constructed along an urban arterial for grade-separation. Diamond interchange results in two or more closely spaced surface intersections and has three configurations based on the spacing between intersections. Tight urban diamond interchange has least spacing between two intersections among all categories of diamond interchange featuring less than 120 m [13]. Several studies have been conducted regarding VISSIM calibration but their focus was on a single intersection or few intersections along a corridor. This study attempts to evaluate the effectiveness of SA in calibration of TUDI under heterogeneous traffic.

1.1. The study site
Selected study site fulfils the geometric, operational and control requirements of this study. The study site referred to as Waris Mir Underpass is a Tight Urban Diamond Interchange (TUDI) having distance between two intersections around 80 m. The study area along with detail of selected corridor is shown in Figure 1.
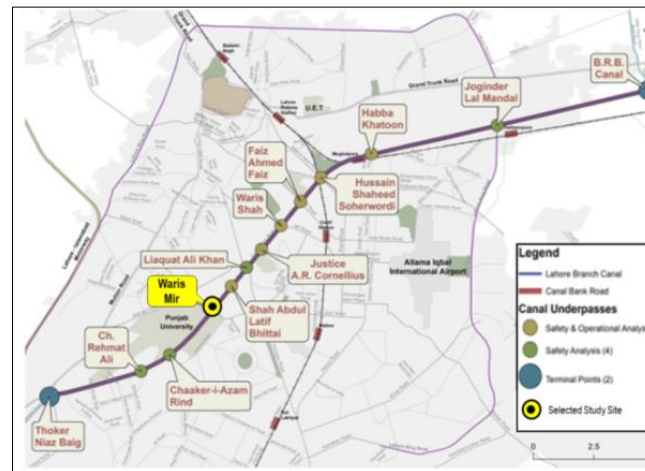
Figure 1. Study area and selected interchange location.

The study site is located in Lahore which is the provincial capital of Punjab. The city has a population of about 9 million people with a growth rate of 3.32% per annum. Current transport demand in the city adds up to 13.5 million daily motorized trips [15]. Total numbers of registered vehicles in the city are 3.392 million in recent past [16]. The study area shows the heterogeneous nature of the traffic mix with motorcycles and cars having more in numbers than other vehicle classes.

1.2. Simulation model
VISSIM, a microscopic and stochastic simulation model, was chosen in this study for evaluation of the proposed procedure. It was developed by Planning Transport Verkher (PTV), a German company. It is one of the finest microsimulation models available and provides diversity in selection of driver behaviour, transit operations, effective interface with planning models and visualization of strategy by 3D simulation [17]. VISSIM is capable of simulating traffic operations on urban streets and freeways, with a special emphasis on public transportation and multimodal transportation [6]. VISSIM works on the basis of two different programs: the traffic simulator and the signal state generator. The traffic simulator being a microscopic simulation model provides simulation environment by applying car-following and lane-changing logics.

2. Methodology
The proposed methodology of this study comprises of the seven major steps including: simulation model setup, data collection, simulation model development, model calibration by using sensitivity analysis and model validation, analysis and results and conclusions. These steps are explained in subsections.

2.1. Simulation model setup
This step consists of the steps which were conducted before the data collection and model development. This involves defining scope and objectives of this study along with selection of site and MOE.

2.2. Data collection
Two types of data were collected from field: 1) geometric data and 2) operational data. Geometric data refers to the data related to number and width of lanes for each approach, turning configuration, interchange configuration, channelization, and length and number of storage lanes. These characteristics were collected by conducting multiple site surveys. Visual observations and field observations were done to collect all the required characteristics from field. This data was necessary to model the physical components of the site. Operational data collected from filed is related to traffic volumes, control type, signal timing and phasing and speed data. Traffic volume data was collected by considering all possible vehicular classes from bicycle to animal driven carts and was collected for each individual movement.

Control type at the selected site was pre-timed signal control with three phase overlapped operation with a cycle length of 110 s. Speed data was collected by using floating car method in which a car was driven along the known stretch of road averaging the travel speed of the traffic. This was done by making sure that the number of vehicles which overtook the observer's vehicle was assured to be equal to the number of vehicles which were overtaken by the observer's vehicle.

Queue length data was important to collect because of selected MOE. This data was collected by counting the maximum number of cars completely stopped in a lane on all approaches and by multiplying these counted numbers of vehicles with 6 m to get the maximum queue length as specified by [18]. Data on saturation flow rate was also collected from field. The saturation flow rate represents the maximum rate of flow in a traffic lane, as measured at the stop line during the green indication. It was measured by adopting Highway Capacity Manual (HCM) methodology. The time which elapsed between the front of fourth vehicle and the last vehicle in queue passes the stop bar is calculated [13].

2.3. Simulation model development
Several steps were done to develop a model ready for output as per requirements of this study. Model was developed by using VISSIM and based on the geometric and operational data collected from filed, initially links were drawn and connectors were used to join those links to formulate network. Physique of network was completed by reflecting the geometric data. After drawing links, the next step was to define vehicle composition as per field conditions and as depicted by the traffic volume data. Vehicle classes were defined for each approach and these were assigned to specific approach. Individual movement from an approach was allotted by vehicle routing. Total approach volume was used at the start of link and relative flows for each movement from an approach were assigned based on vehicle routes. Next step was to define signal control which was done by forming signal groups. Signal heads were placed at each lane and signal groups were assigned to each individual signal head. After completing assignment of signal control, the next task was to run simulations to get output based on data collection points and defined queue counters.

2.4. Model calibration
Calibration is the process of determining appropriate parameters such that simulation model can represent field traffic condition [19]. Calibration is done to make sure that the actual field conditions are simulated in model. VISSIM offers a number of parameters to replicate the traffic flow characteristics, traffic control operations and driver behaviour. VISSIM contains the default parameter values which can be adjusted within the range given by the manual. Unfortunately, there is a little knowledge about the appropriateness of parameters and their values for certain geometric and control conditions. User has to adopt suitable methodology to find the most appropriate parameter and its value which affect the output significantly. For this purpose, SA was done for selection of calibration parameters and output results were compared with the field results. Calibration was done in the following five steps:
  i.   Initial Evaluation
  ii. Experimental Design
  iii. Parameter Adjustments
  iv. Final Calibration
  v.   Model Validation

2.4.1. Initial evaluation. In this step, multiple simulation runs were made with default parameter values and output as obtained and compared with the field measurements (MOE value). Output data was plotted in the form of histograms to check whether the simulation results are comparable with the field measurement. If close match is found, then calibration can be stopped here and default parameters are used for further analysis. Results obtained from 100 simulation runs were performed and it was found that output values are not matching with field MOE value as model is giving higher values of maximum queue length than field observed. So, further calibration of parameters was required to find better simulation results.

2.4.2. Experimental design. This step involved the identification of all calibration parameters which were applicable to the site geometric class. Parameters were categorized based on their effect on the longitudinal or lateral performance and ranges of their values were defined based on VISSIM user manual and literature. Parameters showing less or no effect on output result were excluded from this study. Initially, 3 parameters that showed significant effect on output were identified and for each parameter 5 different scenarios were executed by varying its value. For each scenario, with changing value of one parameter all other parameters were kept at their default values. From this a total of 35 scenarios were run. Table 1 shows the identified parameters and their ranges. Sensitivity of output results against each parameter with variable values was checked and cumulative percentage value was calculated for field and model result.

Table 1. Calibration parameters and ranges of their values.

Sr. No.	Parameter	Range of values	Variable Values for Calibration				
1	Average standstill distance	1 - 3 m	1	1.5	2	2.5	3
2	Additive part of safety distance	0.3 - 1.15 m	0.3	0.5	0.75	1	1.15
3	Multiplicative Part of safety distance	0.6 - 1.45 m	0.5	0.75	1	1.25	1.5

Table 2 shows the cumulative percentage difference for field and model values against each tested value of calibration parameter as given in Table 1.

Table 2. Cumulative percentage difference for field and model values against different parameter values.

Range of Calibration Parameters	Calibration Parameters			Queue Length (m)				Cumulative % Difference
	P1	P2	P3	NB	SB	EB	WB	
	Field Observed			84	90	84	96	
	From Default Parameters			0.25	0.05	0.06	0.16	52%
1 - 3 m	1.00	*	*	0.11	0.14	0.04	0.06	35%
	1.50	*	*	0.16	0.03	0.16	0.01	36%
	2.00	*	*	0.25	0.05	0.06	0.16	52%
	2.50	*	*	0.76	0.16	0.32	0.51	175%
	3.00	*	*	1.18	1.26	0.18	1.07	368%
0.3 - 1.15 m	*	0.30	*	0.16	0.55	0.18	0.09	97%
	*	0.50	*	0.07	0.03	0.15	0.12	37%
	*	0.75	*	0.09	0.13	0.11	0.06	39%
	*	1.00	*	0.19	0.09	0.23	0.02	53%
	*	1.15	*	0.13	0.18	0.21	0.05	58%
0.6 - 1.45 m	*	*	0.50	0.26	0.18	0.29	0.10	83%
	*	*	0.75	0.01	0.10	0.17	0.08	37%
	*	*	1.00	0.12	0.01	0.06	0.05	24%
	*	*	1.25	0.06	0.16	0.10	0.06	38%
	*	*	1.50	0.21	0.23	0.37	0.07	88%

2.4.3. Parameter adjustments. Parameter values which showed smaller values of cumulative percentage difference were again broken down into smaller intervals to get better matching of simulation results with field. Results obtained are shown in Table 3 where it can be seen that a minimum cumulative percentage difference value is achieved by a combination of values from three parameters. A good

combination of parameter values showing best match to field values were selected and was endorsed for final calibration step.

Table 3. Cumulative percentage difference of model for all combinations of different values of selected parameters.

Average standstill distance (P1)	Additive part of safety distance (P2)	Maximum Queue Length (Cumulative % Difference) Multiplicative Part of safety distance (P3)											
		NB	SB	EB	WB	NB	SB	EB	WB	NB	SB	EB	WB
		1.00				1.15				1.25			
0.75 m	0.5 m	5%	19%	7%	16%	6%	17%	7%	12%	9%	22%	5%	15%
			46%				43%				51%		
	0.6 m	3%	16%	1%	10%	17%	21%	18%	9%	14%	15%	13%	16%
			29%				%65				58%		
	0.75 m	2%	19%	3%	1%	7%	21%	5%	8%	10%	21%	7%	12%
			25%				41%				50%		
1.00 m	0.5 m	15%	17%	11%	1%	13%	19%	2%	5%	7%	17%	7%	5%
			44%				39%				36%		
	0.6 m	5%	13%	10%	0%	15%	14%	8%	6%	16%	17%	9%	3%
			29%				43%				45%		
	0.75 m	12%	18%	7%	6%	15%	20%	16%	1%	12%	21%	0%	3%
			43%				53%				36%		
1.25 m	0.5 m	15%	15%	5%	15%	13%	13%	1%	6%	12%	12%	10%	4%
			50%				33%				38%		
	0.6 m	15%	14%	10%	6%	22%	9%	2%	6%	13%	10%	3%	1%
			44%				40%				27%		
	0.75 m	11%	17%	15%	4%	15%	13%	13%	5%	8%	8%	4%	0%
			48%				46%				20%		
1.35 m	0.5 m	11%	11%	6%	10%	19%	7%	11%	3%	17%	11%	8%	3%
			39%				40%				38%		
	0.6 m	9%	11%	18%	2%	14%	13%	33%	11%	14%	12%	13%	23%
			41%				70%				62%		
	0.75 m	19%	10%	6%	15%	21%	10%	24%	1%	17%	10%	8%	5%
			50%				56%				39%		

From the Table 3 it can be seen that the minimum cumulative percentage difference is observed with the values of selected parameters as given in Table 4.

Table 4. Final parameter and their values.

Sr. No.		Selected Parameters	Value
1	P1	Average standstill distance	1.25 m
2	P2	Additive part of safety distance	0.75 m
3	P3	Multiplicative Part of safety distance	1.25 m

SA was also performed for lane change parameters with their variable values but no significant effect on output was observed. So, lane change parameters were excluded.

2.4.4. Final calibration. Set of parameter values obtained from previous step was used in model and multiple runs were made to check the consistency of results. During this step actual traffic volumes, control and geometric conditions were used with a set of selected calibration parameters. This step provides the final output to be compared with the field values. Cumulative percentage difference from calibrated model and filed were obtained and are discussed in later section.

2.4.5. Model validation. Calibrated models were used with another data set for same site but for different time duration and results were compared with the field observed MOE value for the same time period.

3. Results and discussion

Initially, model was calibrated and results were compared with field values. With a cumulative percentage difference of 32% this calibrated model was used for validation with same selected set of parameters and their values. A histogram comparing output results from calibrated model and from field is shown in Figure 2. Figure 3 shows the cumulative percentage difference value for individual approach as well as cumulative for all approaches.
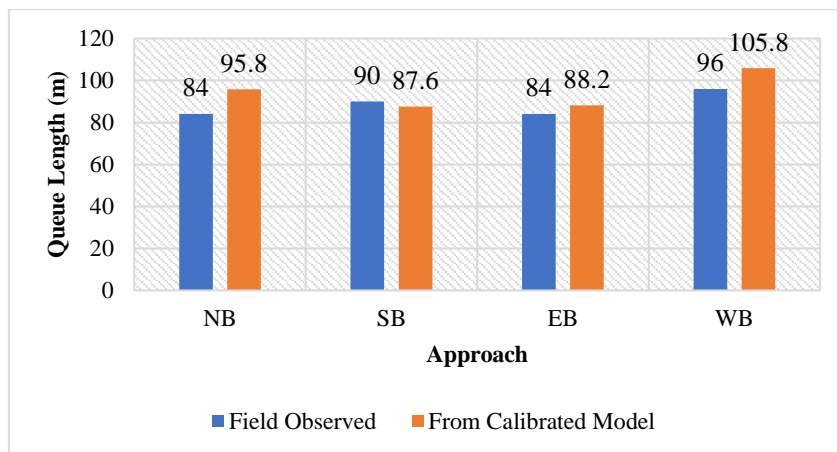

Figure 2. Maximum queue length values from field and from calibrated model for calibration.
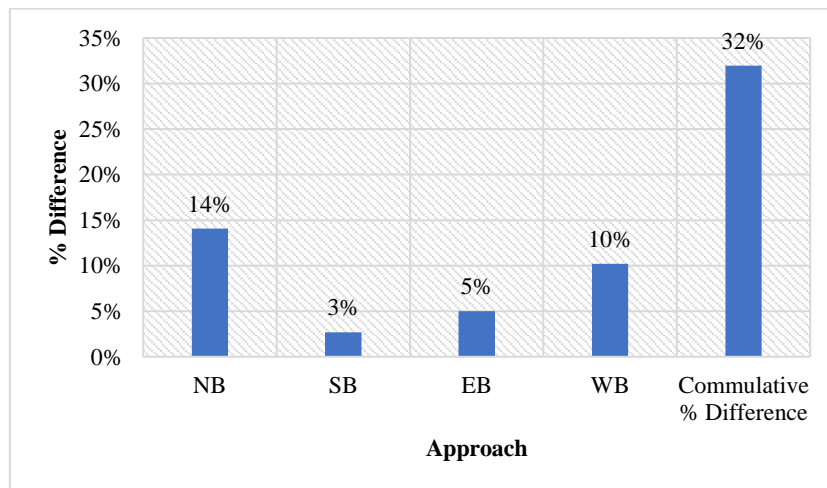

Figure 3. Cumulative percentage difference for field and calibrated model values for validation.

From the Figures 2 and 3 it is obvious that VISSIM is giving greater values for queue length and this difference is consistent for all approaches except SB where a slight lower value is observed. A cumulative percentage difference of 32% is observed for all approaches with NB bearing the highest value of 14%.

Validation of model also gives comparable results. Validations results for maximum queue length are shown is Figure 4 and cumulative percentage difference values for all approaches in Figure 5.
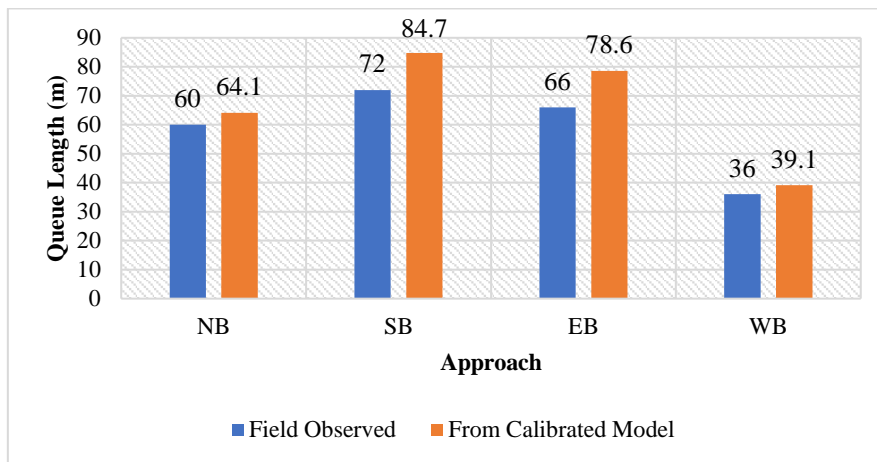
Figure 4. Maximum queue length values from field and from calibrated model for validation.
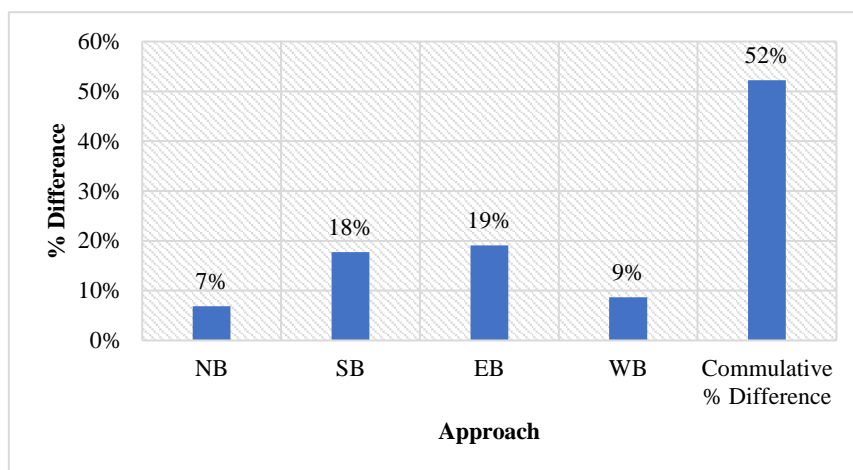

Figure 5. Cumulative percentage difference for field and calibrated model values for validation.

Validation results endorse the results obtained for calibration and depict same trend by showing greater queue length values for model. Difference for values is higher bearing a total of 52% with higher value for SB and EB. Least cumulative percentage difference among all approaches is observed for NB.

Due to constrained finance and shorter span for data collection, actual conditions cannot be modelled in a perfect way and difference in value can be due to various reasons including;

- Different time of data collection and observations as data which have been used for analysis purpose was collected in 2010 and used for analysis in 2018.
- Growth rate used for data extrapolation is taken from some literature and may be the economic and other conditions in the city are different than the assumed in 2012.
- Pattern of traffic changes based on attraction and generation points in the vicinity. This is the reason that some approaches are showing much higher values than calibrated results while other are showing lower.
- Data having a certain accuracy level was difficult to collect from filed due to lack of human, financial and temporal resources to collect the data related to driver behaviour more efficiently.

- Models are showing greater values of queue length for some approaches and this difference is mainly due to driving behaviour which could not be modelled efficiently. Certain slots and breakage of medians used by the motorcyclists cannot be modelled because of much variable geometry and unpredictable behaviour of drivers.
- VISSIM with its most aggressive class of drivers still have some gaps and puts one vehicle (car) in one lane at a time but in actual conditions two motorcycles are in the same lane or sometimes staying on lane marking between two cars.
- The unpredictable and aggressive behaviour of local drivers limits the effective application of VISSIM model for such conditions.

4. Concluding remarks

Based on the procedure of model development, efficiencies in modelling and results obtained from model under defined traffic, control and geometric conditions, following conclusions can be drawn:

- VISSIM can model actual traffic conditions for a TUDI in urban setting under heterogeneous traffic.
- Results from calibrated VISSIM are closer to the actual field observed values. It gives a percentage cumulative difference of 32% from field observed.
- Some driving behaviours and vehicle positions are difficult to accurately model
- Network development process is complex and takes enormous time.
- Field observed vehicle composition can be efficiently modelled in VISSIM.
- If accurate data on vehicular mix and driver behaviour is obtained from filed, then this model can be modelled with much better and comparable results.
- With limited resources, VISSIM reflects the traffic conditions in a way closer to the actual field patterns.

5. References

[1]   Ahmed S A, 2005 Calibration of VISSIM to the traffic conditions of Khobar and Dammam, Saudi Arabia *Doctoral dissertation* KFUPM
[2]   Taplin J, 1999 Simulation models of traffic flow In *The 34 th Annual Conference of the Operational Research Society of New Zealand*
[3]   Shaaban K S and Radwan E, 2005 A calibration and validation procedure for microscopic simulation model: a case study of Simtraffic for arterial streets In *Proceedings of the 84th TRB Annual Meeting* 1-17
[4]   Jones S L, Sullivan A J, Cheekoti N, Anderson M D, and Malave D, 2004 Traffic simulation software comparison study *UTCA report* **2217**
[5]   Ge Q, and Menendez M 2012 Sensitivity Analysis for Calibrating VISSIM in Modeling the Zurich Network *12th Swiss Transport Research Conference* **19**
[6]   PTV-Vision, 2011 VISSIM 5.30-05 user manual
[7]   Norton J 2015 An introduction to sensitivity assessment of simulation models *Environmental Modelling and Software* **69** 166–174
[8]   Lownes N E, and Machemehl R B 2006 VISSIM: a multi-parameter sensitivity analysis In *Proceedings of the 2006 Winter Simulation Conference* 1406-1413
[9]   Ciuffo B, and Azevedo C L 2014 A sensitivity-analysis-based approach for the calibration of traffic simulation models *IEEE Transactions on Intelligent Transportation Systems* **15** (3) 1298-1309
[10]   Shafiee K, Lee J B, Leung V C M, and Chow G, 2011 Modeling and Simulation of Vehicular Networks *Network* 77–85
[11]   Kaseko M S 2002 *Comparative evaluation of simulation software for traffic operations* No. RDT 03-032
[12]   Sun D, Zhang L, and Chen F, 2013 Comparative study on simulation performances of CORSIM

and VISSIM for urban street network *Simulation Modelling Practice and Theory* **37** 18–29

[13]   H C M 2000 Transportation Research Board *National Research Council, Washington, DC*.

[14]   Hughes W, Jagannathan R, Sengupta D, and Hummer J E, 2010 *Alternative intersections/interchanges: informational report (AIIR)*

[15]   Jamal T, Mazhar F, and Kaukab I S, 2012 Transport Network Lahore City *Pakistan Journal of Science* **64** (4) 320–326

[16]   Beureau of Statistics Planning & Development Department Government of Punjab 2016 *Punjab Beureau of Statistics report* 1-456

[17]   Fred choa P E, Ronald T Milam, AICP, David STanek, P. 2003 CORSIM, PARAMICS, and VISSIM: What the Manuals Never Told You In *9th TRB Conference on the Application of Transportation Planning Methods* 392–402

[18]   Byungkyu B P, 2011 Microscopic Traffic Simulation Model Calibration & Validation *Seminars in Thoracic and Cardiovascular Surgery Pediatric Cardiac Surgery Annual* **14** (1) 2–3