DEVELOPMENT OF CALIBRATING MICROSCOPIC SIMULATION MODEL FOR NON-LANEBASED HETEROGENIOUS TRAFFIC OPERATION

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ABSTRACT

In developing countries, the traffic composes of both motorized vehicles and non-motorized vehicles using the same road way, hence the resulting traffic system is non-lane based and heterogeneous. The motorized or fast moving vehicles are mainly bus, cars, auto rickshaws(Compressed Natural Gas), trucks whereas the slow moving vehicles referred as non-motorized vehicles(NMV) consists of rickshaws and bi-cycle, which is different in driving behaviour and shows lack of lane discipline in particular. Even though the proportion of NMV varies from 10-80 percent, it has a major impact on the traffic characteristics and operations at the signalized intersections. NMV not only reduces the roadway capacity and speed of motorized vehicle but also intduces congestion at signalized intersections while discharging and affects the queue length and delay time estimated process. A review of literature has shown thatmany simulation model deveopment works had been done on the lane based homogeneous traffic system consisting of motorized vehicles. This paper mainly deals with the way of visualizing the effect that NMV has on signalized intersection through a microscopic simulation modeling approach which need to calibrated with some preference point. In order to calibrate there are certain parameters that need to be adjusted in order to get results that are closed to field data. The paper may be used as a good reference to show the development of VISSIM packages and its practical applications on heterogeneous traffic system as not much work is done on this topic or not readily available.

Keywords: *Microscopic simulation, motorized vehicles, signalized intersections*

1. INTRODUCTION

Traffic micro simulation models has now became a standard and in most cases an efficient tool for evaluating and developing road traffic management and control systems worldwide. The scenario that is difficult to create or data that is difficult to collect from the field can now be easily be simulated using micro simulation model by calibrating the model properly. But sceptics often view simulation modelling as an inexact science at best and an unreliable “black-box” technology at worst (Hellinga, 1998). This scepticism occurs from having less experience in simulation and from poorly calibrating model.

The software’s used for micro simulation modelling are generally designed for lane based homo generous traffic system. But not all the cases in the real world consist of homogeneous traffic stream. A uniform flow of stream makes many calculations much simpler because vehicles’ size, speed, and following distances can be held constant. This allows for changes in other variables without the worry of confounding. Heterogeneous traffic mixes do not provide this luxury, with a variety of vehicles interacting within the traffic stream (Katz, 2009). As there are many complexities in mixed traffic, it is very much difficult to collect and analyse real world data. Also, procedures to calibrate simulation models are not well defined. Even though it is a challenge to understand driver behaviour in heterogeneous traffic and calibrate the micro simulators accordingly, a few work is done on this field of calibrating a model to create heterogeneous traffic system so that it can be closely simulate the real time condition of the field. To focus and enlighten on the progressive work on calibration to simulate heterogeneous traffic system is the driving force behind this study.

The heterogeneous traffic is characterized by a mix of vehicles having diverse static (length, width, etc.) and dynamic (acceleration/deceleration, speed, etc.) properties. These vehicles include nonconventional motorized as well as non motorized vehicles, and their composition is highly transient. Another distinguishing aspect of such traffic is the absence of lane marking and lane discipline resulting in complex movement of vehicles especially at intersections. Often, the lane widths are not uniform (Manjunatha et. al. 2013). Characteristics and modelling issues of such traffic are well documented in the literature (Arasan & Koshy, 2005).

A number of papers had been published on calibration of micro simulators that are restricted to homogeneous traffic system. Earlier than often researcher used default parameters for developing model. This tends to give erroneous outputs. Taking this in to account, Hellinga (Hellinga, 1998), Cohen (Cohen, 2004), Dowling et al., (Dowling et al. 2004), Zhang et al., (Zhang & Owen, 2004) and others suggested general methodologies and techniques for calibration. Along with a set of guidelines Milam et al.,(Milam & Choa, 2000) implemented the calibration methodology in CORSIM. Toledo et al. (Toledo et. al, 2003) used O-D flow data to calibrate MITSIM Lab. (Manjunatha et al., 2013)

Among the studies on calibration of VISSIM, in particular, a discussion of the car following and driver behaviour logic that is incorporated in the VISSIM is well presented in Fellendorfand Vortisch (Fellendorf & Vortisch, 2001) with a detailed analysis of the Wiedemann driver behaviour model implemented in the VISSIM. Later Park and Schneeberger (Park & Schneeberger, 2003) used Latin Hypercube sampling along with a linear regression model to generate scenarios and solve to match the travel times in field and simulation.

Parameter optimization is one of the important calibration techniques, and various algorithms have been applied for solving this problem by obtaining the optimal values for the parameter sets used in calibration. (Manjunatha et al.,2013). A sensitivity analysis is to be conducted to select parameters and their ranges. An optimization formulation should be introduced to find a solution parameter set so as to minimize the intersection delay. Most of the earlier calibration studies use a single measure of performance for the sake of simplicity. Recently, multi criteria approaches were adopted by Duong et al., (Duong et al. 2010) in VISSIM and Park and Kwak (Park & Kwak, 2011) in TRANSIMS respectively. Traffic representation is considered important and hence a visual check is generally suggested after the calibration process. The present study focuses on dynamic work done on calibrating the micro simulation model in VISSIM.

2. METHODOLOGY

This section deals with the research work developed to improve the calibration process by focusing on the few of the work done. First one is done by Hellinga, then professor in Department of Civil Engineering in University of Waterloo. His work is named as "Requirements for the Calibration of Traffic Simulation Models" published in 1998. Then the paper will focus on "Microscopic Simulation Model Calibration and Validation", a paper done by Park and Schneeberger. The last research that this paper will focus on is done in India by P. Manjunatha, P. Vortisch and T. V. Mathew, which later published as paper titled as "Methodology for the Calibration of VISSIM in Mixed Traffic". Next a thesis regarding calibrating micro simulation model in a developing country with the help of the previous researches is enlightened in this paper.

2.1 Requirements for the Calibration of Traffic Simulation Models

The recent emphasis on utilising advanced technologies to make more efficient use of existing transportation infrastructure, coupled with the continuing advances in desktop computing technologies, has created an environment in which traffic simulation models have the potential to provide a cost-effective, objective, and flexible approach for assessing design and management alternatives. However, the models must be demonstrated to be valid, and they must be adequately calibrated for local conditions (Hellinga, 1998).

The proposed calibration in this paper consists of three main phases and eight component steps. These steps are shown in summaries as follows and shown in Figure 1:

a) Phase 1: It comprises those tasks and activities that are conducted prior to the commencement of any modelling.
b) Phase 2: This phase consists of the initial calibration of model parameter values on the basis of available field data. Typically, these parameters required calibration include network coding, including the specification of the location of zones and nodes; link characteristics such as macroscopic speed-flow-density relationships; driver behaviour characteristics such as routing strategies and gap acceptance requirements; and origin-destination traffic demands.
c) Phase 3: The results from the model are compared to field conditions and tested against the previously established criteria. If these criteria are met, then the model is considered to be adequately calibrated and the model can be used for evaluating non-base case scenarios.

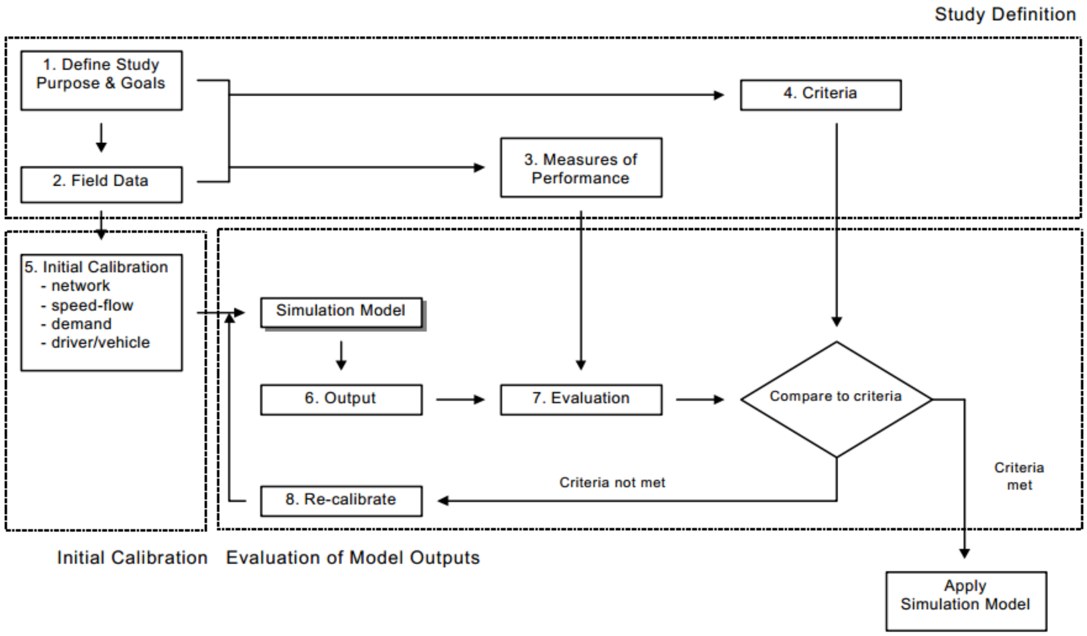

Figure 1 : Proposed calibration process (Hellinga, 1998)

Each of these three phases illustrated below in brief:

2.1.1 Data Required:

Certain input is required to run the VISSIM simulator model. These data are collected directly from the field or certain departments associated with transportation of a country. Some of these collected data are required for calibrating the model and some are required for evaluating the model.

The required data for micro simulation modelling is given in the following table:

Table 1: Data required for calibration (Hellinga, 1996)

Category	Parameter	Data Source
Network Coding	Link length	Plan drawings
	Number of lanes	Plan drawings/Local collection
	Lane connectivity	Base map/Road map
	Lane use restrictions, lane striping, and turn prohibitions	Local collection
	Signal locations and Timings	Local collection
Emergent Behaviour	Speed-Flow-Density Relationships	Loop detector data
O-D Demands	Link traffic flows	Loop detector data
	Turning movements	Manual counts
	Existing O-D data	Local Department of Transportation
	Average trip length	Local Department of Transportation
Driver Routing	Traveller information	Local knowledge

Table 2: Data required to develop criteria for evaluating calibration (Hellinga, 1996)

Data	Source
Detector speed, volume and occupancy	Local Collection
Travel time	Local Collection
Average intersection delay	Local Collection
Congestion patterns during PM peak	Local Collection

Simulation models can generally provide numerous measures of performance (MOPs). Potential MOPs include: link volume, link speed, queue size and location, link travel time, trip travel time by origin and destination and by time of departure, total travel time, average trip length, average number of stops, average fuel consumption, tailpipe emissions of hydrocarbons (HC), carbon monoxide (CO), and nitrous oxide (NOx), and average accident risk. The choice of the appropriate set of MOPs is influenced by the study objectives, the capabilities of the model, and the available field data. Perhaps the most difficult element of traffic modelling is the establishment of criteria by which the adequacy of model results can be determined.

When sufficient field data are available, it may be possible to quantify the mean and variance of the measure of performance of interest, and from these data establish statistical confidence limits that can be used as calibration criteria. However, in practice, field data in sufficient quantity and of sufficient quality are rarely available to permit this type of rigorous statistical approach to more than a few measure of performance Furthermore, study budgetary constraints rarely permit model users to conduct rigorous statistical analysis of field data for the purposes of establishing calibration criteria (ibid).

2.1.2 Initial Calibration

Initial calibration of the model consists of four major elements – namely the representation of the network, the selection of appropriate macroscopic speed-flow-density relationships, the specification of driver routing behaviour, and the development of O-D traffic demands.

2.1.2.1 Network Representation

Network representation is in the form of links indicating roadway segments; nodes which represent the intersection of the road segments; and zones which are sources for vehicles.

2.1.2.2 Microscopic flow characteristic

Microscopic traffic simulation models usually require the specification of macroscopic speed-flow-density relationship. Many models permit these relationships to be specified for each link. But in real time, links are often classified into several categories, and a unique speed-flow-density relationship is specified for each category. Modifications to these relationships might be made for specific links if conditions warrant (e.g. steep vertical grade, restrictive geometry, etc.)

2.1.2.3 Driver Routing Behaviour

The issue of driver routing choice behaviour is an important consideration for studies in which the modelled network presents drivers with more than one viable route choice (Hellinga, 1998).

2.1.2.4 Demand characteristics

O-D demands define the amount of trip making demand between each origin zone and each destination zone during a particular departure time period. Typically, traffic simulation models represent only vehicle traffic, so these demands are generally represented in terms of vehicle trips per hour. A number of methods have been developed for estimating O-D demands, but the most relevant for traffic simulation is the estimation of demands on the basis of link traffic counts. A review of the state-of-the-art of O-D demand estimation is available in another paper (Hellinga, 1996).

2.1.3 Evaluation of Model Outputs

At this phase, attempts are taken to reconcile model outputs with observed field data and determine if the model is adequately calibrated. If care has been taken during Phases 1 and 2 to choose appropriate MOPs, to establish quantitative criteria, and to complete the initial calibration, then the evaluation of the model results and the adequacy of the model calibration may be a well defined process. However, if the model results do not satisfy the stipulated criteria, some form of action is required. Normally, this action takes the form of re-calibrating one or more of the model input parameters. This is the most difficult part of the process, as it requires a well developed understanding of traffic flow theory, the local network conditions, and the model being used. No turnkey approaches exist by which the model user can immediately identify which of the input parameters require re-calibration (Hellinga, 1998).

2.1.4 Microscopic Simulation Model Calibration and Validation

A procedure was proposed for microscopic simulation model calibration and validation, in this paper, prepared by Park and Schneeberger. An example case study was presented with real-world traffic data from Route 50 on Lee Jackson Highway in Fairfax, Virginia (Figure 2).

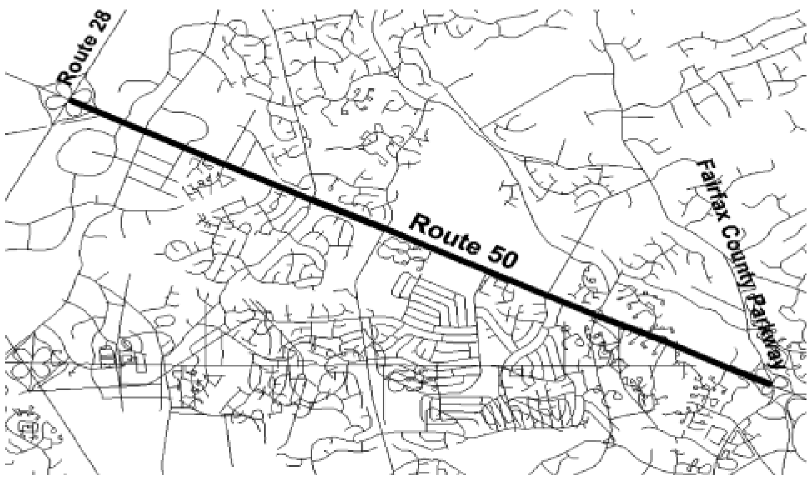

Figure 2: Test site: Lee Jackson Memorial Highway, Fairfax. (Park & Schneeberger, 2003)

2.1.5 Simulation Model: VISSIM

The simulation model used in that research was VISSIM (VISSIM version 3.6 Manual, 2001), version 3.50. VISSIM is a microscopic, time step, and behaviour-based simulation model. The model was developed at the University of Karlsruhe, Germany, during the early 1970s and the commercial distribution of VISSIM was launched in 1993 by PTV Trans world AG. In the United States, ITC Inc. distributes and supports the program.

VISSIM uses the psychophysical driver behaviour model developed by Wiedemann (VISSIM version 3.6 Manual, 2001). The basic concept of this model is that drivers of faster-moving vehicles start to decelerate as they reach their individual perception threshold to a slower-moving vehicle. Because they cannot exactly determine the speed of that vehicle, their speed will fall below that vehicle's speed until they start to slightly accelerate again after reaching another perception threshold. This results in an iterative process of acceleration and deceleration.

2.1.6 Proposed Procedure

The proposed procedure consisted of nine steps: (a) measure of effectiveness selection, (b) data collection, (c) calibration parameter identification, (d) experimental design, (e) run simulation, (f) surface function development, (g) candidate parameter set generations, (h) evaluation, and (i) validation through new data collection. The case study indicated that the proposed procedure appeared to be properly calibrating and validating the VISSIM simulation model for the test-bed network.

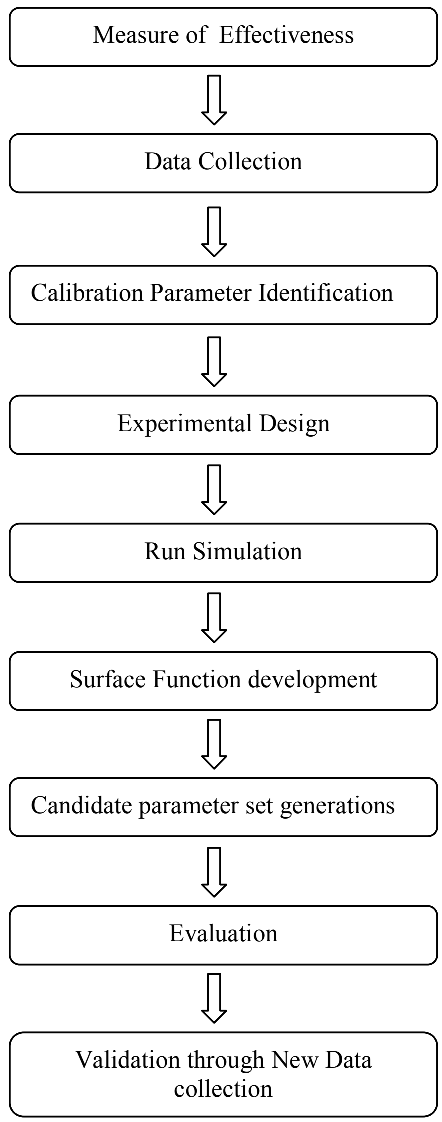

Figure 3: Flow chart of the proposed procedure

2.1.7 Identification of Calibration Parameters

In this section, the parameteres that are needed to be adjusted are put focus on. This parameters are needed to be tuned to create a well calibrated model so that the simulation can give a reliable output which will be close to the real world. These parameters are (a) the emergency stopping distance, (b) lane-change distance, (c) desired speed, (d) number of observed preceding vehicles, (e) average standstill distance, additive part of desired safety distance, (f) waiting time before diffusion, (g) minimum headway.

Table 3: Details of the parameters used in VISSIM

Parameters	Significances	Default values in VISSIM	Acceptable values for calibrations
Emergency Stopping Distance	• the last possible position for a vehicle to change lanes • assigned for each link in the network	5m	2m to 7m
Lane-change Distance	• the distance at which vehicles will begin to attempt to change lanes. • used along with the emer-gency stopping distance parameter to model drivers' behaviour to stay on their desired routes.	200m	150m to 300m
Desired Speed Distribution	• has a sig-nificant influence on roadway capacity and achievable travel speeds. • the speed a vehicle "desires" to travel at if it is not hindered by other vehicles	Based on the field data	Based on the experience in using VISSIM
Number of Observed Preceding Vehicles	• affects how well vehi-cles in the network can predict other vehicles' movements and react accordingly	2 vehicles	1 to 4 vehicles
Average Standstill Distance	• the average desired distance between stopped cars and also between cars and stoplines, signal heads, and so forth.	2m	1m to 3m
Waiting Time before Diffusion	• the maximum amount of time a vehicle can wait at the emergency stop position waiting for a gap to change lanes to stay on its route**.**	60 seconds	Other values can be used
Minimum Headway	• the minimum distance to the vehicle in front that must be available for a lane change	0.5m	0.5m to 7m

2.1.8 Development of Surface Function

A linear regression model was created in S-Plus program with the calibration parameters as independent variables and the eastbound left-lane travel time from VISSIM as the dependent variable Y. The regression model is specific only to this network. A new regression model must be created for each network being considered for calibration and validation (Park & Schneeberger, 2003). The linear regression model is as follows:

$Y = 400.88 - 5.10\, X_1 - .68\, X_2 + 17.80\, X_3 + 28.63\, X_4 + 1.77\, X_5 + 30.20\, X_6$

Where,
Y=eastbound left-lane travel time (s);
X_1 =emergency stopping distance (m) (t value, −2.31; p value, <.0212);
X_2 =lane change distance (m) (t value, −9.15; p value, <.0001);
X_3 =number of observed preceding vehicles (t value, 3.69; p value, .0002);
X_4 =standstill distance (m) (t value, 5.93; p value, <.0001);
X_5 =waiting time before diffusion (s) (t value, 7.32; p value, <.0001); and
X_6 =minimum headway (m) (t value, 11.37; p value, <.0001).

2.1.9 Candidate Parameter Sets and Evaluation of Parameter Sets with Multiple Runs

Candidate parameter sets were created with the linear regression Model in the discussed paper. And also Microsoft Excel's Solver was used to obtain candidate parameter combination sets to obtain the required output.

With the found parameter sets, the model was evaluated. First criterion was to observe the travel time distribution and later one was the visualization. Based on these two criterion best parameter was selected.

2.1.10 Validation with New Data

The best output with the candidates parameter set with the collected data were rechecked and validated with the new filed data to authenticate the simulation model so that it can be reliable for further uses. In the discussed paper (Park & Schneeberger, 2003); the eastbound maximum queue length between the intersections of Muirfield Lane and Intel Country Club Road was used for validation. It was noted that the maximum queue length data were collected on a different day and the input volumes used for the validation process were untried. The maximum queue length observed in the field was compared with the distribution of 100 runs in VISSIM. The field maximum queue length was about the top 90% of simulated distribution as indicated in Figure 4.

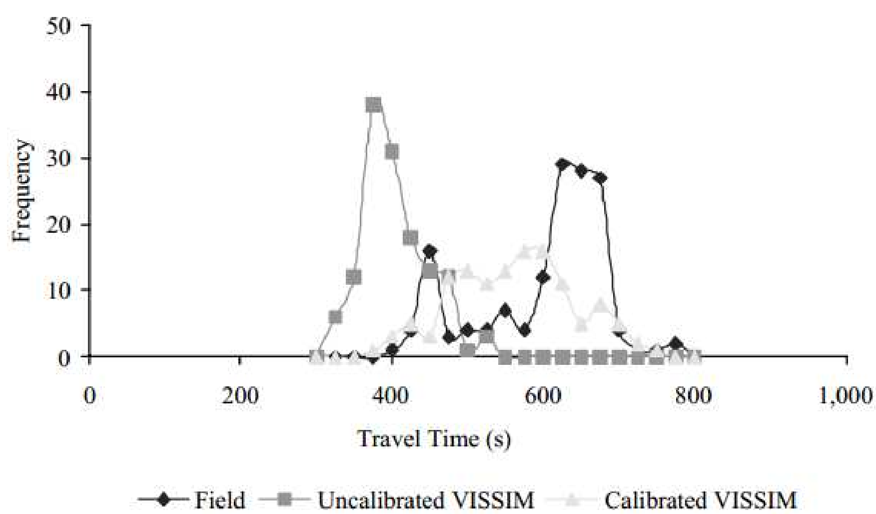

Figure 4: Comparison of field data, uncalibrated VISSIM, and calibrated VISSIM (ibid)

2.1.11 Methodology for the Calibration of VISSIM in Mixed Traffic

The research in the India on which this paper is focusing on was on 2012 and the paper published on the outcomes of this research is named "Methodology for the Calibration of VISSIM in Mixed Traffic". The methodology proposed in the research work was implemented for two signalized intersections in Mumbai. The aim of this case study is to evaluate the effectiveness of the calibration methodology.

2.1.12 Proposed Methodology

The methodology described in the research is same what same which is discussed previously in this paper. The main difference on this research work is the way of optimizing parameter. Parameter optimization is one of the important calibration techniques, and various algorithms have been applied for solving this problem by obtaining the optimal values for the parameter sets used in calibration. Genetic algorithms (GA) are widely used for solving a wide variety of optimization problems including those related to the calibration of simulation models (Manjunatha et al., 2013). GA was explored to determine a suitable combination of parameter values for PARAMICS Lee et al. (Lee, Xu & Chandrasekar, 2001). The proposed methodology in the work is shown in Figure 5.

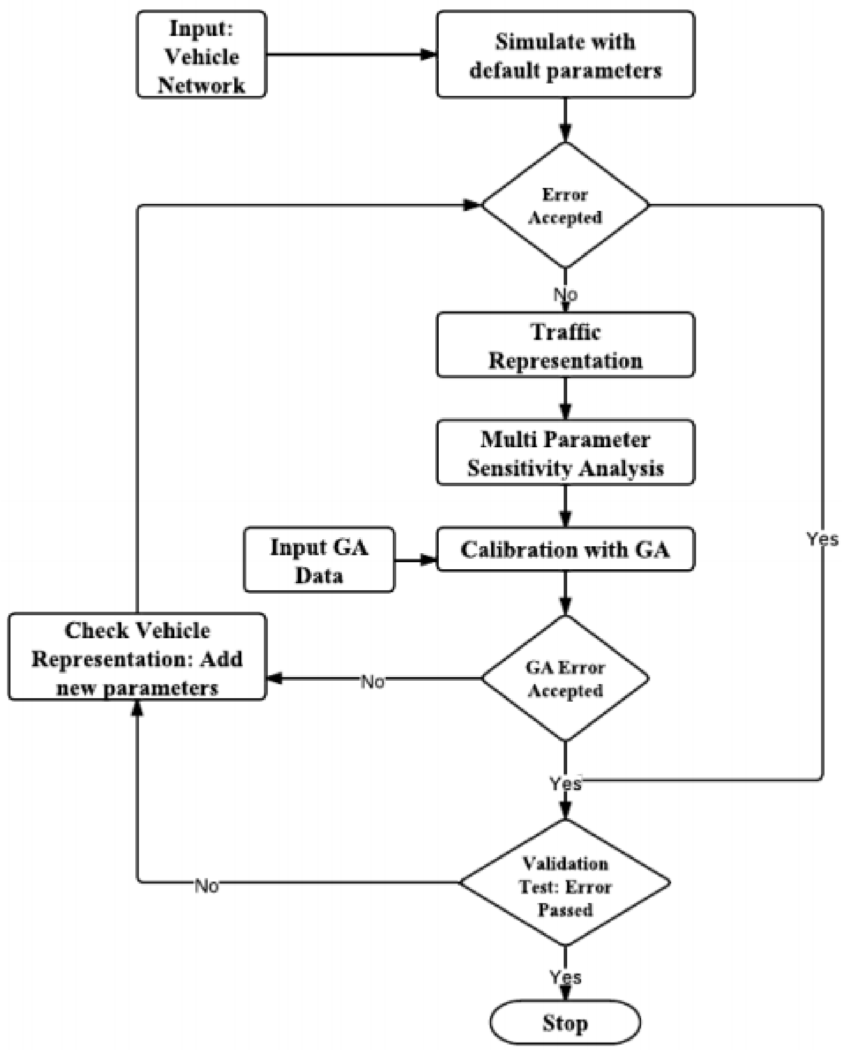

Figure 5: Proposed methodology (Manjunatha et al., 2013)

2.1.13 Visualization of the simulation with real time world

The unique features of mixed traffic are identified and observed it the above discussed research. Some of them are difference in lane behaviour, maneuverability of smaller vehicles and stop line violation, ineffective free left turn etc. Although VISSIM was developed for western traffic, the flexibilities provided by the simulator in defining the network elements can be taken advantage of, to simulate the peculiarities of the driver behaviour in mixed traffic condition (ibid). In the Figure 6, obstruction in free left turn due to large vehicles, making the left turn ineffective, is observed both in simulation model and real time world.

Figure 6: Ineffective free left in simulation and in reality (ibid)

3. APPLICATION

Even though fewer researches are done calibrating micro simulation model to simulate heterogeneous traffic condition, some work had been done on this field in some countries, where traffic system is dominantly heterogeneous such as Bangladesh, India. This paper tends to focus on such research and their outcomes and recommendations.

One of the researches is done on Bangladesh done by M. J. Hossain (Hossain, 2004). The study was on calibration of the microscopic simulation model in VISSIM for urban traffic condition. The site for study was chosen in one of the most densely populated city, Dhaka, where traffic system is non lane based heterogeneous and at the same time the drivers and users of the traffic facilities are not properly educated and trained. So the traffic behaviour is very much hard to predict. Thus to simulate such incident in VISSIM seemed difficult. But the researcher made an attempt to simulate the scenario. He used the methodology that is discussed in the Section 2.2 in this paper.

4. CONCLUSIONS

This paper highlighted on the procedures for microscopic simulation model calibration and validation and demonstrated the work done on calibration process through the years passed by and development of newer modified methodology to calibrate so that simulation can not only become a more effective tools for further study but also reliable outputs can be found.

a) A good calibration requires a wide range of specified data collection which is sometimes is restricted to some constraints. So proper emphasis should be given on data on the basis of their relative importance to the calibration process
b) Two important issues were focused during implementation of the calibration and validation procedures in VISSIM discussed in the paper on Section 2.2.The first issue dealt with statistical testing when claiming the calibrated model was equal to the field data. The second issue was the importance of visualization in the calibration process.
c) From the paper highlighted in Section 2.3, which involved the identification and observation of unique features of mixed traffic and techniques to incorporate them in micro simulation in VISSIM. It was also found that the multi parameter sensitivity analysis was found to be an effective way of finding the significant parameters and the interactions between them while using VISSIM as a microscopic simulator package.

REFERENCES

Arasan, V.T. and Koshy, R.B. (2005). Methodology for Modelling Highly Heterogeneous Traffic Flow. *Journal of Transportation Engineering,* ASCE, 131(7), 544-551.

Cohen, S. L. (2004). An Approach to Calibration and Validation of Traffic Simulation Models. *In 83rd Annual Meeting Preprint*. CD-ROM, Transportation Research Board of the National Academies, Washington, DC.

Donny Katz. (2009) *Heterogeneous Traffic Mixes*.

Dowling, R., Skabardonis, A., and Alexiadis, V. (2004). Calibration of micro simulation models. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1876, Transportation Research Board of the National Academies, Washington, D.C., pp. 1–9.

Duong, D., Saccomanno, F., and Hellinga, B. (2010). Calibration of traffic model for simulating safety performance. *89th Annual Meeting Preprint* CD-ROM, Transportation Research Board of the National Academies, Washington, D.C.

Fellendorf, M. and Vortisch P. (2001) Validation of the Microscopic Traffic Flow model VISSIM in different Real- World Situations. *80th Annual Meeting Preprint* CD-ROM, *Transportation Research Board of the National Academies*, Washington, D.C.

Hellinga, B. (1996) *Test plan for the calibration of the INTEGRATION model to the I-696 Corridor*. Interim report prepared for MitreTek Systems, Inc., Washington DC. (Hellinga, 1996)

Hellinga, B. R.(1998). *Requirements for the Calibration of Traffic Simulation Models*. Canadian Society of Civil Engineering, University of Waterloo.

Hossain M. J.(2004), *Calibration of the Microscopic Traffic Flow Simulation Model VISSIM for Urban Traffic Conditions in Dhaka City,* , Karlsruhe,Germany

Lee, D. H., Xu, Y., and Chandrasekar, P. Parameter Calibration for PARAMICS Using Genetic Algorithm. In *80th Annual Meeting Preprint* CD-ROM, *Transportation Research Board of the National Academies*, Washington, D.C., 2001.

Manjunatha, Mathew, Vortisch. *Methodology for the Calibration of VISSIM in Mixed Traffic*, TRB Annual Meeting, 2013.

Milam, R. T., and F. Choa. (2000) *Recommended Guidelines for the Calibration and Validation of Traffic Simulation Models*. Fehr & Peers Associates Inc., Roseville, California.

Park, B. and Schneeberger, J. D. (2003) Microscopic Simulation Model Calibration and Validation Case Study of VISSIM Simulation Model for a Coordinated Actuated Signal System. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1856, Transportation Research Board of the National Academies, Washington, D.C., pp. 185–192.

Park, B and Kwak, J. (2011) Calibration and validation of TRANSIMS micro simulator for an urban arterial network. *KSCE Journal of Civil Engineering*, Vol. 15, No 6, pp 1091-1100

Toledo T., Koutsopoulos H.N., Davol A., Ben-Akiva M., Burghout W., Andreasson I., Johansson T. and Lundin C. (2003) Calibration and validation of microscopic traffic simulation tools: Stockholm case study.In Transportation *Research Record: Journal of the Transportation Research Board*, No. 1831, Transportation Research Board of the National Academies, Washington, D.C., pp. 65–75.

VISSIM Version 3.6 Manual. Innovative Transportation Concepts. PTV Planung Transport Verkehr AG, Karlsruhe, Germany, Dec. 2001.

Zhang, Y. and L. E. Owen. (2004) Systematic Validation of a Microscopic Traffic Simulation Program. In 83rd Annual Meeting Preprint CD-ROM, *Transportation Research Board of the National Academies*, Washington, D.C.