CALIBRATION OF VISSIM MODEL FOR MULTILANE HIGHWAYS USING SPEED FLOW CURVES

Seelam Srikanth, Arpan Mehar and Asish Parihar

Department of Civil engineering, National Institute of Technology, Warangal,India; e-mail: ssseelamsrikanth@gmail.com, arpanmehr400@gmail.com, civilaparihar@gmail.com

ABSTRACT

Traffic flow is a complex phenomenon that needs better understanding of basic concepts and methods for its analysis. As a solution to practical problems, computer simulation has been proved to be a powerful tool in replicating complex traffic systems which allows experimentation to the basic traffic flow system. Various methods are available in literature, some of the methods use statistical tools to verify the difference between simulated and actual outputs and some are based on optimization which tries to minimize the error. For the present work, suitable methodology is adopted for the calibration process. Field data is collected, statistical tests are performed. For the simulation, VISSIM microscopic simulation tool is used and data analysis is performed by considering individual parameters and performance measures like speed, volume and random seed number. Statistical tests have been performed to check the sensitivity of the different simulation parameters. Calibration is done using trial and error method and optimization is performed using solver function. The maximum simulated flow rate was found with default values as 4599 veh/hr, and with calibrated values is 5147 veh/hr which is close to the target capacity 4958 veh/hr as obtained using field composition. Calibrated values of CC0 and CC1 and CC2 parameters were found as most optimized values to achieve target capacity. Finally, validation of calibrated parameter was performed by using different section of a multilane highway.

KEYWORDS

Driver-behavior model, Speed-flow calibration, Capacity, VISSIM.

INTRODUCTION

In India, multilane highways are categorized as National highways or State highways, both have equal importance based on their purpose. Due to rapid increase in industrialization the importance of roads become most favourable topic for discussion as now it is contributing to economy of the country. India is a country with total of 2,56,749 km of highways including 92,851 of national highways and 1,63,898 of state highways as per 2011 census which is second highest in the world. With this much of network problems of traffic are increasing day by day, measures have been taken to control up maximum utilization of resources but still we are lacking as our traffic conditions are not same as in other countries. In India traffic is a mixed traffic as well as no particular lane behavior for highways, drivers want to get maximum speed so overtaking is main issue in moving traffic. The collection of traffic data is also difficult because of these mix traffic conditions and unpredictable traffic movement. So forth in India, the analysis is being done using HCM methodology, which is based on US traffic conditions but Indian traffic conditions are much different than the US traffic conditions. In simulation of traffic the models are of two types which are known as macroscopic and microscopic models, the macroscopic one is used when the traffic process with aggregate quantities is need to be discussed and the microscopic one is used to describe the behaviour of individual driver/vehicle and their interaction with respect to roadway geometry.

India is a country with mixed traffic flow conditions and abrupt lane change behaviour. The main problem has been seen on highways as the heavy vehicles are moving in inner lanes with slower speed due to their slower speed other categories of vehicles like cars and two wheelers have to reduce their speeds and they try to overtake from the opposite direction which is not good as per the guidelines, as there is no space available in the right direction to overtake. Therefore, it is very difficult to apply any available conventional methods for analysis of traffic flow. Therefore, calibration of traffic flow models is required to set the parameters values which can replicate the real world scenario.

In the field of calibration of parameters to get the most effective parameters only few works have been done in India. It is necessarily required to set criteria for better analysis, and practice under Indian traffic conditions where no lane behaviour exits and, drivers accelerate vehicles and move in any lane based on the available effective sight distance to overtake leading vehicle. While overtaking, vehicles move close to each other for a while and then when they find a gap they are used to overtake. When vehicles are overtaking then some kind of parameters like headway, following distance, follow-up time etc. need to be taken under consideration but they are not easily available so we need to have video graphical survey to get data but that data is not that much accurate as it is difficult to predict the field conditions. Calibration of such kind of parameters will help to get our data up to maximum satisfaction level of actual field data. The calibrated result is now comparable with actual field conditions; there are so many methods available to compare field data with calibrated data.

LITERATURE REVIEW

Fellendorf et al. [1] validated microscopic traffic flow model VISSIM in different real-world situations. They suggested that the VISSIM after its calibration shows most realistic driving behaviour. Dey et al.[2] developed a computer simulation program for two lane highway in Indian traffic conditions. The program can handle all types of vehicles as well as mixed traffic condition Found estimated capacity is lower when compared to US condition because of slower operating speed of vehicles, it was also reported that drivers in India are more aggressive than their counter parts in Germany or US. Velmurugan et al. [3] have developed speed – flow equations based on of different vehicle types for eight lane divided urban expressways using micro-simulation model VISSIM. Authors found the roadway capacity of eight lane divided highway is about 11435 PCU/hr/direction and main percentage error in speed is ranging between 2 to 15%. Praveena et al. [4] tried to find the applicability of various performance measures under mixed traffic condition only for two lane highways. Authors proposed threshold values for different LOS based on suggested parameter for mixed traffic conditions. Chandra [5] discussed the highway capacities values including single lane, multilane highways, expressways and freeways calculated by researchers in past few decades. Author revealed that capacity values in Indian road condition is varying by considering different parameters for different conditions, also Indian driver behaviour is different and can be classified state-wise. Park et al. [6] developed a procedure for calibration of simulation models. Authors used Genetic algorithm (GA) as a base tool for calibration of simulation model VISSIM. The results clearly indicated that the calibrated parameters replicating the field conditions while defaults parameters showing significant discrepancies between simulated and field data. Hofmann [7] discussed very interesting facts on complexity of parameter calibration for simulation models. Author has introduced formal approach for the model calibration and made argument that on increasing the model size (number of parameters) calibration becomes computationally challenging even if excellent field data is available. Models are based on abstractions, idealization and many disputable assumptions so the model calibration is a necessary step to be taken. Lownes et al. [8] did calibration of parameters and the measure of effectiveness was taken as capacity value. Author measured the variation in capacity for each driver behaviour parameter including look back distance. Method of simulation was applied using evolutionary algorithm to get most favourable results found close to default values. This methodology was also compared with traditional method of calibration and shown that this method performance is better. Mehar et al. [9] performed calibration of simulation model and developed speed flow curves for 4-lane divided highway. The speed flow curves from both field data and simulated data were compared. For the simulation only two driver behaviour parameters were taken into consideration i.e. CC0 (standstill distance) and CC1 (Time Headway in seconds) as these two parameters are the most effective parameters for calibration, the values suggested by Shukla and Chandra. Jingtao et al. [10] studied calibration of micro simulation with heuristic optimization methods and proposed a new heuristic calibration algorithm which is based on simultaneous perturbation stochastic approximation (SPSA) scheme. The results obtained using this technique have the same level of accuracy with considerably less iteration and less time as compared to other heuristic algorithms like Genetic algorithm (GA) and the trial and error iterative adjustment (IA) algorithm.

FIELD INVESTIGATION AND DATA COLLECTION

Field data was collected at different mid-block sections of multilane divided intercity highways. Five different sections of divided highway were identified and a field investigation was carried out. Section I is located at NH 58 which is a four lane divided intercity highway having unpaved shoulders. Section II, Section III and Section V are located on NH 163 and sections are four lane divided intercity highway having 1.5 m shoulder in both direction of travel. Section IV is located at NH 332. Video graphic method was used for collecting speed and volume data. A trap length of 50 metres was marked on highway sections to estimate the speed of vehicles by noting down the travel time. Traffic flow data was collected about 3 hours from 04:00 PM to 7:00 PM on Section I, four hours from 09:00 AM to 01:00 PM on Section II, 07:00 AM to 11:00 PM on section III, 09:00 AM to 11:00 AM on section IV and 03:00 PM to 06:00 PM on Section V. Vehicle type survey was also carried out to obtain the clear dimensions of different vehicle types and is given in Table 1. Traffic volume and speed data was extracted manually from the video recording played on big screen monitor in traffic engineering laboratory.

Tab. 1 - Dimension of vehicles.

Types of Vehicles	Length of Vehicles (m)	Width of Vehicles (m)
Standard Cars (CS)	4.11	1.50
Big Cars (CB)	5.00	1.70
Buses (Bus)	11.54	2.50
Autos (3W)	2.36	1.40
Two-Wheelers (TW)	2.0	0.60
Heavy Vehicles (HV)	10.21	2.40

DOI 10.14311/CEJ.2017.03.0026

DATA ANALYSIS

Data collected from the field is analysed using statistical techniques and Mathematical distributions are used to understand behaviour of the traffic flow. Vehicle composition data for different sections of highways are collected and are given in Table 2. Statistical tests are applied on speed and vehicle arrival rate and found that the speed of all vehicle typesfollows normal distribution and vehicle arrival rate follows poisson distribution. Field capacity is difficult to achieve on highways, because congestion condition is rarely occurring. To calculate field capacity value, literature based method is used which is given by Chandra et al. [11] based on the composition of the vehicles.

$$C_{mix} = 4950 - 24.1 \times P_{CB} - 65.7 \times P_{HV} - 20.6 \times P_{3W} + 34.8 \times P_{2W} \qquad (1)$$

Where, C_{mix} is the capacity of the mixed traffic and P is the proportion of the respective vehicle type. Mathematical signs represent effect of vehicle type, either increasing capacity or decreasing. Capacity is calculated for all highway sections and results are given in Table 3. It was found that when percentage of heavy vehicle is more, capacity is less and vice versa. Chandra et al. [11] found that the capacity of the four-lane divided highway is 4950 vph and it is close to Section I. For the purpose of calibration of capacity, Section-I is taken into consideration for further analysis.

Tab. 2 - Vehicular Composition on different Sections of Multilane Highways.

Traffic Composition (%)					
	Section I	Section II	Section III	Section IV	Section V
	NH58	NH163	NH163	NH45 A	NH163
CS	41	31	11	27	20
CB	8	7	3	13	6
3W	3	5	22	9	12
LCV	3	3	5	8	7
HV	14	8	16	20	17
TW	34	46	43	23	45

Tab. 3 - Capacity for different Highway Sections

		Percentage Share				
NH No.	Constant	CB	HV	3W	2W	Capacity (vph)
NH58	4950	8	14	3	34	4958
NH45 A		13	20	9	23	3937
NH163		3	16	22	43	4869
NH163		6	17	12	45	5007
NH163		7	8	5	46	5753

CALIBRATION METHODOLOGY

Microscopic traffic simulation software VISSIM was used for the simulation work. Figure 1 shows calibration methodology for calibration as well as for validation of the model parameters. To develop microscopic simulation model initial steps were taken for input data which was extracted from the field studies. The input data included Speed distribution of each vehicle type, observed volume, number of lanes and lane width, vehicular composition, dimension of each type of vehicles. The driver behaviour such as car-following, lane-change and overtaking were also considered during calibration process. The calibration was done on the basis of field data and analysis to replicate the mixed traffic condition.

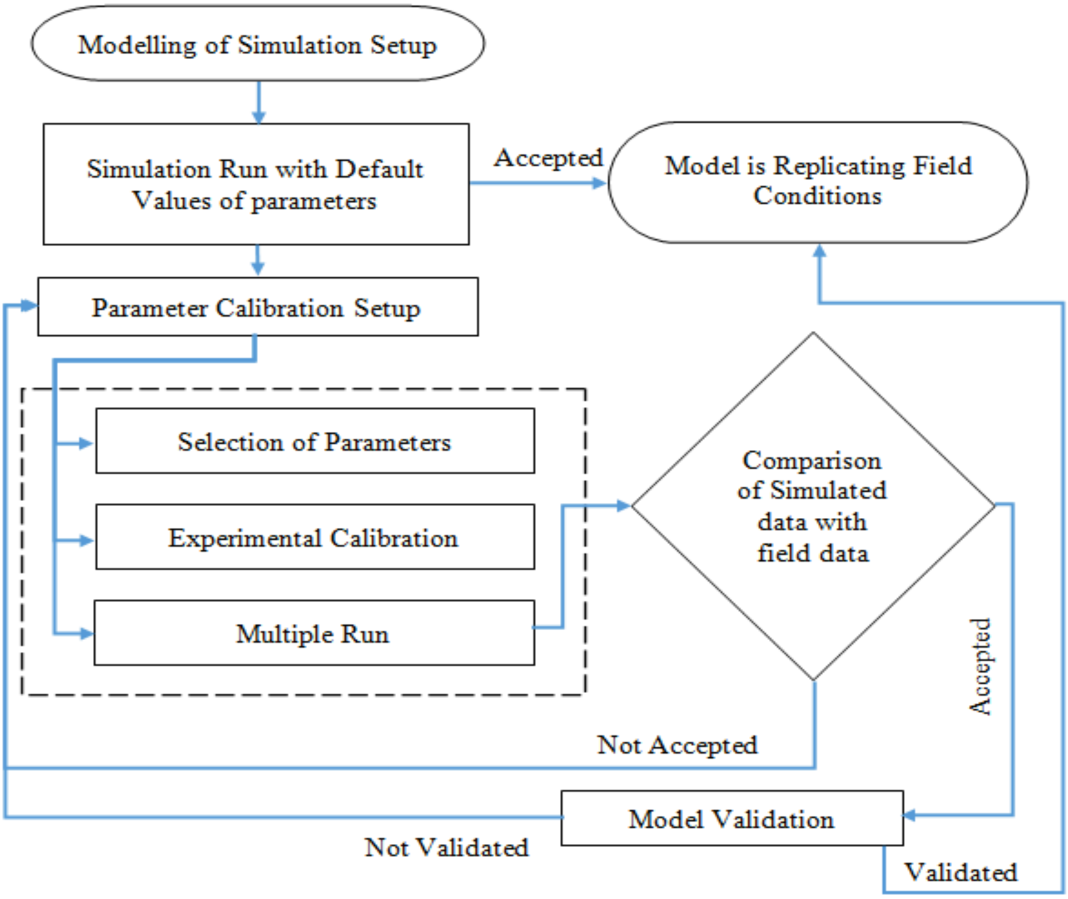

Fig. 1 - Calibration Methodology

DOI 10.14311/CEJ.2017.03.0026

DEVELOPMENT OFSIMULATION MODEL

The field data collected from the highway section NH 58 was used as input to the VISSIM and base link network was created.

Preparation of Base link network

A straight link of more than 1000 meters was created in VISSIM and inputs were assigned as per field data. A travel time section of 50 m was assigned at the 600 m away from the point of vehicle input that allowed vehicles to get warm up before reaching the travel time section. Vehicle type data such as length and width was assigned as per field data. Speed is given in terms of percentile speed, 15th, 50th and 85th percentile speed obtained from the field is given as an input in the desired speed distribution. Speed distribution for each vehicle type is given individually.The new traffic composition was created in VISSIM by assigning proportional share and desired speed profile of each vehicle type. Simulation runs were performed based on the default values of parameters. The speed flow relationship is drawn for simulated data and is overlapped with the field speed flow curves, significant difference has been noticed.Traffic volume data and Speed data are matching with the simulated data but when compared together, showing variations is shown in Figure 2 and hence calibration is required to match speed flow curve of field and simulated data. Mehar et al. [9] suggested that the effect of CC0 and CC1 is more on capacity and is used to calculate safety distance. So, Wiedemann 99 parameters are taken into consideration for the calibration purpose. For this work one more parameter i.e. CC2 following variation is considered.

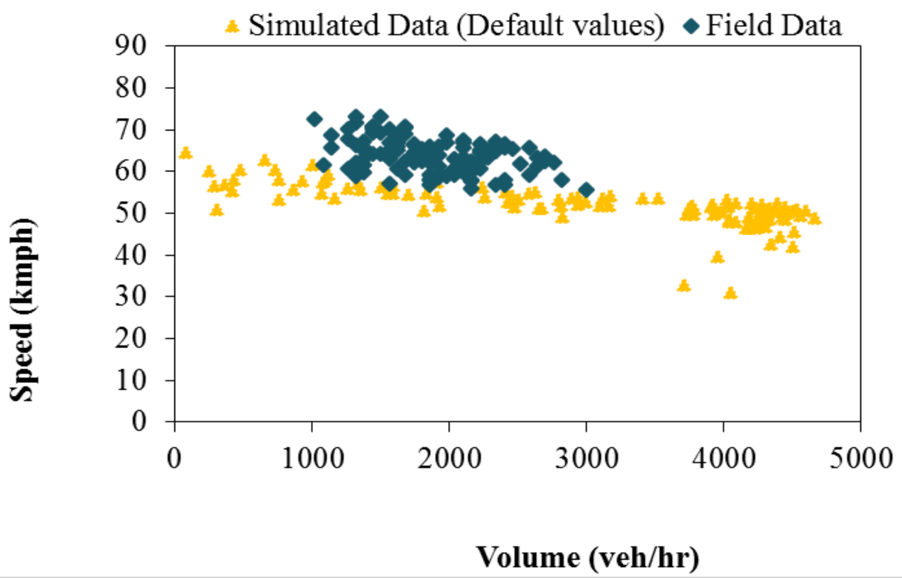

Fig. 2 - Comparison of Speed-flow Curves on four Lane Divided Highway

SENSITIVITY ANALYSIS

To calibrate the model, analysis was performed to check the sensitivity of the parameters which was done by making groups of parameters. In first trial, group of CC0 and CC1 was made and the parameter values were changed and effect of variation of parameter value was observed in flow values. In another set the group of CC1 and CC2 was made. Sensitivity analysis was performed for all the parameters and found that the sensitivity of CC1 was more.

To check the variation of CC1 on flow values, CC1 values changed from 0.5 seconds to 1.5 seconds and simulation has been run for 3 hours to get more accuracy. From the Figure 3, the effect on flow value on changing CC0 shows almost flat lines, which indicates that the effect of CC0 parameter is very less. On increasing standstill distance between vehicles, the capacity values decrease but with a small amount.

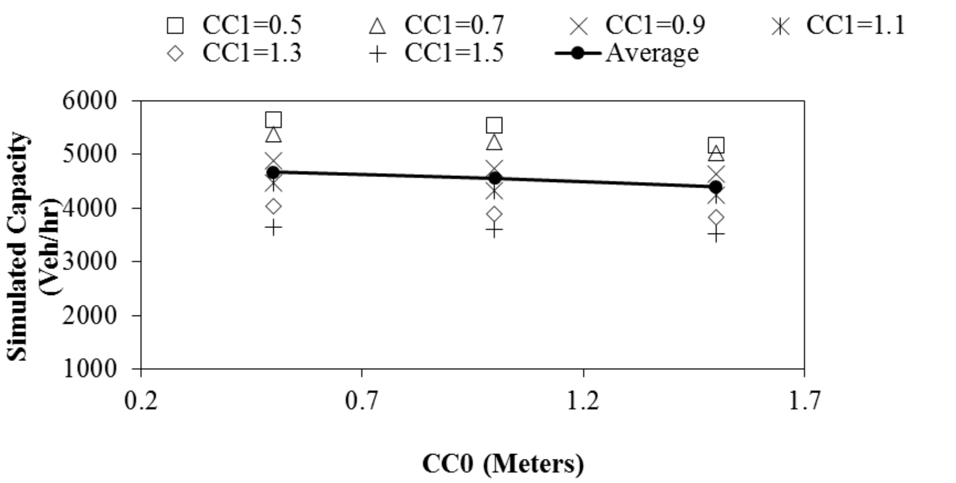

Fig. 3 - Variation in traffic flow values (*CC0, m*)

From the Figure 4, the effect on flow value on changing CC1 shows decreasing trend, which indicates that, the effect of CC1 parameter is more. On increasing the CC1 value the flow value decreases linearly. Practically, on increasing spacing between vehicles capacity of roadway section will decrease which is proved with the following curve.

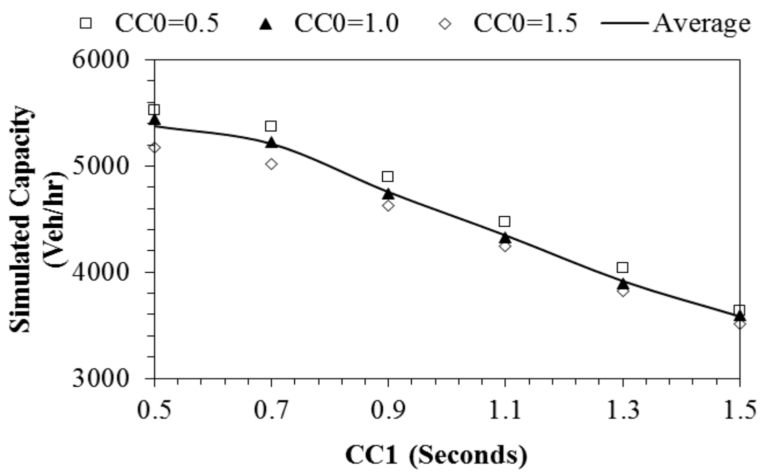

Fig. 4 - Variation in capacity due to CC1 (*sec.*) *on different CC0 values*

On increasing the parameter value (CC2), flow values decreases linearly and the desired field capacity exists in between these parameter values. Trend in Figure 5 also shows significance difference. On increasing both the parameters i.e. CC1 (Headway) and CC2 (following variation) the capacity value of the road section will decrease. Although, parameter CC2 does not show significance difference compared to CC1 parameter.

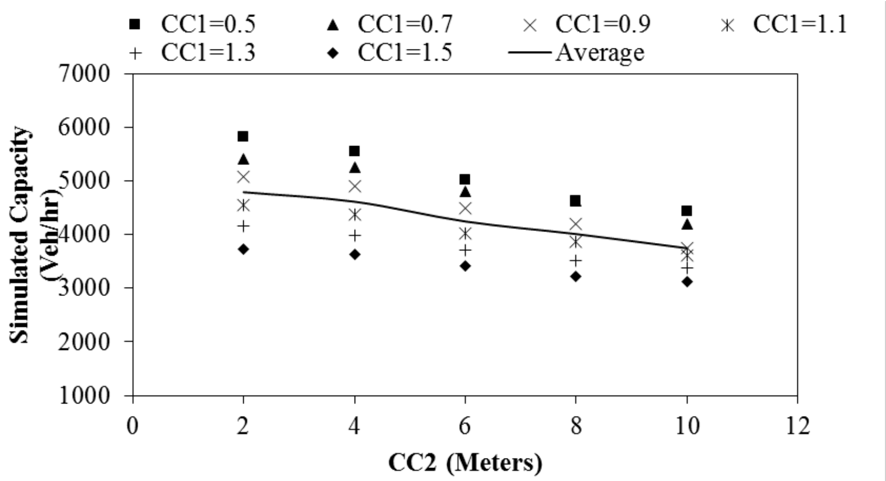

Fig. 5 - Variation in capacity due to CC2 (*sec.*) *on different CC1 values*

Figure 6 shows a drop in capacity value due to change in CC1 values for different CC2 combinations and found significant, groups have been made between parameters, calibration of all parameters is not possible at the same time, so sensitivity is discussed individually and found that each parameter affects flow value effectively. Some parameters affect more and some affect less. To understand the combined effect of parameters several statistics methods can be used.

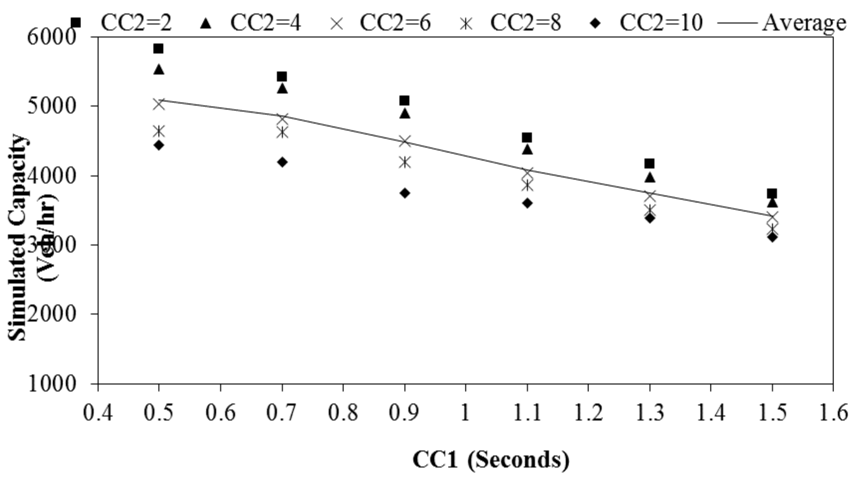

Fig. 6 - Variation in capacity due to CC1 (*sec.*) *on different CC2 values*

DOI 10.14311/CEJ.2017.03.0026

DEVELOPMENT OF OBJECTIVE FUNCTION

It has been noticed that parameters (CC0, CC1 and CC2) affect each other, to get the effect of three parameters at the same time regression analysis was done.

Tab. 4 - Range and Interval of driver behaviour parameters

Parameters	Range	Interval
CC0 (m)	0.5-1.5	0.5
CC1 (Sec.)	0.5-1.5	0.2
CC2 (m)	2-10	2

Table 4 shows the variation of the parameters, based on the variation simulated capacity was measured using speed-flow curves obtained from the simulated data. Equation 2 was prepared in which capacity is dependant variable and parameters are independent variables.

Capacity = 7034.2 - 183.6 × CC0 - 1801.4 × CC1 - 130.4 × CC2 …………… (2)

Equation 2 can be used as an objective function for the purpose of the optimization as left side variable i.e. capacity is a measure of effectiveness. To get the optimum value of the parameters, optimization technique was used and constraints equations have been formed using the simulated data and ranges for the decision variables haves been fixed for the case. The following constrained equations have been formed

6326.23 - 183.67*CC0 - 1801.49*CC1 <= 5333………………….. (3)

6850.51 - 1801.49*CC1 - 130.41*CC2 <= 5689………………….. (4)

5232.69 - 183.67*CC0 - 130.41*CC2 <= 4788…………………… (5)

To solve the optimization problem, solver function was used in MS excel and template was prepared to solve optimization function for different values of decision variables and is shown in Figure 7.

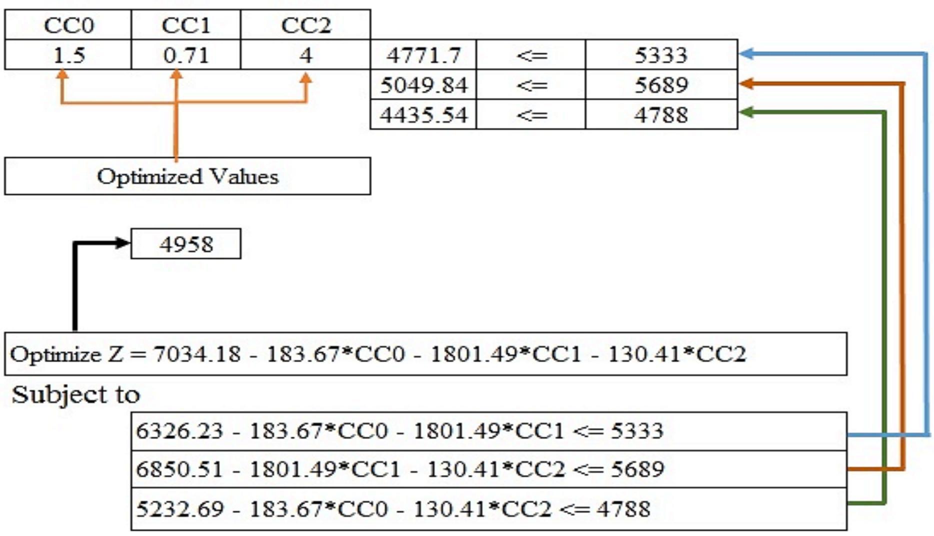

Fig. 7: Template to solve optimization problem using solver function in MS Excel

Two optimal points (i.e. 1.8, 0.53, 6 and 1.2, 0.74, 4) have been found and simulation was run for these parameter values. Speed flow curves obtained for the optimal points is shown in Figure 8 and found that the speed flow curves are replicating field condition.

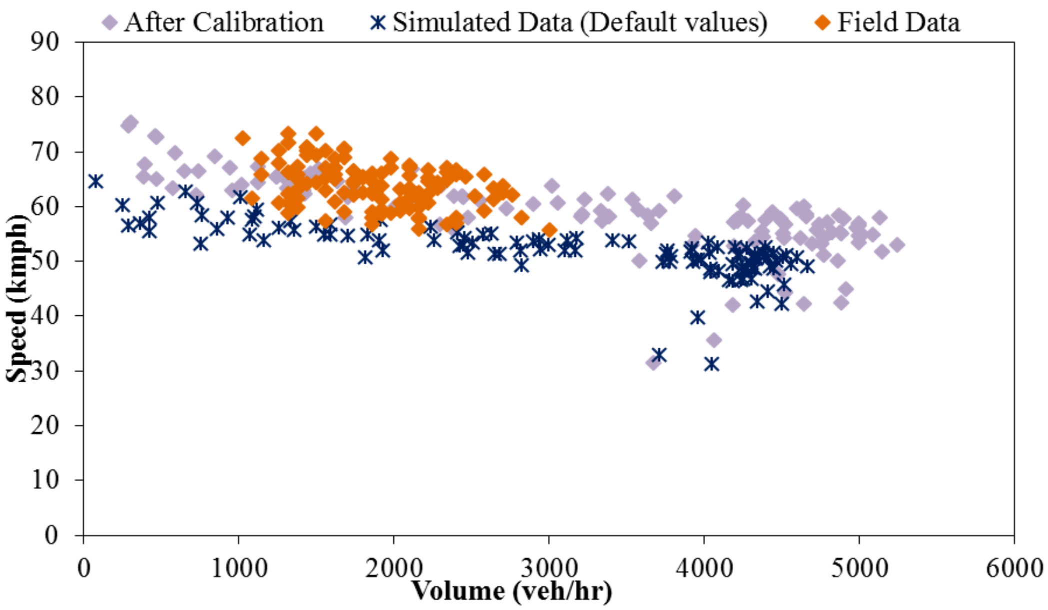

Fig. 8 - Speed flow comparison before and after calibration

VALIDATION OF CALIBRATED PARAMETERS

For the purpose of the validation, data set from NH-16, a 6-lane highway having 1.8 m paved shoulder was used. Six-lane highway section was selected in such a way that the composition of vehicle types should be closed to the composition of the data used for the purpose of the calibration. Six-lane highway used for validation was to make sure that calibrated values of CC0, CC1 and CC2 for four-lane highway were also used for to estimate the capacity of six-lane highway. Field data were analysed and descriptive statistic is given in Table 5.

Tab. 5: Descriptive statistics for field data

	CS	CB	LCV	Auto	TW	HV
Mean (km/h)	84.04	81.61	58.99	48.93	56.20	56.27
Std Dev (km/h)	13.32	18.63	13.34	5.82	11.87	11.37
Total Number	571	252	92	38	1191	311
Composition (%)	23.3	10.3	3.7	1.5	48.5	12.7
Minimum (km/h)	40.01	33.18	34.79	35.58	12.92	21.90
Maximum (km/h)	129.50	143.88	91.09	64.47	112.22	91.93
15th Percentile (km/h)	70.41	62.74	42.82	43.13	44.68	45.41
50th Percentile (km/h)	84.03	81.89	59.41	47.87	55.37	56.64
85th Percentile (km/h)	96.96	100.88	72.68	54.78	67.99	67.62

Calibrated values were used for the simulation of the data and it was found that the calibrated parameters of four-lane highway are able to reflect field traffic condition on 6 lane highway as well. Speed flow curves obtained after calibration are shown in Figure 9. Simulation was run using default parameters values and it was found that maximum flow value to 4925 veh/hr after using calibrated parameters the capacity value is coming to 6142 veh/hr.

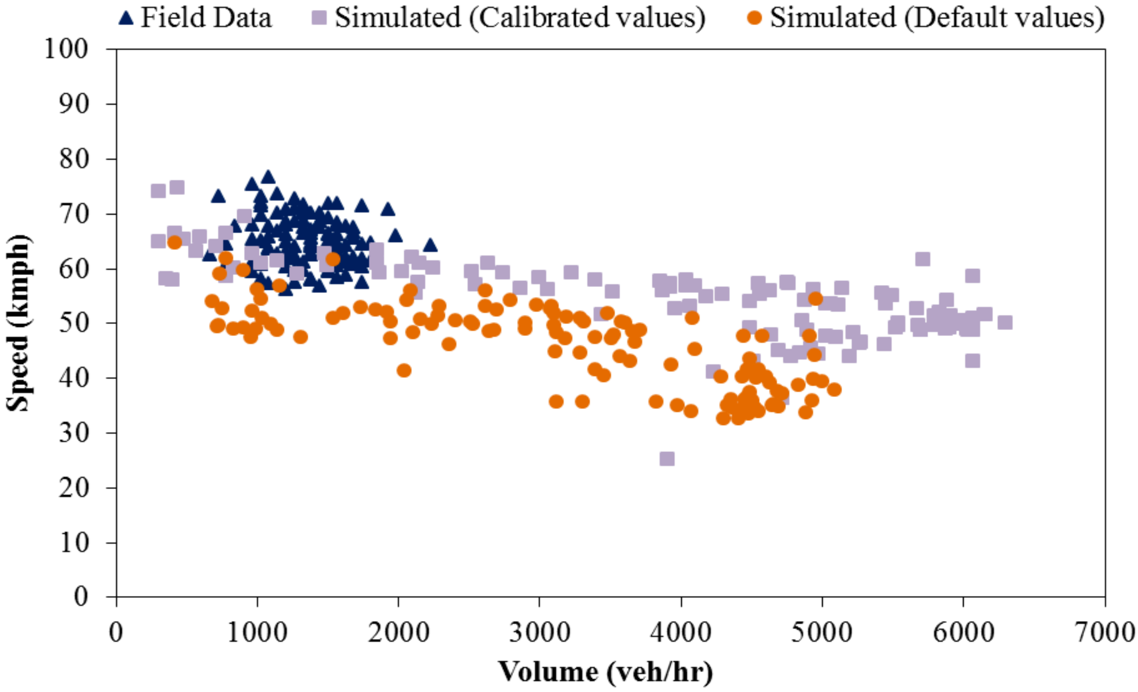

Fig. 9 - Speed flow comparison before and after calibration of parameters

CONCLUSION

- Speed data analysed on different sections of four lane divided highways were analysed to fit to mathematical probabilistic distributions. As a result, normal distribution was failed to fit the field speed data but Poisson distribution was found best fit for mixed traffic condition.
- Among the available popular microscopic simulation tools, model VISSIM 5.4:32 was found more flexible and user friendly for mixed traffic conditions.
- Random seed numbers (RSN) variation was found insignificant with volume output at 5% level of significance. Hence, any value of random seed can be taken for simulating mixed traffic flow. However, the change in RSN values changes the volume outputs inconsistently. RMSE estimated to compare field and simulated speed data were found less than 5% at different RSN.
- Sensitivity analysis performed on simulated capacity with the different combinations of model parameters (CC0, CC1and CC2) were found significant at 5% level. However, CC0 and CC2 were found significant when tested at 1% significance level.
- Sensitivity analysis was performed for all the parameters and found that the sensitivity of CC1 is more. Slightly increase in CC1 parameter reduces the capacity consistently.
- Optimal values for CC0, CC1 and CC2 are 1.8, 0.53, 6 and 1.2, 0.74, 4 to obtained accurate capacity of multilane highways under mixed traffic conditions.

.

REFERENCES

[1] Fellendorf M, Vortisch P., 2001. Validation of the microscopic traffic flow model VISSIM in different real-world situations. Transportation Research Board 80th Annual Meeting.

[2] Dey PP, Chandra S, Gangopadhyay S., 2008. Simulation of mixed traffic flow on two-lane roads. Journal of Transportation Engineering,134(9): 361-369.

[3] Velmurugan S, Errampalli M, Ravinder K, Sitaramanjaneyulu K, Gangopadhyay S., 2010. Critical evaluation of roadway capacity of multi-lane high speed corridors under heterogeneous traffic conditions through traditional and microscopic simulation models. In Journal of Indian Roads Congress, 71(3): 235-264.

[4] Penmetsa P, Ghosh I, Chandra S., 2015. Evaluation of Performance Measures for Two-Lane Intercity Highways under Mixed Traffic Conditions.Journal of Transportation Engineering, 141(10).

[5] Chandra S., 2015. Highway Capacity Research on Inter-urban Highways in India. Transportation in Developing Economies, 1(1): 20-24.

[6] Park B, Qi H., 2005. Development and Evaluation of a Procedure for the Calibration of Simulation Models. Transportation Research Record: Journal of the Transportation Research Board, 1934: 208-217.

[7] Hofmann M., 2005. On the complexity of parameter calibration in simulation models. The Journal of DefenceModelling and Simulation: Applications, Methodology, Technology, *2*(4): 217-226.

[8] Lownes N,Machemehl R., 2006. Sensitivity of simulated capacity to modification of VISSIM driver behaviour parameters. Transportation Research Record: Journal of the Transportation Research Board, 1988: 102-110.

[9] Mehar A, Chandra S,Velmurugan S., 2014. Highway capacity through VISSIM calibrated for mixed traffic conditions. KSCE journal of Civil Engineering, *18*(2): 639-645.

[10] Ma J, Dong H,Zhang H., 2007. Calibration of microsimulation with heuristic optimization methods.Transportation Research Record: Journal of the Transportation Research Board.

[11] Chandra S, Mehar A, Velmurugan S., 2016. Effect of traffic composition on capacity of multilane highways. KSCE journal of Civil Engineering, *20*(5): 2033-2040.

DOI 10.14311/CEJ.2017.03.0026