Effect of Driver Behaviour Parameters on Vehicle Conflict at Uncontrolled Intersections using Micro-simulation

Pradhan Kumar AKINAPALLI [a*], Dr. Digvijay S. PAWAR [b], Dr. Hussein DIA[c], Dr. Chang-Yi LUO[c]

[a] *Research Scholar, Department of Civil Engineering, Indian Institute of Technology Hyderabad, Sangareddy, India*
[b] *Assistant Professor, Department of Civil Engineering, Indian Institute of Technology Hyderabad, Sangareddy, India*
[c] *Associate Professor, Department of Civil and Construction Engineering, Swinburne University of Technology, Australia*
[d] *Social System Research Div., V2X Group, TOYOTA InfoTechnology Center Co., Ltd, 6-6-20 Akasaka, Minato-ku Tokyo 107-0052, Japan*

E-mail: ce17resch11012@iith.ac.in
Email: dspawar@iith.ac.in
Email: *hdia@swin.edu.au*
Email:cy-luo@jp.toyota-itc.com

Abstract: Accident models are generally used to analyze the safety of vehicular interactions. However, a paradoxical situation arises as accidents are infrequent, and large data yields better models. Therefore, proactive surrogate safety measures (SSM) are used to analyze the interactions. The present study identifies the driver behavior parameters affecting the SSMs at an uncontrolled intersection in rural mixed traffic using VISSIM software. Empirical data was collected and was inputted into VISSIM software. The Wiedemann-99 model was used to simulate the scenario. The vehicle trajectories generated were used in SSAM software to evaluate the interactions. The analysis revealed that CC1 (representing the speed-dependent part of desired safety distance), CC2 (parameter restricting the longitudinal oscillation), CC4 & CC5 (defines the negative and positive speed difference while in the following process) significantly influenced the conflicts. The insights from the study can be used for safety performance evaluation of uncontrolled intersections in mixed traffic conditions.

Keywords: Uncontrolled intersection, Conflicts, VISSIM, Wiedemann-99, Sensitivity Analysis, SSAM

1. INTRODUCTION

Micro-simulation software packages are used to study various scenarios such as the effects of geometry, active traffic management, public transport, emissions modeling, etc. However, recently, the micro-simulation software packages are being employed to study road safety proactively. That is, the surrogate safety measures (SSM) of road safety are extracted from the trajectories of the vehicles generated in the micro-simulation software and various countermeasures to increase the safety are tested in the software. Nevertheless, such software needs to be calibrated to represent real traffic conditions on the site before studying the effect of various countermeasures. Moreover, the road traffic scenarios in developing nations are quite different from those observed in developed nations. The developing nation's traffic heterogeneity, non-lane discipline, non-adherence to stop sign at unsignalized intersections, drivers' prospection about the interactions, non-channelization of the intersection traffic renders the calibration of micro-simulation's parameters into a prominent step. Most of the research in the past was directed towards calibration for capacity, signal control efficiency, etc. However, only a few studies are available on calibration for safety at unsignalized intersections albeit in urban and semi-urban areas.

The present study, therefore, aims at identifying the driver-behavior parameters affecting the safety at un-channelized unsignalized intersections in heterogeneous traffic conditions. The interactions at un-channelized intersections are quite different from that at channelized intersections. The prospection of drivers at un-channelized intersections gives rise to a virtual stop-lines and reduces the number of crossing conflicts between major and minor-road right turning vehicles in low traffic scenarios. This paper aims to represent the effect of non-channelization on interactions of vehicles and more details of the study location are given in the section 3. Section 2 gives the background to the sensitivity analysis and calibration methodology in the previous literature. Section 4 details the data collection, extraction processes and section 5 details the VISSIM analysis performed. Section 6 explains the influential parameters identified from the analysis and compares to the previous studies. Section 7 concludes with the future scope of the study.

2. BACKGROUND

Traditionally microsimulation software is employed for feasibility studies of various traffic management alternatives and geometrical alternatives for congestion mitigation. In the past decade, the research focus has shifted to calibrating the parameters of micro-simulation software to better simulate the actual field conditions. As many microsimulation software packages are available, the choice of the software for simulation plays an important role in simulating the traffic closer to the field conditions. Towards identifying the best software, Fang and Elefteriadou (2005) have studied three software namely AIMSUN (Advanced Interactive Microscopic Simulator for Urban and non-urban Networks), CORSIM (Corridor Simulation), and VISSIM (Verkehr in Stadten – simulation) on five elements to identify the suitability of the software for simulating various road facilities and interchanges in particular. The elements considered include: (1) the capability of representation of specific geometric characteristics; (2) the capability of simulating specific signal control plans; (3) calibration needs and accuracy in comparison to field conditions; (4) the extraction of specific performance measures from the simulator; and (5) other observations from the research. While all the three software performed well in few elements, VISSIM performed well in all the five elements, i.e., it contains all the parameters required to replicate a vehicle's trajectory in the simulation. Another study by Panwai and Dia (2005) evaluated three microsimulation software to represent field car-following behavior. The authors evaluated the performance of software namely AIMSUN, VISSIM, and PARAMICS (parallel microscopic simulation). And it was observed that the psycho-physical car-following models in VISSIM performed better as compared to the car-following models used in other two simulation software. A detailed explanation of the car-following models used in AIMSUN, MITSIM, VISSIM and the Fritzche car-following models (PARAMICS) can be found in work done by Olstam and Tapani (2004). The definitions of the various parameters of the VISSIM can be found in the VISSIM manual and are based on the work by Weidemann and Reiter (1992). Improvements in the VISSIM software are continuously being made in the newer versions of the software making it one of the best alternatives for simulating the traffic. However, the software's default parameter values need modification for different types of intersections to represent the field traffic in the simulation software. Therefore, calibration forms an important step in simulating traffic in any scenario.

The calibration studies generally consist of two steps. The first step is to perform sensitivity analysis to identify the influential parameters and second, to derive optimal values of the parameters at which simulation represents reality. The calibration studies can be classified based on location and type of control at the intersection as a) Urban signalized intersection b) Urban un-signalized intersection, c) Rural signalized intersection and d) Rural unsignalized intersection. The urban and rural intersections differ both in geometrical and traffic characteristics and the control at these intersections depends upon whether the intersection is signalized or not. Therefore, the calibration studies pertaining to a type of intersection will not be applicable to other types of intersections.

Simulation and calibration of urban signalized intersections have been the major focus of researchers in the recent past. Dowling et al. (2004). Park and Qi (2005) have studied the effects of various driver behavior parameters on the urban signalized intersections in homogeneous traffic. A study for the urban signalized intersection for heterogeneous traffic was carried out by Mathew and Radhakrishnan (2010). The authors calibrated the driver behavior parameters so that the variance between the simulated and field delay was minimized. Siddharth and Ramadurai (2014) also performed a study for urban signalized intersection and identified the parameters affecting the simulated capacity in Indian conditions. The authors employed Latin Hypercube Sampling (LHS) technique, one-way ANOVA and elementary effects technique for the signalized intersection and corridor in the urban area of Chennai. The authors observed that one-way ANOVA is suitable for identifying the significant parameters at the first level of sensitivity analysis and the optimized trajectories for elementary effects suited for identifying the significant parameters which are overshadowed by other parameters in the first level of sensitivity analysis. However, a study by Lu et al. (2016), instead of varying the parameter values in a range, extracted the values of parameters using automated video extraction software and inputted into the VISSIM software.

Few researchers have explored the simulation calibration in the urban unsignalized scenario to replicate the field observed conditions. Caliendo and Guida (2012) simulated an urban unsignalized intersection using AIMSUN software and found that conflicts from simulation trajectories were more representative of the crashes than traffic flows. Another study by Paul et al. (2017) performed on a semi-urban unsignalized intersection using Weidemann-74 model in VISSIM revealed that six parameters significantly affected the 85th percentile gap namely W74ax, W74bxAdd, minimum look ahead distance, minimum look back distance, maximum deceleration of own vehicle, maximum deceleration of the trailing vehicle and min headway.

Lownes and Machemehl (2006a) performed a sensitivity analysis to identify the parameters significantly influencing the simulated capacity at a rural signalized intersection. Authors performed another simulation study on the same study stretch and investigated the effect of a combination of various driver behavior parameters on the simulated capacity. Both these studies were carried out on the same interchange which represented rural roads. For rural roads, according to VISSIM manual, Weidemann-99 psycho-physical car following model was employed in the VISSIM software.

Apart from calibrating the VISSIM software for capacity, recently, VISSIM software is also being employed to study traffic safety using proactive surrogate safety measures (SSM). Surrogate safety measures (SSM) form the proactive method of measurement of safety as they do not rely upon accident data. The accident data is generally prone to errors while recording, and also it is paradoxical to wait for a greater number of accidents to occur to analyze better and predict safety level. Therefore, simulation software is used to generate trajectories of vehicles in the simulation environment at every time-step based upon the psycho-physical car-following models, rule-based lane changing algorithms and gap acceptance models. And these trajectories of individual vehicles produced in the simulations are analyzed using the surrogate safety assessment model (SSAM) software developed by Federal Highway Authority (FHWA), and the conflicts are identified. Thresholds of various SSM are used to extract conflicts from trajectories. The thresholds for post-encroachment time (PET) and time-to-collision (TTC) can be varied for data extraction from the trajectory files. Huang et al. (2012) have estimated the effect of TTC threshold on the number of conflicts and have found that TTC threshold has a significant impact on the rear-end conflicts but not on crossing and lane-changing conflicts. However, the authors varied only the gap values in the priority rules, and trajectories were generated without modifying the car-following parameters. A study by Essa and Sayed (2015) addressed this problem by studying the effect of car-following parameters and various other parameters on the number of conflicts. The authors highlighted the importance of initial calibration before analyzing the trajectories using SSAM. And they showed that the simulated conflicts generated after calibrating VISSIM models represented the field-measured conflicts at higher TTC values more accurately. However, the work was limited to signalized intersections.

Fan et al. (2013) have studied the effect of various driving behavior parameters on the simulated conflicts at freeway merging area. The authors identified that safety distance (represented by CC0, CC1), CC3, safety distance reduction factor, minimum gap time influenced the simulated conflicts significantly (See section 5 for a detailed explanation of CC0, CC1, and CC3).

As very few studies have attempted to calibrate VISSIM software for rural unsignalized intersections, the current study is an attempt to identify the driver behaviour parameters affecting the conflicts. However, the SSAM software was developed and validated by the FHWA for only four-legged signalized intersections. Therefore, the SSAM's applicability to unsignalized intersections, especially unsignalized T-intersections is based on the research work by Caliendo and Guida (2012). The study consisted of nine intersections out of which seven intersections were unsignalized T-intersections whereas the remaining two were four-legged unsignalized intersections. The authors used AIMSUN software and validated the conflicts generated. They observed that conflict-based model fitted well with the accident data for both the three-legged intersections and four-legged intersections. Therefore, in the current study, we aim to identify the driver behavior parameters that significantly influence the number of crossing conflicts at a rural unsignalized T-intersection in VISSIM. Moreover, the intersections considered by FHWA for the validation of SSAM software had approaches that follow lane-discipline. Therefore, the validity of SSAM for Indian traffic is explored before employing. As the study site had low to medium traffic on the approaches; rapid lane changing behaviour closer to the intersection were not observed. It was also ensured that there wasn't any wrong directional traffic. Hence, SSAM software was applicable to the study site. Following the verification of applicability of SSAM to the study site, the study was performed that includes two major tasks. (1) Simulation of the rural unsignalized intersection with the turning volumes, speeds, gap acceptance behavior observed in the field by using appropriate priority rules and (2) determining the consistency between simulated and field-observed conflicts and identifying the parameters influencing the consistency by performing paired t-tests.

3. STUDY LOCATION, DATA COLLECTION & EXTRACTION

3.1 Study Location

A three-legged unsignalized intersection located on the National Highway 65 (NH-65) in the state of Telangana, India was selected to simulate the rural unsignalized scenario (See figure 1). The preliminary site study indicated that the minor road connecting the major road (NH-65) predominantly caters to heavy motor vehicles (HMV) due to the presence of industries near the intersection. The intersection area was wide enough to allow the heavy motor vehicles and tractor-trailer combinations to turn with ease. The minor road intersected major road at 60^0 forming an acute angle. The acute angle intersections generally increase the exposure time of vehicles crossing the main traffic flow (conflicting traffic) thus increasing the crash potential.

Figure 1 indicates that the intersection does not have channelization. Channelization of at-grade intersections generally results in a reduction of the number of conflicts as the location and angle at which the vehicles cross, merge, or diverge are controlled.

Figure 1 Conflicts avoided between major and minor road right turning vehicles

Though it was observed that channelization was absent in the selected intersection, the crossing conflicts between major and minor road right turning movements were reduced because of the wider intersection area and the prospection of drivers. The minor road right-turning vehicles move towards the right of the intersection (see Figure 2 for illustration) within the minor road itself, thereby avoiding conflicts with the major road right turning traffic. In the process, a virtual stop-line is created by the minor road right-turning vehicles. The major road is a divided four-lane road, and the intersection was without any influence of road-side parking, bus stops, and any other side frictions. The intersection had very limited pedestrian and cyclist movements.

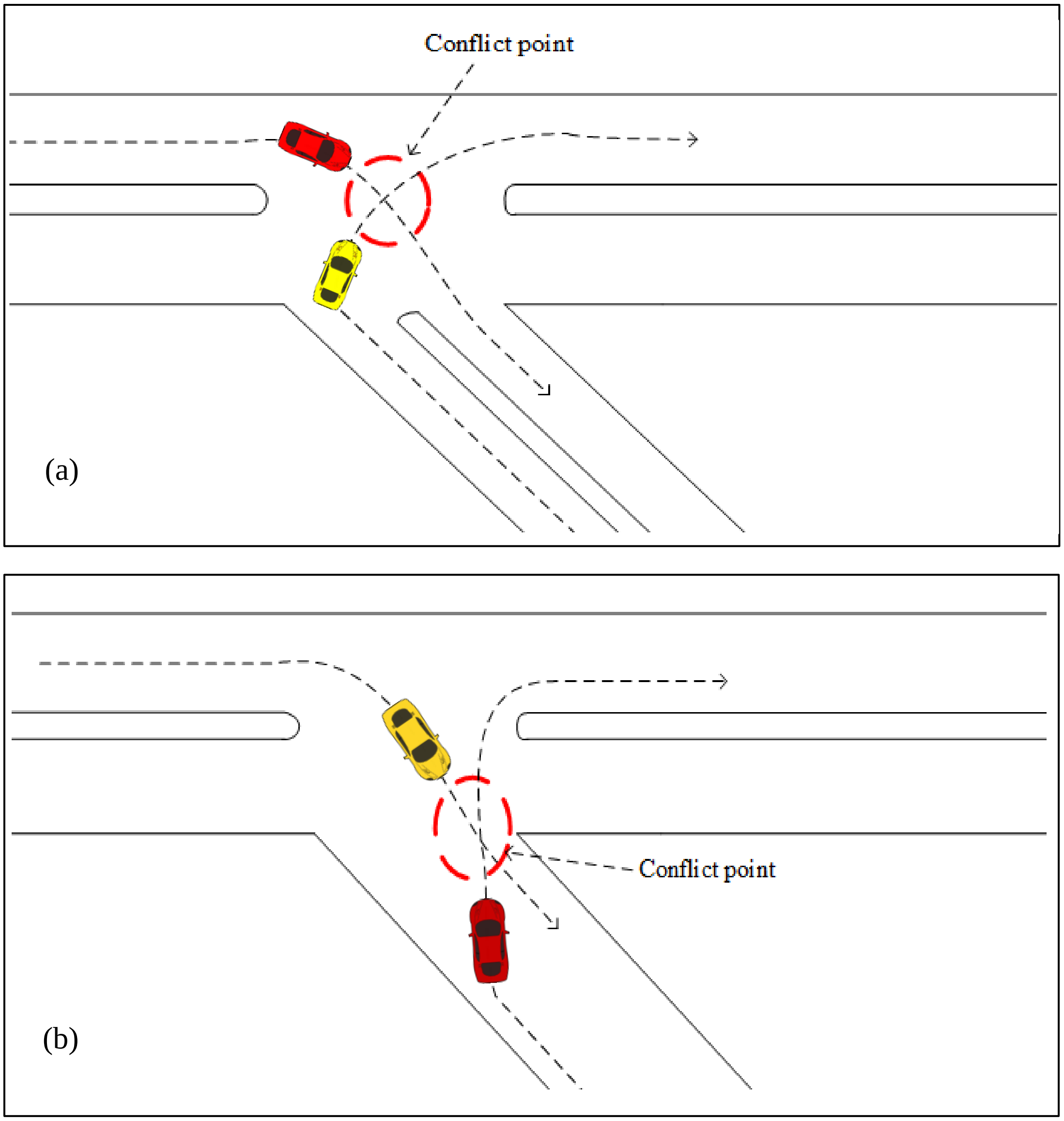

Figure 2 Illustration of path adopted by minor-road right turning vehicles a) typical standard conflict point location between right-turning vehicles b) observed crossing conflict point location

3.2 Data Collection and Extraction

The data for the modeling the base-network in the simulation was obtained through field study. The geometrical characteristics were found out from the field by using measuring wheel. To obtain the traffic characteristics, a video camera with the capability of recording high-definition videos at 25 fps was used. Video-graphic data collection technique was chosen as it allowed for a re-examination of data, particularly the extraction of near-miss data. The camera was set-up using a tripod with a total extendable height of 25 feet. Care was taken to capture the functional area of the intersection. A trained observer was employed to extract the conflict data from the videos. To extract the data, AVS video editor software that allows playing the video frame-by-frame was utilized. Markings were drawn on the video to extract PET data. The video-data frame rate was set to 25 frames per second which allowed to extract the time-data with an accuracy of 40 milliseconds. Apart from the PET data, classified turning volume counts, and critical gaps for major and minor right turning vehicles were extracted. For obtaining the speeds, radar-guns were used in the field and both the approach and turning speeds of vehicles were measured. The morning peak-hour and evening peak-hour conflicts were extracted for the selected road intersection.

The process of extraction of PET data consisted of extracting the time-stamps of the minor and major road right turning vehicles when they arrived at the corresponding stop-lines and departed from the conflict areas. Apart from these, the time-stamp of the arrival of the major road vehicle (conflicting vehicle) at the conflict points are also extracted. The difference of the time-stamps between the arrival of the conflicting vehicle at the conflict point and the departure of the crossing vehicle from the conflict point gave the post-encroachment times (PET). The average number of conflicts with PET less than 5 seconds was observed to be 61. The number of conflicts from the simulation were compared with the observed conflicts from video and the consistency was evaluated with the default driving behavior parameters.

4. DEVELOPMENT OF SIMULATION MODEL

The development of the VISSIM simulation model begins with the usage of the google-earth image of the site as background and drawing the links and connectors with the appropriate number and widths of lanes. Based on the heterogeneity of the traffic observed in the field, four types of vehicles are utilized in the simulation environment namely heavy motor vehicles (HMV), Motorcycles (powered two-wheelers), cars, auto-rickshaws (powered three-wheelers). The three-dimensional models are obtained from PTV Vision. The maximum and desired acceleration and deceleration functions of the various types of vehicles are given as input based on the study by Bokare and Maurya (2017). The volume inputs, routing decisions, desired speed decisions, reduced speed areas, etc., are given as inputs based on the data extracted from videos and collected from the site using speed-guns. The gap values in the priority rules were defined according to that obtained from the gap-acceptance data extracted from the videos. The critical gap values obtained in the study were close to the value obtained in the study by Patil and Pawar (2014). Modified Raff's method was employed to identify the critical gaps for the turning movements (Figure 3). As discussed in section 3.1, the network and the priority rules are defined such that the minor road right turning vehicles move to the right of the intersection within the minor road itself (Figure 4). The visual inspection of the simulation for possible errors was carried out, and it was observed that some crashes occurred in the simulation environment. The reasons were identified, and the network was corrected. However, some crashes were observed and could not be eliminated as explained by Huang et al. (2013). After confirmation that the network and priority rules are defined correctly, the initial calibration was performed. The Geoffrey E. Havers (GEH) statistic for the volume of vehicles generated in the software was observed to be less than 5, and the performance of the simulation was observed to be satisfactory.

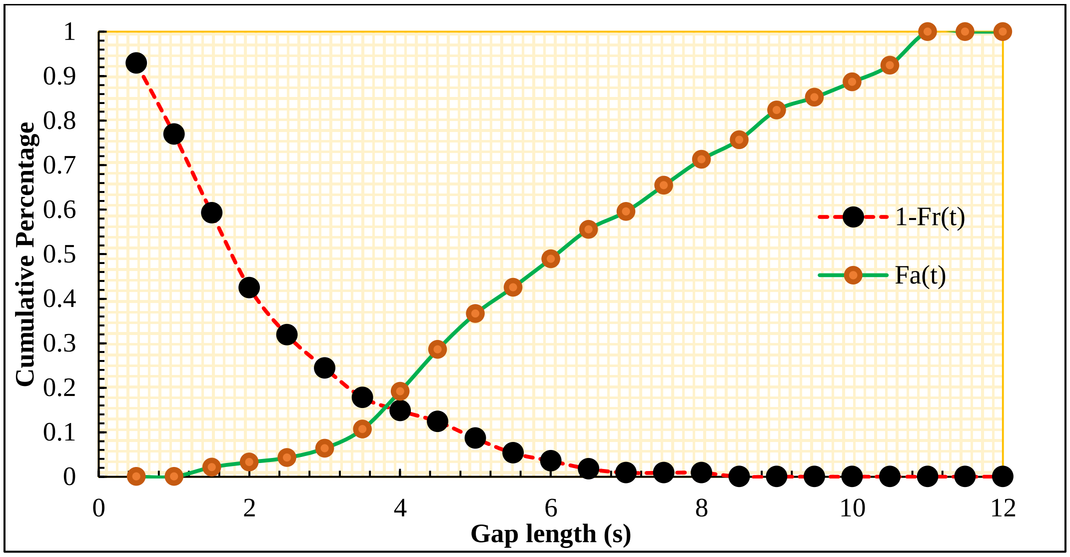

Figure 3 Critical gap estimation using Modified Raff's method

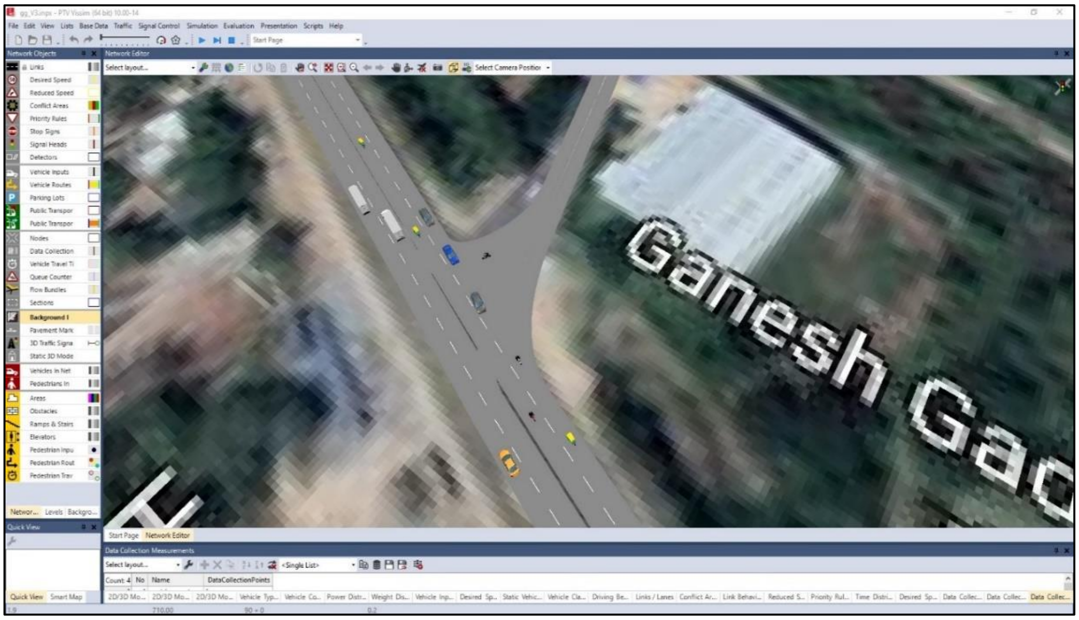

Figure 4 Snap-shot of VISSIM simulation indicating the effect of non-channelization

5. VISSIM SENSITIVITY ANALYSIS

After the initial calibration, sensitivity analysis is performed that identifies the effect of various driver behavior parameters on the number of crossing conflicts. It consists of varying the value of one parameter while keeping the values of other parameters constant at the default values. And determining whether the variation of the considered parameter significantly impacts the number of conflicts/near-misses. The parameter ranges are according to Lownes and Machemehl (2006). Four alternative values for each parameter are taken and defined as low, medium, high and calibrated. The parameter values are not exceeded when the number of simulated conflicts approximately matched the number of field-conflicts. For a particular value of a parameter, if the simulated number of conflicts is closer to that of field-observed from the various alternative values, it is regarded as calibrated and rest are regarded as low, medium and high accordingly. A total of ten car-following parameters CC0 to CC9 of Weidemann-99 model are studied for their effect on the number of crossing conflicts. The description of the parameters is given in Table 1 for reference. For each value of the parameter, six simulation runs were carried out for six different values of the random seed keeping the values of other parameters at default. To perform the simulation at various values of the parameters and with different random seeds, COM interface of MATLAB for VISSIM was used, and the process was automated. The trajectory files generated by the simulations are loaded into SSAM software, and the number of conflicts are extracted. The results are discussed in the following section (section 6).

Table 1 Weidemann - 99 Car following Parameters
(Source: PTV VISSIM 10 User Manual)

S. No.	Parameter	Description
1	**CC0** **(Default value = 1.5 m)**	Standstill distance: The average desired standstill distance between two vehicles. It has no variation.
2	**CC1** **(Default value = 0.9 s)**	Time distribution of speed-dependent part of desired safety distance. Shows number and name of time distribution. Each time distribution may be empirical or normal. Each vehicle has an individual, random safety variable. VISSIM uses this random variable as a fractile for the selected time distribution CC1.
3	**CC2** **(Default value = 4 m)**	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. If this value is set to, e.g. 10 m, the following behavior results in distances between dx-safe and dx-safe + 10m. The default value is 4.0m which results in a quite stable following behavior.
4	**CC3** **(Default value = -8 s)**	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.
5	**CC4** **(Default value = -0.35)**	Defines negative speed difference during the following process. Low values result in a more sensitive driver reaction to the acceleration or deceleration of the preceding vehicle.

6	**CC5** **(Default value = 0.35)**	Defines positive speed difference during the following process. Enter a positive value for CC5 which corresponds to the negative value of CC4.
7	**CC6** **(Default value = 11.44)**	Influence of distance on speed oscillation while in the following process: Value 0: The speed oscillation is independent of the distance Larger values: Lead to a greater speed oscillation with increasing distance. Units: (1/m.s)
8	**CC7** **(Default value = 0.25 m/s^2)**	Oscillation during acceleration
9	**CC8** **(Default value = 3.5 m/s^2)**	Desired acceleration when starting from a standstill (limited by maximum acceleration defined within the acceleration curves).
10	**CC9** **(Default value = 1.5 m/s^2)**	Desired acceleration at 80 km/h (limited by maximum acceleration defined within the acceleration curves).

6. RESULTS

The simulated number of conflicts for various values of random seeds are found out, and the means, medians, standard deviations (SD) and standard errors (SE) are calculated. Table 2 summarizes the various values of parameters used in the sensitivity analysis, the simulated number of conflicts, the standard errors and the t-stat values along with degrees of freedoms and critical values and the decision whether the parameter affects significantly. The formulae employed for finding out the degrees of freedom and t-statistic are shown in equations (1) and (2).

$$df = \frac{\left(\frac{s_{calibrated}^2}{n_{calibrated}} + \frac{s_{high}^2}{n_{high}}\right)^2}{\frac{\left(\frac{s_{calibrated}^2}{n_{calibrated}}\right)^2}{n_{calibrated} - 1} + \frac{\left(\frac{s_{high}^2}{n_{high}}\right)^2}{n_{high} - 1}} \tag{1}$$

$$t = \frac{\bar{x}_{calibrated} - \bar{x}_{high}}{\sqrt{\frac{s_{calibrated}^2}{n_{calibrated}} + \frac{s_{high}^2}{n_{high}}}} \tag{2}$$

Where s^2 is the sample variance and n is the number of observations and $\bar{x}$ is the sample mean.

Table 2 Significance of driving behavior parameters

Parameter	Level	Value	Resulting Near-miss conflicts	SE	t-statistic	Degrees of freedom	Critical t-value	Significantly different from Value at Calibration?
CC0 (Default value = 1.5 m)	Low	1.5	57	5.58	1.08	8	1.86	N
	Calibrated	3	62	9.84	--	--	--	--
	Medium	3.5	60	4.95	0.44	7	1.89	N
	High	4	65	5.26	0.66	8	1.85	N
CC1 (Default value = 0.9 s)	Low	0.5	46	5.93	3.309	10	1.81	Y
	Calibrated	1	57	5.58	--	--	--	--
	Medium	1.5	71	4.04	4.977	9	1.83	Y
	High	2	88	5.18	9.973	10	1.81	Y
CC2 (Default value = 4 m)	low	4	53	5.41	3.04	9	1.83	Y
	Calibrated	7	61	3.53	--	--	--	--
	medium	8.5	70	6.63	2.93	8	1.86	Y
	high	10	109	12.39	9.1	6	1.9	Y
CC3 (Default value = -8 s)	high	-16	59	4.84	0	9	1.83	N
	Calibrated	-12	59	7.52	--	--	--	--
	medium	-8	57	5.58	0.52	9	1.83	N
	low	-4	54	5.19	1.34	9	1.83	N
CC4 &CC5 (Default value = -/+0.35)	Calibrated	0.1	63	6.39	--	--	--	--
	low	0.5	56	6.64	1.86	10	1.81	Y
	medium	1	57	5.34	1.76	10	1.81	N
	high	2	54	4.78	2.76	9	1.83	Y
CC6 (Default value = 11.44)	low	2	56	4.84	0.94	10	1.81	N
	Calibrated	8	59	6.07	--	--	--	--
	medium	11.44	57	5.58	0.59	10	1.81	N
	high	20	57	7.45	0.5	10	1.81	N
CC7 (Default value = 0.25 m/s^2)	low	0.15	54	5.90	1.3	10	1.81	N
	med	0.25	57	5.58	0.34	10	1.81	N
	Calibrated	0.35	58	4.68	--	--	--	--
	high	0.45	54	5.49	1.35	10	1.81	N
CC8 (Default value = 3.5 m/s^2)	low	2	67	7.03	2.169	7	1.89	Y
	Calibrated	2.8	60	3.61	--	--	--	--
	Medium	3	57	5.30	1.145	9	1.83	N
	High	3.5	57	5.58	1.105	9	1.83	N
CC9 (Default value = 1.5 m/s^2)	low	0.5	55	6.4	0.851	10	1.81	N
	Calibrated	1	58	5.7	--	--	--	--
	Medium	1.5	57	5.58	0.305	10	1.81	N
	High	2	55	4.19	1.034	9	1.83	N

6.1 Key parameters Significantly Influencing the Number of Conflicts

The five driving behavior parameters CC1, CC2, CC4 and CC5 were found to affect the number of conflicts at the selected unsignalized intersection. The reasons for the parameters being significant/non-significant are stated below.

CC0: CC0 represents the standstill distance between a leader-follower vehicle pair. It can be observed from the results that CC0 was not significantly affecting the near-misses because of the reason that most of the vehicles do not need to come to a halt and maneuver the intersection. The vehicles slow down and/or swerve to negotiate the intersection. Moreover, the intersection geometry in the study site allows the vehicles to ply at reasonable speeds without coming to a halt (minimum of 20 km/h and a maximum of 75 km/h for all the vehicle types) and therefore, the VISSIM network is also designed to let the vehicles move at such relatively higher speeds. Hence the effect of CC0 is observed to be not as pronounced as CC1. The effect of CC0 can be seen in cases such as bottlenecks or signalized intersections in which the vehicles come to a halt.

CC1: It is a parameter for calculating the safe distance that the driver maintains based upon his speed. When the speed of the following vehicle is relatively low in magnitude, CC0 parameter plays a major role in the calculation of minimum safety distance (dx_safe). Whereas, when the speed of the following vehicle is relatively high, CC1 plays a dominant role. When approaching an intersection, as the minimum safety distance between the leader and the follower increases because of CC1, the gaps generated thereby are liable to be accepted. And, therefore, the higher number of conflicts, which is replicated by table 2. The graph shown in figure 5 gives the pictorial representation of the effect of CC1 on the number of conflicts.

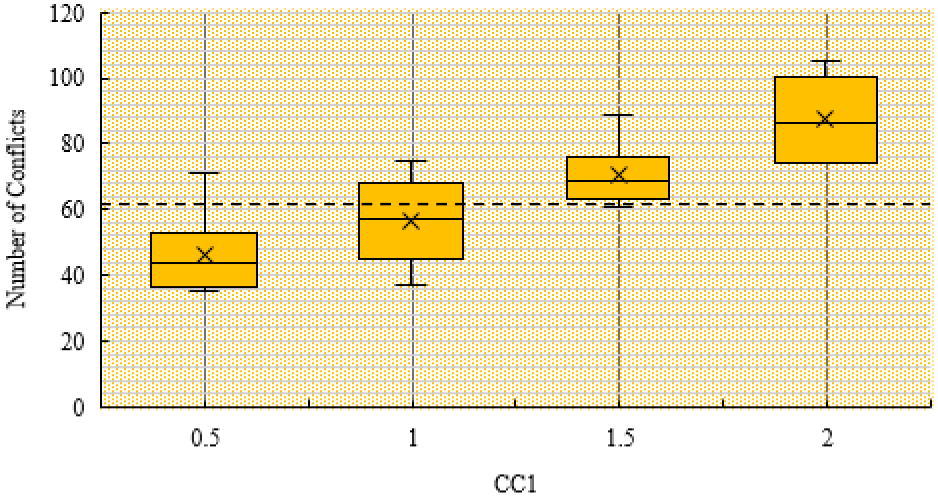

Figure 5 Influence of CC1 on the number of conflicts

CC2: This parameter restricts the longitudinal oscillations of the following vehicles with the lead vehicles. VISSIM manual states that the stable car following behavior will be observed for CC2 of 4 meters. It implies that any value greater or less than four will lead to higher oscillations, within the range from zero to the specified value of CC2. It is evident from table 2 that the number of conflicts increases as CC2 value increases. This is because, as the distance to the lead vehicle increases, turning vehicle finds better opportunity to cross the intersection with lower PET and TTC values. Figure 6 shows the variation in the number of crossing conflicts with respect to different CC2 value. It is observed that the number of crossing conflicts increases with the increase in CC2 values.

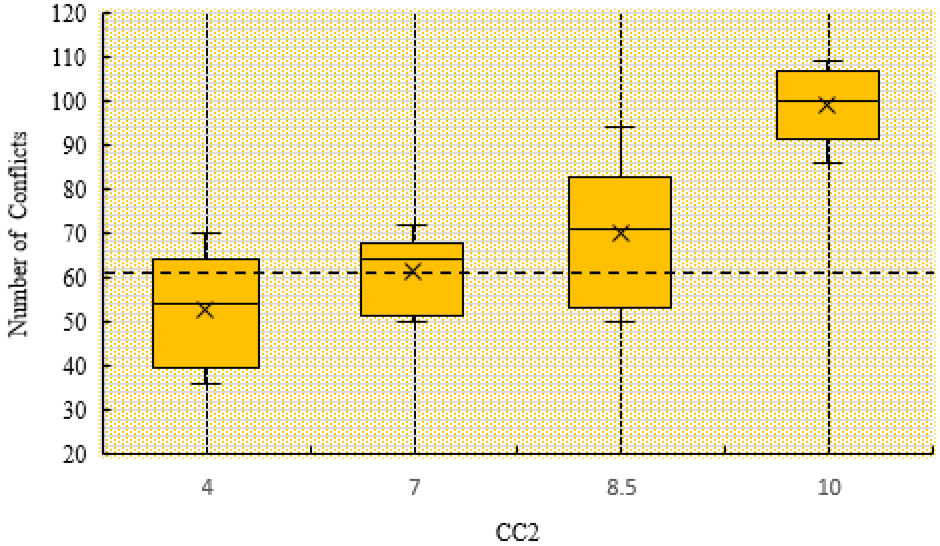

Figure 6 Influence of CC2 on the number of conflicts

CC3: It controls the start of the deceleration process. It is expected to influence the number of near-miss conflicts. However, it was found that the effect of CC2 on the number of conflicts was not significant. This is because the rate at which the vehicle decelerates is more related to the conflicts rather than the time at which the deceleration process starts.

CC4/CC5: These parameters signify the "following thresholds." Lower values of CC4 and CC5 indicate more sensitive reactions of drivers and higher values indicate less sensitive reactions of the drivers to the accelerations and decelerations of the preceding vehicles. It can be observed that the number of near-miss conflicts decreases significantly as the values of CC4 and CC5 increase (Figure 7).

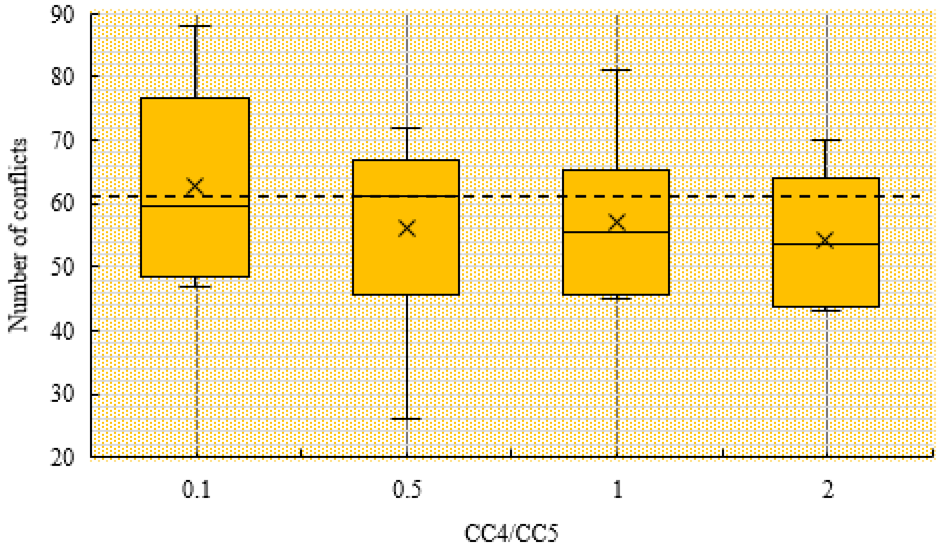

Figure 7 Influence of CC4/CC5 on the number of conflicts

CC6: This parameter indicates the influence of following distance on speed oscillation. Larger values indicate higher speed oscillations which result at higher distances. In other words, vehicles act independently of the distance to the lead vehicles. In the case of higher values of CC6, higher gaps to the lead vehicle will be maintained. So, when the lead vehicle approaches an intersection, the following vehicle oscillates freely at larger distances and will be governed by CC1 and CC2 at the intersection. Therefore, the number of near-miss conflicts at higher values of CC6 is low. Similarly, when the value of CC6 is low, the speed oscillation will also be lower relatively, as the vehicle maintains the same speed as the lead vehicle and therefore the near-miss conflicts are low. At values of mid-range (CC6 ~ 8/m.s) where the vehicles are in transition from the control of the lead vehicle to independence, because of the dilemma in control, relatively more number of near-miss conflicts are seen.

CC7: The parameter represents the oscillation during acceleration. It is observed that CC7 does not affect the number of near-miss conflicts.

CC8: The parameter represents the desired acceleration from standstill. It is expected that the higher values of CC8 would yield higher number of conflicts. However, it was found to be non-significant. At the higher values of desired acceleration, as the priority rules that define the gap acceptance were the same, the number of critical conflicts were not affected. The CC8 parameter is bounded by the maximum and minimum acceleration values defined by base data functions of the individual vehicle types. Hence, it limits the acceleration values for different vehicle types like Trucks, auto-rickshaws and motorcycles according to the respective vehicle specific acceleration functions, thereby showing no significance in the number of conflicts.

CC9: The parameter represents the desired acceleration at 80 km/h. As the speed distribution of the vehicles limits the speeds to 65 km/h, it is expected that CC9 should not have any effect on the car-following behavior and thereby near-miss conflicts, which is validated from the simulations.

7. CONCLUSION AND DISCUSSIONS

As a relatively higher number of accidents occur at unsignalized intersections on the rural roads in India, the current study gives insights into the driving behavior parameters affecting the conflicts which act as surrogates for accidents at unsignalized intersections. The study consisted of creating the base-network in VISSIM replicating the driver gap-acceptance behavior similar to the field conditions. The priority rules were well defined so as to replicate the real world driver behaviour. The minor roads at most of the rural intersections in India do not possess medians or channelizing islands because of which the vehicles from the minor road try to optimize their path by choosing the shortest path. This process gives rise to a virtual stop-line, thereby changing the standard conflict location expected in lane-disciplined traffic. Care was taken while creating the VISSIM network and defining priority rules to replicate the virtual stop-line condition observed in the field. The initial performance check was conducted visually and upon satisfactory simulation, the GEH (Geoffrey E Havers) statistic for volumes was found out and was observed to be less than 5 indicating satisfactory performance. In the next step, the sensitivity analysis was performed by varying the values of one parameter and keeping all other parameters constant at the default values. The importance of the priority rules and the differences between the occurrence of conflicts in a channelized and non-channelized intersection along with the variability of the stop-line are discussed. Five out of ten driver behavior parameters were obtained to be significantly affecting the number of crossing conflicts. The significant parameters are CC1, CC2, CC4, and CC5. CC1(representing the speed-dependent part of desired safety distance) was found to significantly increase the number of conflicts, CC2 (parameter restricting the longitudinal oscillation) also showed the same trend i.e., as the oscillations of vehicles increases, larger gaps will be created, which are accepted by the minor road vehicles resulting in conflicts. It was expected that CC4 & CC5 (defines the negative and positive speed difference while in the following process) affect the number of conflicts significantly and results obtained validated the assumption. The limitation of the study is that the effect of the combination of parameters was not taken into consideration which forms the future scope of the study. Another limitation of the study is the inability to carry out the validation study because of the absence of reliable and pertinent data.

The findings of this study contribute to better understanding the effect of various driver behavior parameters on the number of conflicts. A useful extension of the results would be identification of the effects of interaction of various driver behavior parameters on the number of conflicts at unsignalized T-intersections in heterogeneous traffic environment. By complimenting the study with the use of optimization techniques such as genetic algorithm with the optimal values of the parameters can be found out. The practical application of the study could be in the field of safety simulation of driver assistance systems and autonomous vehicles in VISSIM. The autonomous vehicles’ penetration in Indian market is expected to be relatively slow compared to developed nations and therefore the autonomous vehicles are expected to perform well amid manually driven vehicles. The optimal driver behavior parameter values of the parameters obtained in this study form the input into the simulation system of connected and autonomous vehicles to better represent the driving pattern of manually driven vehicles and thereby calibrating the movements of the autonomous vehicles resulting in an increase in the overall safety of traffic interactions in the simulation system. Another practical application of the study is for the traffic engineers who while evaluating geometric alternatives and traffic management alternatives for ease of congestion, etc. can also modify the significant driver behavior parameters and study the effect on traffic safety.

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