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Prediction of Traffic Conflicts at Signalized Intersection: A Case Study of New Baneshwor Intersection

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Abstract

Microsimulation environment has been widely used for the evaluation of a network under various conditions. However, only few studies have been done for the safety performance evaluation of networks and are rarely performed in the Nepalese context. Such evaluation of an intersection is usually done with the statistical analysis of the crash data collected over a period before and after the modifications have been made in the intersection. However, the data collected may not be reliable as the damage only crashes have a higher chance of being unreported. Furthermore, the collection and documentation of crash records demand a huge amount of time and the solution needed to reduce the possible crashes may not be implemented timely on the site. This study demonstrates the use of microsimulation environment to predict vehicular interactions. VISSIM was used to model and calibrate New Baneshwor Intersection and generate vehicles trajectories. The trajectories thus generated was then fed into SSAM to predict the possible conflicts. Number of potential crossing crashes, lane changing crashes and rear-end crashes that are likely to occur per day at New Baneshwor intersection were found to be 1, 9 and 945 respectively. The relationship between the simulated and observed conflicts was found to be statistically significant with a R-squared value of 0.8545, 0.7474, 0.8677 and 0.9138 for crossing, lane-changing, rear-end and total conflicts respectively.

Keywords

VISSIM, SSAM, Surrogate Safety Measure, PET, TTC, Traffic Conflicts, Crashes, Safety Performance

1. Introduction

1.1 Background

The estimated fatalities rate per 100,000 population due to road crashes in Nepal is 15.9 [1]. Road crashes have been shown to cost annually between 1 percent to 3 percent of GDP in developing countries [2]. In Nepal, the economic cost of RTIs increased by threefold since 2007 and is equivalent to 1.52 percent of GNP as of 2017, indicating the growing national financial burden associated with preventable RTIs [3]. The safety performance evaluation of the roadway network and facilities thus turns out to be necessary.

The safety performance evaluation of an intersection is usually done with the statistical analysis of the crash data collected over some time before and after the modifications have been made in the intersection. However, the data collected may not be reliable as the damage only crashes have a higher chance of being unreported. Thus, the results obtained from such crash data may encounter a reliability issue. Similarly, the collection and documentation of crash records take a huge amount of time and the solution needed to have put on the field sooner to reduce the possible crashes could not be implemented. And the fact that crashes just occur before one can determine the risk of locations is, from an ethical point of view, a disadvantage [4].

It has been found that traffic conflicts are good surrogates for crashes. This means that conflict data may be used as a substitute for crash data [5]. Thus, the way of estimating the crashes based on conflicts have been practiced. The conflict points are determined with the help of microsimulation combined with the Surrogate Safety Assessment Model (SSAM) developed by the Federal Highway Administration (FHWA). The steps in applying simulation are to ensure that the important model inputs have been determined based on observational data and they ensure calibration of the used traffic

simulation model on traffic safety performance values obtained from real trajectories [6].
PTV VISSIM has been used as a microsimulation software. SSAM has been used to perform analysis of vehicle trajectory data output from microscopic traffic simulation models. The output of SSAM includes the number and the type of simulated conflicts.

1.2 Research Objectives

This study is being carried out to predict the vehicular conflicts in New-Baneshwor intersection using microsimulation and SSAM. Specific objectives of the study can be listed as follows:

- To perform microsimulation and calibrate driving behavior to obtain calibrated values.
- To calibrate and validate VISSIM model for traffic volume and average travel time.
- To perform microsimulation of New-Baneshwor intersection and generate trajectories using VISSIM.
- To determine the number of conflicts and classify them according to their types using SSAM and validate them.

2. Literature Review

A traffic conflict is a traffic event involving the interaction of two or more road users usually motor vehicles, where one or both drivers take evasive action such as braking or swerving to avoid a collision [5]. They risk colliding if their movements remain unchanged.

- Time-to-collision (TTC) is the time that is left until a collision occurs if both vehicles continue on the same course and at the same speed. [7].
- PET is the minimum post encroachment time observed during the conflict. Post encroachment time is the time between when the first vehicle last occupied a position and the second vehicle subsequently arrived at the same position. A value of 0 indicates an actual collision. [8]
- MaxS is the maximum speed of either vehicle throughout the conflict (i.e. while the TTC is less than the specified threshold).

Smaller values of TTC and PET shows danger imminent cases and larger values for both PET and TTC result in safe condition [7].

Relationship between conflicts and crashes

A relationship between conflicts and crashes has been presented in equation (1). This result was achieved despite simulating only morning peak-hour volumes [9].

$$\frac{Crashes}{year} = 0.119 * (\frac{conflicts}{hour})^{1.419} \tag{1}$$

The use of microsimulation in combination with surrogate safety measures is a viable and consistent method to perform safety evaluation on different intersection designs [10]. It was found that there is reasonable consistency between the simulated and the observed rear-end and crossing conflicts [11]. VISSIM model cannot provide the necessary results until the prepared model is calibrated and validated [6]. Thus, it has been found that the well-calibrated and validated model can yield promising result regarding the prediction of conflict points at a signalized intersection.
Results obtained and conclusion made from various related papers were also studied.

- TTC ranges between 0.05 - 1.0 second, while the PET ranges between 0.05 - 2.0 seconds [12].
- The best goodness of fit between simulated conflicts and observed conflicts when the maximum TTC threshold was set to 2.7 and the maximum PET threshold was set to 8 [13].
- The R-squared value for the total conflict model was 0.783 [11].

Observing the results, it can be found that the value of TTC and PET assigned depends upon the traffic conditions on a particular site under consideration. For calibration, the best universal measure to compare simulation inputs and outputs is the GEH formula [14]. For hourly flows, the GEH formula is:

$$GEH = \frac{\sqrt{2(m-c)^2}}{\sqrt{m+c}}$$

where,

- m = output traffic volume from the simulation model (vph)
- c = input traffic volume (vph)
- GEH <5.0 - Acceptable fit
- $5.0 <=$ GEH $<= 10.0$ - Caution: Possible model error or bad data
- GEH >10.0 - Unacceptable

Classification of type of conflicts [8]

- Rear-end conflict if conflict angle is less than 30 degrees.
- Crossing conflict if Conflict angle is greater than 85 degrees, else a lane-changing conflict.

Few types of research have been carried out regarding the determination of conflicts using the surrogate approach in developed countries. Research focusing on determining vehicular conflicts in developed countries may not apply to the study of a similar situation in developing countries. This study thus can be used for locating conflicts and thereby such results can be used for the improvement of traffic facilities to reduce the number of vehicular conflicts.

3. Methodology

3.1 Study Area

Several pieces of literature have been studied regarding the determination of conflicts and the way how the study area have been selected were found to be quite similar. The study area was selected with high traffic volume. New Baneshwor intersection has found to satisfy the criteria and hence selected as the study area for the research. General layout of New Baneshwor Intersection has been shown in figure 1.

Figure 1: New Baneshwor Intersection

3.2 Video-graphic Survey and Data Extraction

3.2.1 Video-graphic Survey

The video was taken for morning and daytime for six days. The video was taken at three different times in a day – 5:00 - 7:00 AM, 9:00 - 11:00 AM and 1:00 - 3:00 PM for six days.

3.2.2 Data Extraction

The obtained video was played several times to carry out classified volume count. The vehicle types were considered as per Nepal Road Standard 2070 [15] shown in table 1.

Table 1: Vehicle Types and Equivalency Factors

SN	Vehicle Type	Equivalency Factor
1	Bicycle, Motorcycle	0.5
2	Car, Auto Rickshaw, SUV, Light Van and Pickup	1.0
3	Light (Mini) Truck, Tractor, Rickshaw	1.5
4	Truck, Bus, Minibus, Tractor with trailer	3.0
5	Non-motorized carts	6.0

Non-motorized carts, rickshaw and tractor have not been considered while classifying the total vehicles counted as their frequency is relatively low compared to other vehicle types. Directional movement involving through movements, left turns, right turns and signal timing and phase data were also obtained from the video. The traffic volume was also extracted from the video.

3.3 Microscopic Simulation Model

PTV VISSIM was used for the development of the model. Following data were used as input for VISSIM such that the model prepared reflects the existing field condition.

- Vehicle Types
- Classified Vehicle Count
- Directional movement of vehicles
- Relative flows for static vehicle routing
- Signal Timing

3.4 Processing With SSAM

The trajectories obtained from VISSIM after simulation were then fed into SSAM for prediction of conflicts. The TTC and PET were set so as to obtain the conflict with maximum severity. The simulated conflicts so obtained were then compared with the observed conflicts in the field.

4. Calibration and Validation of the Model

4.1 Calibration of Driving Behvaior

Driving behavior parameters were altered so as to match the traffic volumes obtained from VISSIM with the field data. The calibrated driving behavior parameters have been presented in table 2.

Table 2: Calibrated Driving Behaviour Parameters

SN	Parameters	Calibrated Values
1	Look ahead distance-min	30.00 m
2	Look back distance-min	5.00 m
3	Average Standstill Distance	0.30 m
4	Min headway (front/rear)	0.50 m
5	Average standstill distance	0.30 m
6	Additive part of safety distance	0.19
7	Multiplicative part of safety distance	0.71

4.2 Calibration and Validation of Model for Traffic Volume

On using GEH formula, the values were obtained below 5, that indicated acceptable fit when the total field volume and the VISSIM volume were compared and analyzed. Furthermore, considering a total of twelve days data for time period 9:00 – 11:00 AM (4 days), 1:00 – 3:00 PM (4 days) and 5:00 – 7:00 AM (4 days), the calibration of VISSIM model and its validation are presented in figure 2 and figure 3 respectively. R squared value after calibration was found to be 0.9998 which indicates 99.98 percent of the variance of the field data is explained by the variance of the VISSIM output. Regression equation so obtained is given by:

VISSIM Volume = 0.9631*Field Volume

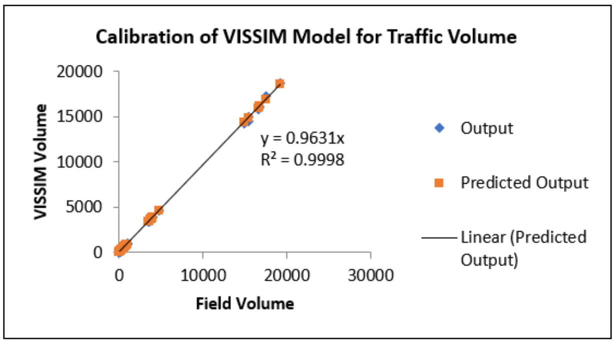

Figure 2: Calibration of VISSIM Model for Traffic Volume

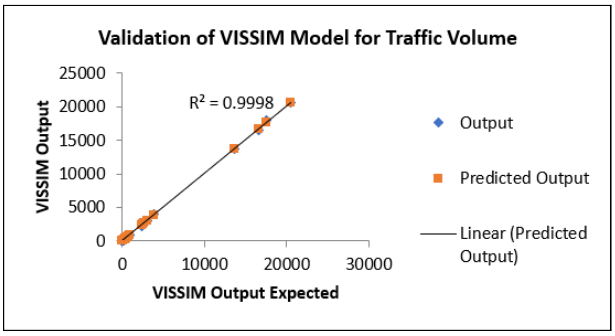

Figure 3: Validation of VISSIM Model for Traffic Volume

4.3 Calibration and Validation of Model for Travel Time

The average field travel time and average VISSIM travel time using the data for four days were compared by performing regression analysis. The R squared value after calibration (figure 4) was found to be 0.9782 and regression equation so obtained is given by:

Average Field Travel Time = 1.0259*Average VISSIM Travel Time

The validation was done using two days data with a R-squared value of 0.9655 (figure 5).

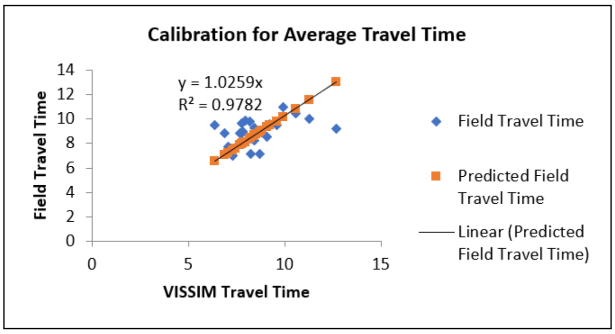

Figure 4: Calibration of VISSIM Model for Average Travel Time

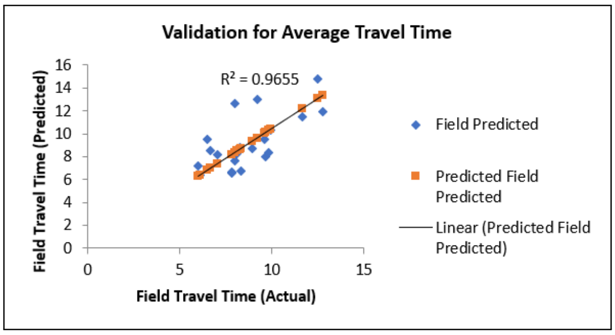

Figure 5: Validation of VISSIM Model for Average Travel Time

5. Data Analysis and Results

5.1 Traffic Volume and Traffic Composition

The directional traffic volume at New Baneshwor intersection for a single day throughout the study period of 5:00 - 7:00 AM, 9:00 - 11:00 AM and 1:00 - 3:00 PM has been shown in figure 6, figure 7 and figure 8 respectively.

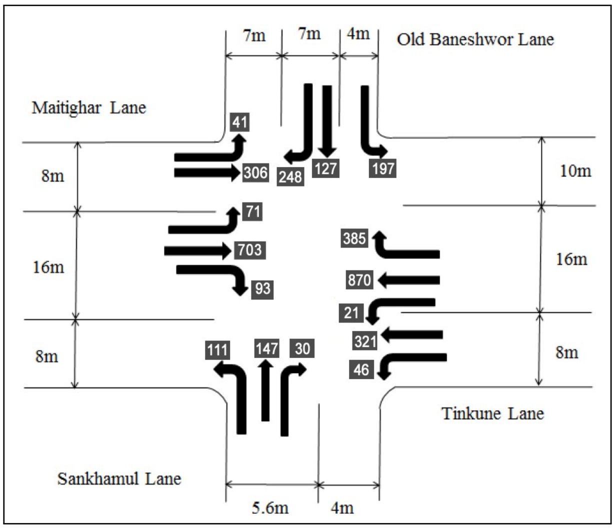

Figure 6: Directional movement in PCU (5:00-7:00 AM)

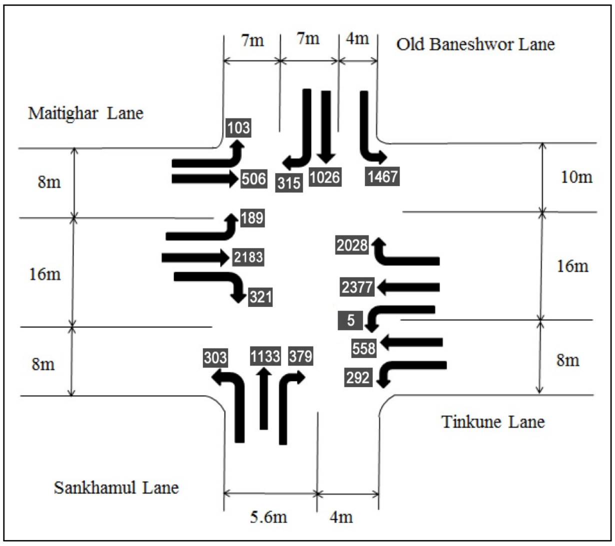

Figure 7: Directional movement in PCU (9:00-11:00 AM)

The traffic volume at the intersection for the study period of 5:00 - 7:00 AM, 9:00 - 11:00 AM and 1:00 - 3:00 PM was found to be 3717 PCU, 13185 PCU and 14276 PCU respectively. Traffic study showed that motorcycle contributed the maximum to the total traffic volume. Motorcycle alone contributed to 75 percent of total volume followed by car with 16 percent. Minibus, microbus, pickup, tempo, big bus, minitruck contributed to 3.5, 1.1, 1.02, 1.47, 0.13, 0.39 percentage respectively. The percentage of privately-owned vehicles seemed to be more than that of publicly operated vehicles.

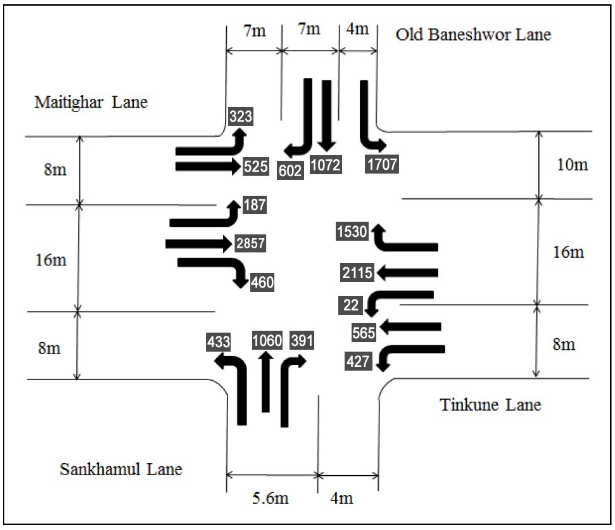

Figure 8: Directional movement in PCU (1:00-3:00 PM)

5.2 Relative Flows

The total volumes from Maitighar in the main lane was split towards Sankhamul, PuranoBaneshwor, Tinkune (on Service lane and the Main lane). The relative flow for vehicles moving from other directions were also calculated accordingly. A sample data of relative flow is shown in figure 9. Figure 9 shows the relative flow of microbus from Maitighar main lane to respective lanes. The relative flow from Maitighar to Sankhamul is taken as unity as a separate right turning lane has been used for vehicular movement for that route.

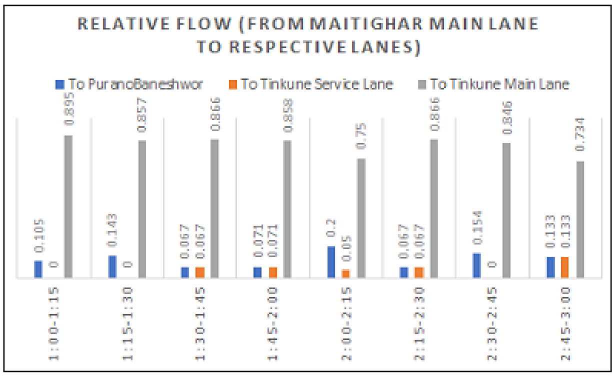

Figure 9: Relative Flows: Maitighar Main Lane to Respective Lanes

5.3 Evaluation: Prediction of Conflicts

The trajectories extracted from VISSIM were then fed as input into SSAM. For the minimum value of TTC and PET, the danger is imminent, and the condition is safer for higher values of TTC and PET [7]. Initially, an analysis was done setting maximum PET and TTC as 1.50 seconds. However, for lower values of PET, the rear end conflicts were found to be underestimated. Therefore, maximum PET was taken as 5 seconds. Any conflicts with conflict angle less than 30 degrees were categorized as rear-end conflicts, more than 85 degrees were categorized as crossing conflicts, else were categorized as lane changing conflicts. [8]. The analysis was performed with priority rules (i.e. yield sign has been placed for through vehicles from Sankhamul against right-turning vehicles from Purano Baneshwor and similar conditions for other lanes). Thousands of conflicts were obtained while processing the trajectories obtained from VISSIM using SSAM. The summary of conflicts as per their type has been presented in table 3 for 5:00 - 7:00 AM, in table 4 for 9:00 - 11:00 AM and in table 5 for 1:00 - 3:00 PM.

Table 3: Traffic Conflicts for 5:00 - 7:00 AM

Day	Crossing	Lane change	Rear-end
Monday	144	125	1442
Tuesday	122	149	1363
Wednesday	139	145	1548
Thursday	85	83	521
Friday	81	97	854

Table 4: Traffic Conflicts for 9:00 - 11:00 AM

Day	Crossing	Lane change	Rear-end
Sunday	623	2353	65200
Monday	502	2500	76460
Tuesday	614	2499	92604
Wednesday	299	3828	108933
Thursday	398	2286	78310
Friday	462	3551	103953

The number of crossing conflicts was higher although the volume for 5:00 - 7:00 AM is comparatively less than for 9:00 - 11:00 AM and 1:00 - 3:00 PM. It is due to the absence of traffic police officer in the field to guide the movement of vehicles. The rear-end conflict was found to increase after 6:00 AM due to queuing of vehicles beyond the stop line after the police officer arrives in the field.

Table 5: Traffic Conflicts for 1:00 - 3:00 PM

Day	Crossing	Lane change	Rear-end
Sunday	261	2719	52661
Monday	520	2151	45560
Tuesday	376	2518	55415
Wednesday	366	3215	80288
Thursday	414	2855	71482
Friday	485	3115	88646

The total number of vehicles being higher on Wednesday for 5:00 - 7:00 AM (6525), Wednesday and Friday for 9:00 - 11:00 AM (22800 and 25017 respectively), the rear-end conflict has also found to be higher on these days. The rear-end conflict depended not only on the total vehicles but also on the vehicle arrival pattern and the phase duration. The rear-end conflicts are found to be lower on those days when the intersection is cleared quickly than on those days when the vehicles have to be in a queue for a longer duration. The effect of such arrival pattern and phase duration can be seen in case of Tuesday for time period 1:00 - 3:00 PM (Table 5). The volume of Tuesday (23402) being higher than other days of the week, lesser rear-end conflicts have been seen.

The crossing conflicts were found to increase on those days when vehicles still tend to move even after the traffic police officer indicated to stop. Such crossing conflicts were mostly concentrated on the link joining Maitighar (Main Lane) to Tinkune (Main Lane) and the link joining Tinkune (Main Lane) to Maitighar (Main Lane). This was due to the movement of right-turning vehicles from Tinkune towards Purano Baneshwor, from Purano Baneshwor towards Maitighar and from Maitighar towards Sankhamul. The considerable effect of right-turning vehicles from Sankhamul towards Tinkune was not seen due to lower traffic volume.

The lane changing conflicts were seen maximum during merging. The interaction of vehicles moving from Maitighar (Main Lane) to Tinkune (Main Lane) and Purano Baneshwor to Tinkune (Main Lane) suffered maximum lane changing conflicts. The number of lane changing conflicts observed due to interaction of vehicles from Tinkune to Purano Baneshwor and Sankhamul to Purano Baneshwor was also high. The sample of the total number of conflicts located on some links as per their types for Wednesday 9:00 - 11:00 AM has been presented figure 10.

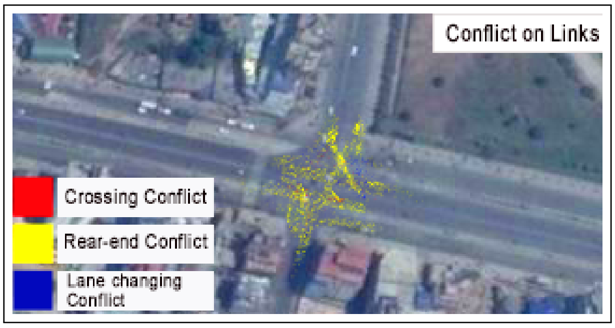

Figure 10: Types of conflict on links

The maximum speed of either vehicle (MaxS) throughout the conflict (i.e. while the TTC is less than 1.50) for different time period along with the total number of vehicles within the study period has been shown in table 6. It can be seen that the MaxS if higher when the total number of vehicles is less and vice-versa.

Table 6: MaxS for the various study periods

SN	Time	Total Vehicles	MaxS (kmph)
1	5:00 - 7:00 AM	5891	14.823
2	9:00 - 11:00 AM	21542	14.310
3	1:00 - 3:00 PM	21465	14.311

The potential crashes throughout the year determined after simulating only the peak hour morning volume has been presented in table 7 and the average crashes per day has been presented in table 8.

Table 7: Potential Crashes Per Year

Day	Crossing	Lane change	Rear-end
Sunday	299	3661	310076
Monday	221	3376	353186
Tuesday	551	2320	355666
Wednesday	160	4773	496447
Thursday	229	2084	193537
Friday	107	3954	362789

Table 8: Potential Average Crashes per day

Day	Crossing	Lane change	Rear-end
Sunday	1	10	850
Monday	1	9	968
Tuesday	2	6	974
Wednesday	1	13	1360
Thursday	1	6	530
Friday	1	11	994

5.4 Validation of Simulated Conflicts

The validation of simulated conflicts was done through field validation as done in reviewed literatures [12], [11], [13]. Linear regression analysis was performed to study the relationship between the simulated conflicts and observed conflicts in the field. The results of the analysis have been presented in figure 11, figure 12, figure 13 and figure 14 for crossing, lane-changing, rear-end and total conflicts respectively.

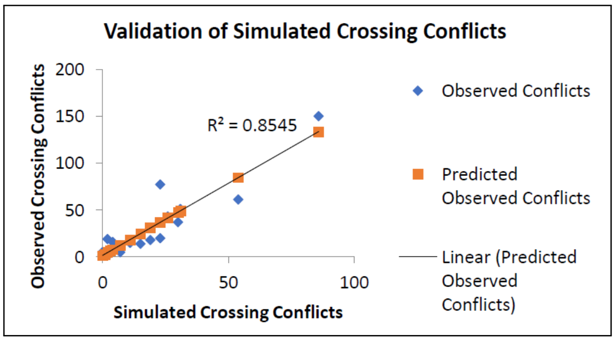

Figure 11: Validation of Crossing Conflicts

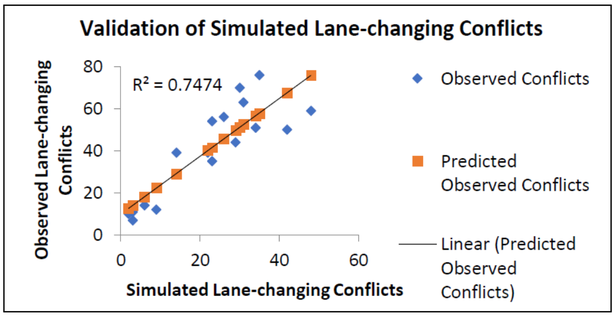

Figure 12: Validation of Lane-changing Conflicts

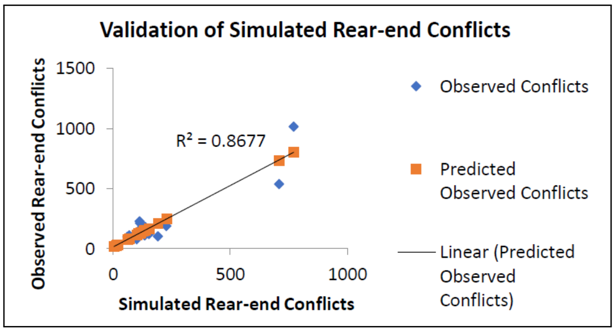

Figure 13: Validation of Rear-end Conflicts

It was found that the relationship between the simulated and observed conflicts was found to be statistically significant with a R-squared value of 0.9138 for total conflicts which indicates 91.38 percent of the variance of the observed conflicts is explained by the variance of the simulated conflicts. The R-squared value for crossing, lane-changing and

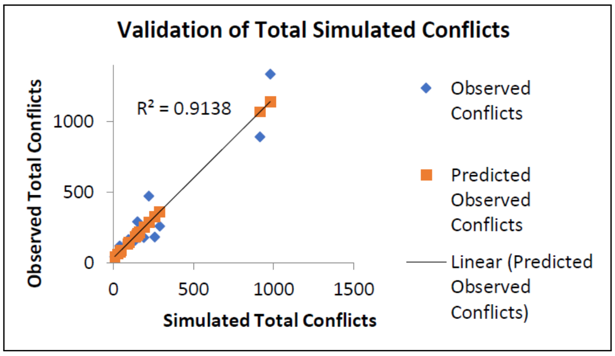

Figure 14: Validation of Total Simulated Conflicts

rear-end conflicts were found to be 0.8545, 0.7474 and 0.8677 respectively.

6. Conclusion

It can be seen that 1 crossing crash, 9 lane-changing crashes and 945 rear-end crashes are likely to occur, which is high. The crossing conflict is concentrated near the intersection as no effective clearance time has been provided after each phase to clear vehicles remaining in the intersection. The number of rear-end conflict is high due to lesser space headway between vehicles and congestion. Such rear-end conflict involves damage only crashes which generally goes unreported. Few lane-changing conflicts can also be seen. It can be seen that for the limited traffic facilities provided, with the increase in traffic volume, the rear-end conflicts tend to increase. However, the severity of conflicts goes on decreasing as the velocity of the interacting vehicle decreases with higher traffic volume. The reduction of conflicts can be done by providing a longer clearance time. Scenario analysis can be performed by bringing out changes in the traffic facilities so as to find out a better alternative for the improvement of safety performance.

7. Recommendations

Following tasks are recommended for further studies.

- Study of pedestrian-vehicle interaction taking pedestrian modelling into account.
- The type of interacting vehicle can be taken into consideration so that the most vulnerable of crashes can be identified.
- Study considering the movement of vehicles from service lane to the main lane and vice-versa within a particular intersection leg.

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