

INTERSECTION GEOMETRIC DESIGN MODIFICATIONS AND THEIR EFFECTS ON TRAFFIC CONFLICTS: A VISSIM AND SSAM-BASED STUDY

K. M. T. Jubaer^{*1}, M. S. Rahman² and M. M. Rahman³

¹ Student, Department of Civil Engineering, BUET, Bangladesh, e-mail: tjtanvirjubaer@gmail.com

² Student, Department of Civil Engineering, BUET, Bangladesh, e-mail: shajidurrahman1998@gmail.com

³ Professor, Department of Civil Engineering, BUET, Bangladesh, e-mail: mizanur@ce.buet.ac.bd

***Corresponding Author**

ABSTRACT

Urban intersections in developing countries such as Bangladesh operate under highly mixed traffic conditions, where cars, buses, motorcycles, and para-transit vehicles share limited road space with a large number of non-motorized vehicles (NMVs), including rickshaws and bicycles. At busy signalized intersections in Dhaka, this interaction often leads to unstable traffic flow, frequent conflicts, and elevated safety risks. While previous studies have largely focused on signal optimization, the safety impacts of geometric design interventions - particularly the separation of NMVs from motorized traffic - remain relatively underexplored. This study evaluates the safety effects of introducing a dedicated 2.5-m NMV lane at the Shajahanpur four-way signalized intersection in Dhaka. A detailed microscopic traffic simulation model was developed in PTV VISSIM 2024 using field-observed data on roadway geometry, traffic volumes, vehicle composition, and signal control. The model was carefully calibrated and validated using the GEH statistics, with all approaches achieving values below 5, ensuring a realistic representation of local mixed-traffic behavior. Intersection safety was assessed using vehicle trajectory data analyzed in the Surrogate Safety Assessment Model (SSAM) Version 3.0. Under existing conditions, a high number of conflicts, mainly rear-end and lane-changing interactions, were observed due to frequent speed variations and close vehicle spacing. After reallocating existing road space to provide separate NMV lanes on all approaches, total conflicts were reduced by 43.65%. Substantial reductions in rear-end and lane-changing conflicts indicate smoother vehicle interactions and improved lane discipline. Although crossing conflicts increased due to turning movements and fixed-time signal control, the overall safety performance improved markedly. The findings suggest that providing dedicated space for NMVs through simple geometric design modifications offers a practical and low-cost approach to improving safety at mixed-traffic intersections in developing cities.

Keywords: *Mixed traffic, NMV lane, Microsimulation, Traffic conflict, Intersection safety*

1. INTRODUCTION

Urban intersections in developing countries like Bangladesh often face highly mixed traffic conditions. Cars, buses, motorcycles, rickshaws, bicycles, and pedestrians share the same limited road space, each moving at different speeds and with different behaviors. This mix creates frequent interactions, irregular traffic flow, and higher safety risks. In densely populated cities such as Dhaka, rising travel demand and limited road infrastructure worsen congestion and increase the likelihood of conflicts, making intersection safety a major concern for traffic engineers and urban planners (Hossain, 2004; Alam & Habib, 2016).

A growing number of studies have highlighted the role of geometric design in improving intersection safety. Features like lane width, turning radius, lane layout, and dedicated space for slower vehicles can strongly influence crash patterns and severity (Lord & Bonneson, 2007; Elvik et al., 2009; AASHTO, 2018). When intersections do not properly accommodate non-motorized vehicles, conflicts such as rear-end crashes, sideswipes, and collisions during lane changes become more common (Zhou et al., 2016; Park & Abdel-Aty, 2018). These findings show that traffic signals alone are not enough—careful geometric design is essential to reduce risk in mixed-traffic environments.

Simulation-based approaches have become valuable tools for studying these safety issues. Microsimulation models like PTV VISSIM can replicate the complex interactions between different traffic modes, and when combined with the Surrogate Safety Assessment Model (SSAM), they can identify and quantify potential conflicts such as rear-end, crossing, and lane-changing events (Gettman & Head, 2003; Tarko, 2012; Fan et al., 2013). Several studies have successfully used this approach to evaluate the safety impacts of lane reallocation, channelization, and other geometric design changes (Shrestha et al., 2017; Zhao et al., 2019; Muley et al., 2018).

Despite these advances, research in Bangladesh remains limited. Most studies focus on signal timing, traffic flow management, or general mode separation, with little attention to how geometric design changes, like reallocating space for non-motorized vehicles, affect safety under mixed-traffic conditions (Ahmed et al., 2020; Singh et al., 2024).

To fill this gap, this study examines the effect of introducing a dedicated 2.5-meter lane for non-motorized vehicles at the Shajahanpur four-way signalized intersection in Dhaka. A calibrated microsimulation model was developed using detailed field data, and the model was validated using the Geoffrey E. Havers (GEH) statistic. Vehicle trajectories were analyzed with SSAM Version 3.0 to evaluate conflict frequency and types under both the current and modified intersection layouts. The results aim to provide practical insights for urban planners and policymakers seeking cost-effective ways to improve safety and traffic flow in mixed-traffic intersections.

2. METHODOLOGY

This study emphasizes on observing the change in conflict by assessing NMV lanes in a 4-way intersection. First a VISSIM 2024 model was developed with proper lanes, vehicle compositions, routes, phase etc. Later the model was calibrated and validated with real time data. Then with the help of SSAM software the change in conflict was observed. The research methodology was progressed as shown in Fig 1.

2.1 Site Selection & Data Collection

Traffic engineering relies on real-world data to analyze and improve roadway performance. For this study, a 4-way intersection in Shajahanpur area (Fig 2) was selected. The selection criteria were; presence of heavy and mixed traffic flow so that a noticeable change occur, adequate road width to accommodate NMV lane, an intersection that was never studied before, suitable place for instrument setup to collect data etc. Video for 60 minutes at peak hour (8 a.m. to 9 a.m.) was recorded for 2

consecutive days(Tuesday and Wednesday). Traffic data such as vehicle composition, routes, types etc. were collected from the recorded video. Vehicle speed and signal phase was measured by calculating several readings and taking the averages. On the other hand, road geometry data such as number of lanes at each side, lane width, island width, shoulder width were measured using odometer. During the measurement of road geometry diverse data was found. In the case of lane numbers, Both upstream and downstream had 2 lanes in East and West side, each lane having a width of 3.81m(12.5ft). The upstream of North and South had 3 lanes and downstream consists of 2 lanes. The South side upstream and downstream both had a lane width of 3.35m (11ft). The north side upstream had a lane width of 3.66m(12ft) and downstream had a lane width of 3.81m(12.5ft). Presence of shoulder, island and footpath were also noted.

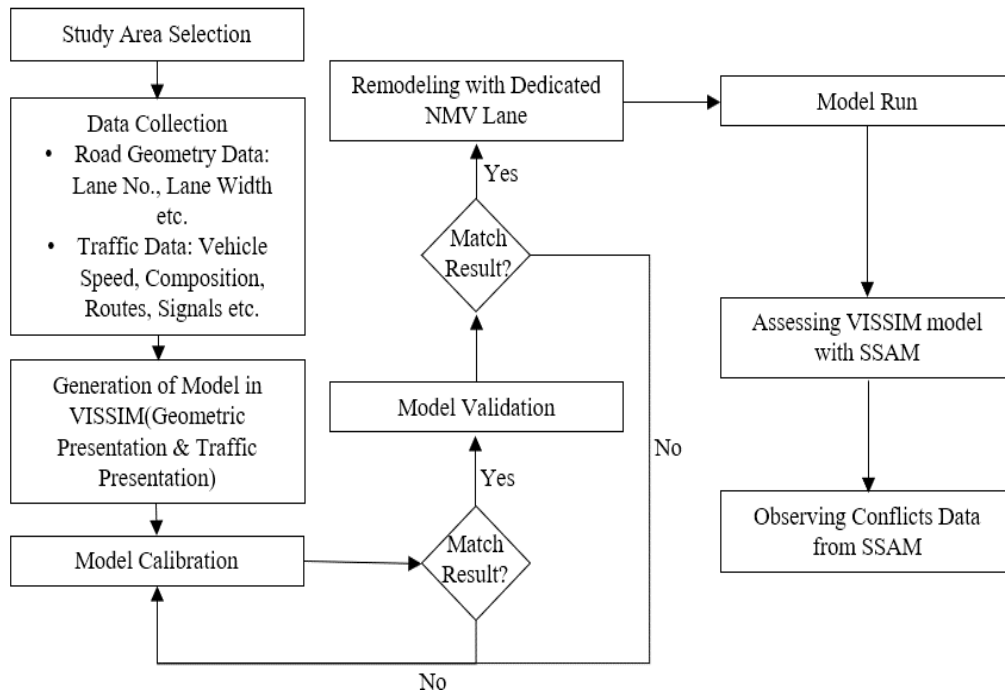


Fig 1: Study Approach



Fig 2: Study Area (Shajahanpur Four-way Intersection)

The study area includes 8 types of vehicles (Fig 3). In the motorized section we have cars, buses, trucks, motorcycles, legunas and CNGs. On the other hand, in the non-motorized section, we have cycle and rickshaw only. This indicates that the Shajahanpur intersection experiences significant congestion due to the high proportion of NMV's (38%) and shared transport vehicles. This intersections traffic issue seems more influenced by the slower movement of NMVs. All these suggests that adding NMV lane will surely give a noticeable change in the intersection.

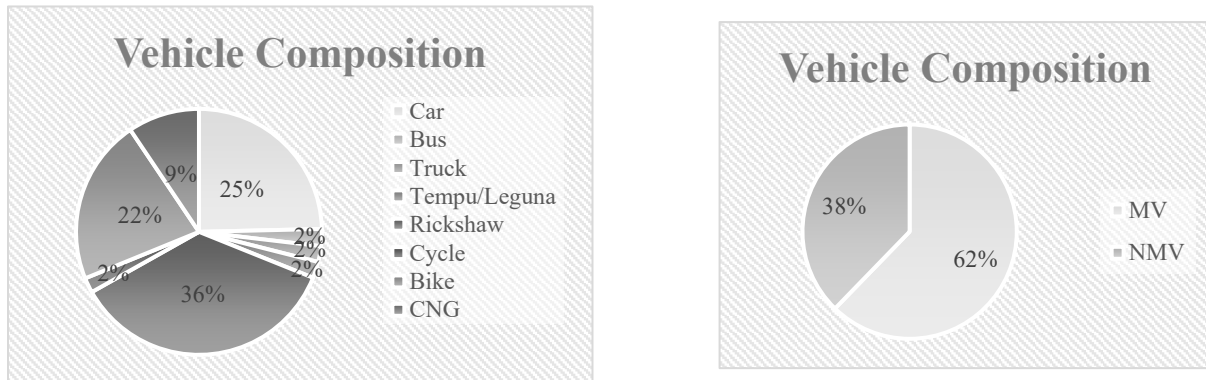


Fig 3: Vehicle Composition

2.2 Model Development, Calibration and Validation

The model of the 4-way intersection was developed using internal map of VISSIM 2024 software. Creating the model required existing road geometry data (Fig 4) which were collected via on site survey. Then vehicle routes were added. For traffic input, vehicle count from 15 minutes video was converted to hourly data using reasonable factors and added to simulation according to their vehicle composition. Rickshaw being a locally used vehicle, the 3D model was manually added to the simulation. Signal phasing was included by taking the average value of real time data (Fig 5). In this case, east and west approach was found to be green at the same time.



Fig 4: Four-way intersection

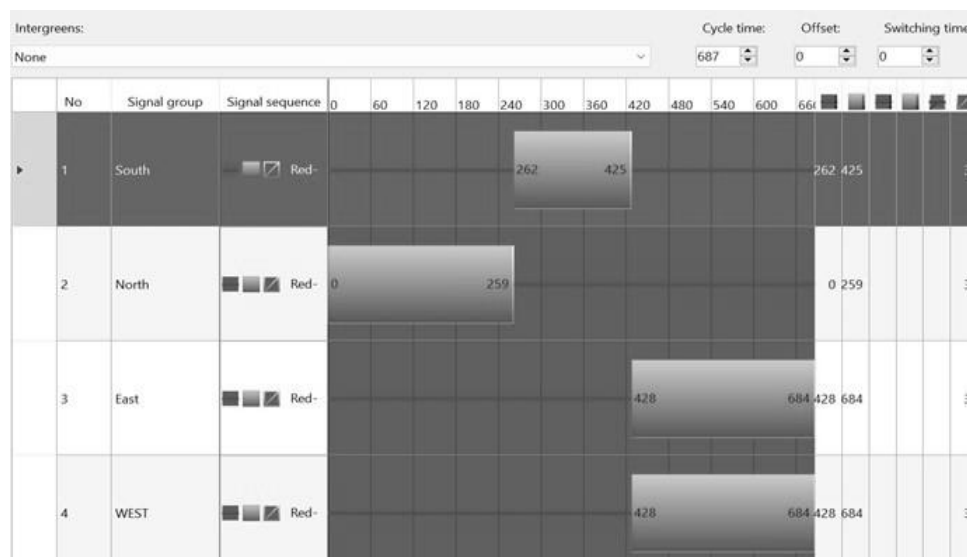


Fig 5: Signal group of 4-way Intersection Model

Calibration was done to adjust parameters to replicate real life scenario as well as satisfy GEH (Geoffrey E. Havers statistic) criteria which is,

$$GEH = \sqrt{\frac{2 * (\text{simulated volume} - \text{observed volume})^2}{(\text{simulated Volume} + \text{observed volume})}} \quad (1)$$

As general guideline, in equation (1), values of $GEH < 5.00$ means acceptable fit, $5.00 \leq GEH \leq 10.00$ meaning further adjustment required and $GEH > 10.00$ is unacceptable. As for parameters, car following (Wiedemann 74 model) was adjusted using Genetic Algorithms while lane changing and lateral aspects parameters were adjusted by visual observation at site for attaining field conditions (Table 1). Calibration was done by using the data from first day and validation was done by using the data from the next day. Table 2 and 3 shows the GEH value for both calibration and validation data. In all cases The GEH value was found to be less than 5 meaning the model was ready to progress further.

Table 1: Calibrated value of parameters

Aspect	Parameter	Default	Calibrated
Car Following	Average Standstill Distance (m)	2	0.15
	Additive part of the safety distance (m)	2	0.08
	Multiplicative part of the safety distance (m)	3	0.96
Lane Changing	Overtake reduce speed areas	Not Allowed	Allowed
	Vehicle Routing Decision	Not Allowed	Allowed
	Min Clearance Front/Rear (m)	0.5	0
	Safety Distance Reduction Factor	0.6	0
	Maximum deceleration for cooperative breaking (m/s ²)	-3	-10
Lateral Aspects	Overtake on same lane – Left	Not Allowed	Allowed
	Overtake on same lane – Right	Not Allowed	Allowed
	Desired position at free flow	Middle of lane	Any
	Observe adjacent lanes	Not Allowed	Allowed
	Consider next turn	Not Allowed	Allowed
	Minimum lateral distance at 0 km/h (m)	0.2	0
	Minimum lateral distance at 50 km/h (m)	1	0

Table 2: GEH Value from Calibration

Upstream	Input	Output	GEH
North	1886	1701	4.37
South	976	840	4.51
West	1902	1751	3.53
East	1596	1423	4.45

Table 3: GEH value from Validation

Upstream	Input	Output	GEH
North	1280	1226	1.53
South	1050	913	4.37
West	1740	1611	3.15

East	2058	1879	4.03
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2.3 Modifying Model for Dedicated NMV Lane:

Completing the calibration and validation process, the model was then redesigned for a dedicated NMV lane. A 2.5m (8ft) lane was created without exceeding the existing road space (Fig 6). As a result, the 3 lanes mixed traffic road (north and south upstream) became dual lane for MV and single lane for NMV. Similarly, 2 lane mixed traffic (except north and south upstream) became single lane for MV and single lane for NMV. Vehicle composition was kept same but NMV was assigned in NMV lane and MV was assigned in MV lane.



Fig 6: Modified Model having dedicated NMV Lane

2.4 Assessing with SSAM and Conflict Data Extraction

PTV VISSIM lacks the tool required to analyze conflict data at intersection. To overcome this limitation, Surrogate Safety Assessment Model (SSAM 3.0) was used to analyze conflict. After calibrating and validating both models (Models before and after adding NMV lane) the vehicle trajectory files were extracted from VISSIM and imported into SSAM to analyze conflict data. Three types of conflicts was categorized by the SSAM software. These included rear-end conflicts, which occur when a following vehicle approaches too closely to the one ahead, indicating a risk of sudden braking or collision; lane-change conflicts, which arise when vehicles in adjacent lanes perform abrupt or unsafe lane changes, increasing the likelihood of side-swipe incidents; and crossing conflicts, typically found at intersections where vehicles from different directions come into close proximity, posing a risk of right-angle or T-bone crashes.

3. RESULTS AND DISCUSSION

At the Shajahanpur four-way intersection, introducing a 2.5-meter dedicated NMV lane significantly improved safety. Total conflicts decreased from 55,490 to 31,269, representing an overall reduction of 43.65% (Table 4). Rear-end and lane-changing conflicts dropped by 53.6% and 64.5%, respectively, reflecting smoother car-following and more disciplined lane use, while crossing conflicts increased to 7,151 due to concentrated turning movements under fixed-time signals.

Table 4: Change of Traffic Conflicts Before and After NMV Lane Implementation

Parameter	Rear-End Conflicts	Crossing Conflicts	Lane-Changing Conflicts	Total Conflicts
Before (Base Scenario)	49,599	2,738	3,153	55,490
After (With NMV Lane)	23,000	7,151	1,118	31,269
Percentage Change	-53.6%	161.10%	-64.5%	-43.65%

Figure 7 illustrates the absolute number of conflicts by type, highlighting the reductions in rear-end and lane-changing interactions and the slight increase in crossing conflicts. Together, the table and figure show that reallocating space for NMVs redistributed conflicts and enhanced overall intersection safety in mixed-traffic conditions.

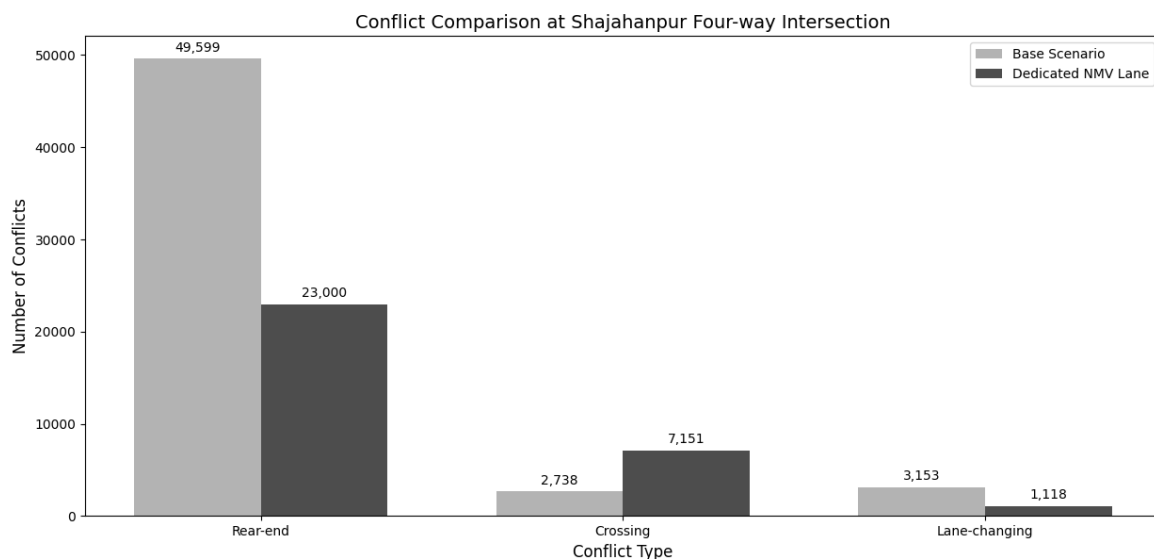


Fig 7: Comparison of Conflicts Before and After the NMV Lane Implementation

4. CONCLUSIONS AND RECOMMENDATIONS

The study successfully calibrated and validated the VISSIM model for the four-way intersection, with GEH values remaining below 5 in all cases, ensuring high accuracy in representing real-world traffic conditions. The introduction of a dedicated Non-Motorized Vehicle (NMV) lane significantly reduced vehicle conflicts, including rear-end, lane-changing, and crossing conflicts, resulting in a total conflict reduction of 43.65%, thereby lowering the potential risk of accidents. Some limitations were noted. A complex situation in the signal timing occurred which could not be overcome due to the use of fixed signal timing, causing more vehicles to cross at intersections and resulting in the overestimation of crossing conflicts in some cases. The study only considered the number of conflicts, while other conflict severity parameters, such as TTC (Time-to-Collision) and PET (Post Encroachment Time), were not included. Additionally, node results from VISSIM provide only approximate values for emission and fuel consumption, which are not fully accurate. Future research could focus on implementing vehicle-actuated signal control for complex intersections, developing comprehensive algorithms to accurately determine driving behavior parameters, and integrating VISSIM with SSAM to measure conflict

severity and estimate accident probability. These measures would further enhance traffic safety and the effectiveness of conflict mitigation strategies at four-way intersections.

DECLARATION OF USE OF AI

The authors declare that artificial intelligence (AI) tools were used solely for language-related assistance in the preparation of this manuscript. Specifically, AI-based tools were employed to correct grammatical errors, improve sentence structure, and enhance overall writing clarity and readability. No AI tools were used in the research design, data collection, data analysis, interpretation of results, or development of scientific content. All technical content, analyses, and conclusions presented in this manuscript are the original work of the authors.

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