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Prediction of Traffic Conflicts at Signalized Intersections using SSAM

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Abstract

The use of microsimulation to model the vehicles movement and pedestrian movements within a traffic network is widely undertaken to test and evaluate operational performance of a traffic network under different traffic conditions and control schemes. However, few studies have used microsimulation techniques to study pedestrian-vehicle interactions and potential conflicts, as safety assessment tool. This paper demonstrates the use of microsimulation environment to predict vehicle-vehicle and pedestrian-vehicle conflicts at signalized intersections. A case study from Doha in the State of Qatar was used as a study site. The real-life conflicts were observed and recorded, along with traffic and pedestrians' data. The studied intersection is then modeled and calibrated using VISSIM microsimulation tool, where vehicles and pedestrians' trajectories were generated. Then, Surrogate Safety Assessment Model (SSAM) was used to analyze the simulated trajectories to identify potential conflicts within the study area. The results showed that potential conflicts could be reasonably predicted. Moreover, microsimulation can be used to predict the location of potential conflicts while scenario testing and the results can be determined to assess the impact of geometric improvement in reducing potential conflicts.

Keywords: Traffic conflicts; microscopic simulation; surrogate safety assessment model; pedestrian-vehicle interaction; pedestrian simulation

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1. Introduction

Traffic safety is an integral aspect of traffic operations while designing any transport facility. There are many instances where road users compromise their safety and take undue risks. This requires them to take certain countermeasures, such as acceleration, deceleration, application of sudden breaks, change of path, or coming back to original position, to ensure safety. This phenomenon does not involve crash but gives rise to conflicts between various road users; for example, vehicle-vehicle, pedestrian-vehicle, or vehicle-object. It is essential to predict these conflicts for developing robust simulation models.

Previously, the pedestrian movements at signalized crosswalks were simulated to assess the effect of bi-directional flow on crossing speed and subsequently on crossing time[1]. The impact of pedestrians' random crossings on traffic operational performance of urban streets was quantified[2]. A framework was developed for assessing pedestrian-vehicle conflicts based on the interaction between the two road users at signalized intersections in China[3]. Pedestrian safety conflict index was determined for signalized intersections for assessing pedestrian safety when in conflict with left turning vehicles in China. It should be noted that traffic flows on the right side of the road in China[4]. A quantitative analysis of lane-based pedestrian-vehicle conflicts at unsignalized marked crosswalks in China, based on Post-Encroachment Time (PET), was presented by Almodfer et al.[5]. Surrogate safety measures were applied to assess the pedestrian and left turning vehicle conflicts for nine crosswalks in Japan. The actual conflicts were determined from observed PET values for far-side and near-side pedestrians. The crash risk was estimated based on past records[6]. It is worth to mention that the traffic flows on the left side of the road in Japan.

These studies assessed the conflicts while crossing but did not predict or simulate them. A Surrogate Safety Assessment Model (SSAM) that was developed by US Department of Transportation (DOT) evaluates the conflicts from the vehicle trajectories obtained from microsimulation models, namely from VISSIM, AIMSUN, PARAMICS and TEXAS[7]. It is important to realize that SSAM is capable of graphically presenting the locations and severity of conflicts but it does not specify whether the conflicts are pedestrian-vehicle conflicts or vehicle-vehicle conflicts. Therefore, manual processing of the raw conflicts data is necessary to identify the conflict involvement.

The applicability of VISSIM model and SSAM to predict vehicle-vehicle conflicts at signalized intersections was studied by considering 80 hours of data at ten intersections in China. The two-step calibration process improved the prediction of simulated conflicts when compared with real conflicts[8]. SSAM was used to test and evaluate the conflicts at roundabouts in the USA and encouraging results were obtained[9]. The transferability of calibrated VISSIM model to different sites was analyzed by using video data from two sites. Automated video-based analysis was used to measure rear-end conflicts. It was found that the calibrated parameters provided better results than the default values. Out of six identified parameters, two were transferable directly, three were transferable to some extent and one was non-transferable[10]. Two types of pedestrian-vehicle conflicts were simulated using VISSIM and SSAM using 42 hours of video data from seven signalized intersections. The results showed that best fit between simulated and observed conflicts was obtained when the maximum thresholds for time-to-collision and post-encroachment time was set at 2.7s and 8s respectively[11].

Apart from conflict assessment, SSAM was validated to predict crashes at intersections in urban areas by comparing the number of conflicts in SSAM with the number of conflicts predicted from analytical models and observed conflicts at intersections[12]. Further, an integrated platform comprising of microsimulation, SSAM, and emission models were developed to evaluate pedestrian safety while determining mid-block crosswalk location between two closely located roundabouts[13]. Recently, SSAM was applied to study the vehicle conflicts at signalized intersections in Doha, State of Qatar[14].

In this paper, the application of SSAM is studied to predict vehicle to vehicle as well as vehicle to pedestrian conflicts at signalized intersections and associated exclusive right turn lanes which, to the best of our knowledge, was not studied before. In addition, the study utilizes VISSIM as microscopic simulation environment for different reasons. For instance, this simulation environment has been widely used with to simulate pedestrian and vehicular movements and assess traffic conditions[15]. Also, it provides flexibility to test highly detailed geometric configurations and traffic control algorithms[16].

Moreover, this software is the only microscopic traffic simulation software that is approved by Ministry of Transport and Communications in the State of Qatar, which would make it the first choice to assess its applicability to analyze traffic conflicts for the local conditions in the State of Qatar[17].

2. Research Statement and Objectives

The common practice to assess traffic safety at signalized intersections is through the analysis of historical crash data at those intersections, and then propose certain countermeasures based on observations. The success or failure of these countermeasures requires the collection of additional crash data. Over the last few years, and because of the advancements in developing microscopic traffic simulation software packages, and their ability to consider many human factors, the use of these software packages to generate potential traffic conflicts has gained more attention.

This study aims to evaluate the applicability of Surrogate Safety Assessment Model (SSAM) to identify vehicle-vehicle and pedestrian-vehicle conflicts using microscopic traffic simulation approach at a major signalized intersection in the City of Doha. To do so, a major signalized intersection that experiences heavy traffic and pedestrians demand is chosen. A bird-view video footage was taken at the selected signalized intersection and potential traffic conflicts were manually processed to serve as a benchmark when SSAM is validated. The study also aims to perform before-and-after comparison from the perspective of traffic conflicts.

3. Methodology

3.1. Study Area

In this study, a signalized intersection in the West Bay area is selected. The intersection is a T-intersection that is adjacent to one of the major shopping malls in the State of Qatar, and many other governmental and private offices. This intersection experiences significant vehicular traffic volumes and pedestrians' movements as well. Therefore, is has a noticeable vehicle-vehicle and pedestrian-vehicle potential conflicts. Moreover, it has been noticed that the intersection has illegal crossing behavior by some pedestrians to shorten their travel path when crossing the road. Fig. 1 shows the geometric layout of the intersection. The major street is forming east and west approaches, while the intersecting north approach is the minor street. The intersection has multiple approaches and departure lanes with dedicated lanes for right turning vehicles and pedestrians can cross at marked crosswalks on these lanes. U-turn is allowed for all approaches and has separate phasing for westbound approach, for other approaches the U-turn shares phasing with corresponding left turns. As for pedestrians, two signalized crosswalks exist; one on major road and another on minor road. However, some pedestrians were seen illegally crossing the eastbound approach. The pedestrian green signal display on major road has a countdown timer of 26s and minor approach has 10s of green time and 9s of flashing green time.

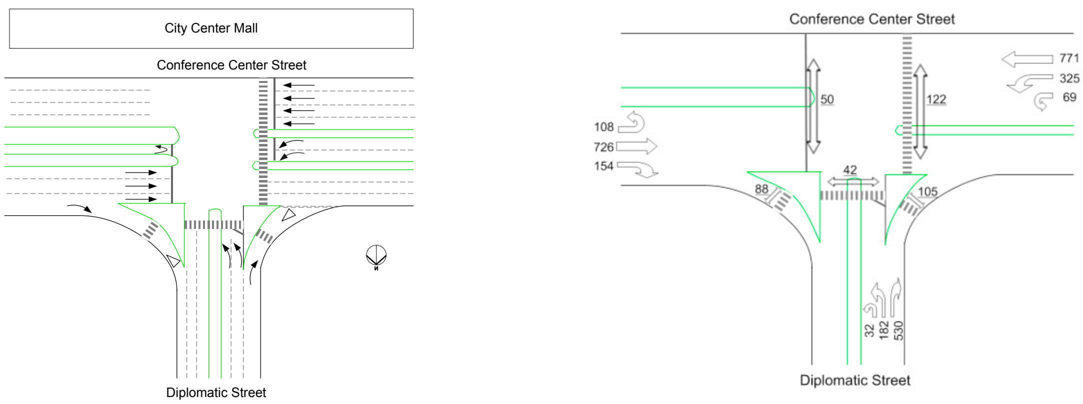

Fig. 1. (a) Layout of study intersection (b) Peak hour volumes (vph) for the intersection
Note: Underlined values are pedestrian volumes in ped/hr

3.2. Video Image Processing

Video footages were recorded on a typical weekday for continuous 12 hours (between 9:00 AM and 9:00 PM) to record traffic and pedestrians' movements, and to observe potential traffic conflicts. Traffic and pedestrian counts were conducted for the highest two hours, using COUNTpro and COUNTpad. A two-hour interval with the highest traffic and pedestrian volumes is chosen as an analysis period. The analysis period between 4:30 PM to 6:30 PM is then selected. Traffic flows, vehicle classification, signal timing plan, and pedestrians' movements were extracted and summarized, as can be seen in Fig. 1 and Fig. 2. On average, this intersection handled 2897 vehicle movements and 407 pedestrian crossings during peak hour.

3.3. Signal Timing Plan

The signal timing plans and phasing schemes for each cycle were extracted from the video footage. Just like most of the signalized intersections in the City of Doha, the signals are controlled by SCATS. These signal timing plans and phasing schemes are then hard-coded within the microscopic simulation environment. Fig. 2 shows a sample of one cycle.

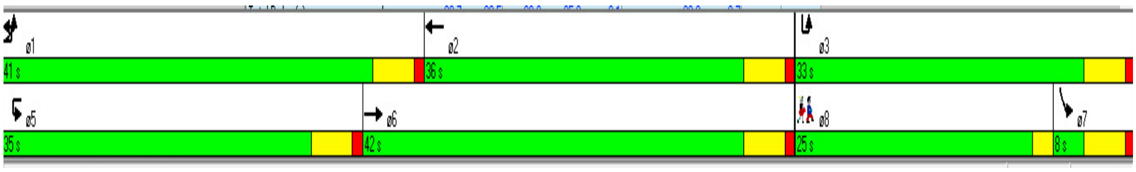

Fig. 2. Sample of Signal Timing Plan and Phasing Scheme at the Study Intersection

3.4. Microscopic Simulation Model

In this study, VISSIM multimodal traffic simulation model is used to model the study intersection. This software is selected because of its ability to model several human factors, including driving behavior. It will also allow the modeling of pedestrians as well.

Firstly, the intersection geometry is built within VISSIM, along with traffic and pedestrians demand during the selected two-hour analysis period. Traffic and pedestrian's data are disaggregated at 15-min interval. Turning movements were coded using static routing functionality in the simulation environment. Since this intersection is originally controlled with SCATS, VisVAP functionality is used to replicate the signal timings for each cycle. The driving behavior parameters were used as recommended by Ministry of Transport and Communications (MOTC) to serve the objective of this paper, which is the use of surrogate safety assessment model in identifying potential traffic conflicts of an intersection. Finally, the simulation model is calibrated by fine-tuning priority rules, conflict areas, and vehicle characteristics to replicate real-life observations. The simulation is run for two-hour duration and multiple runs were considered.

It is important to mention that, initially, a microsimulation model was developed in VISSIM with VISWALK, which is an add-on module. VISWALK provides a tool to model interactions between pedestrians and motorized modes of transport. It uses social force model which considers pedestrian movements similar to Newtonian mechanics[18]. However, it was observed that SSAM failed to recognize the pedestrians' trajectories using VISWALK and their interaction with vehicles. Hence, the pedestrians were coded using VISSIM functionalities, which consider pedestrians as a "vehicular object" in the simulation environment, but with "human" vehicle characteristics. More information about this topic can be found in Ghanim & Abu-Eisheh[2] and Wu et al[11].

4. Results

4.1. Observed conflicts

This study used number and locations of conflicts to calibrate the microsimulation model. Initially, all pedestrian and vehicle movements were observed and recorded. Conflicts details (such as type, involvement, and location) were then manually identified by observing the recorded videos multiple times. This process was used to identify the conflicts qualitatively using conflict duration, proximity, and pedestrians/vehicles behavior. Examples of some of the generally observed conflicts can be found in Parker and Zegeer[19]. Fig. 3 shows examples of observed conflicts and Fig. 4 shows the locations of all conflicts observed during two hours of analysis period. In total, 54 conflicts were observed; 41 pedestrian-vehicle conflicts and thirteen vehicle-vehicle conflicts. Most of the conflicts involving pedestrians were observed during illegal crossings at the crosswalk and due to confusion about right of way at the marked crosswalk placed on the dedicated right turn lanes. Ideally, vehicles should give way to pedestrians, but it was observed otherwise practically which created a state of confusion.

The pedestrians who were involved in conflict at the marked crosswalks experienced a conflict on major road as well. Mainly, conflicts were observed for pedestrians crossing towards intersection; this may be because opposite side has more visibility of oncoming traffic. It should be noted that when pedestrian crosses with large rolling gap that is not considered as conflict due to high PET. In addition, if traffic is queued and pedestrian crosses then that is also not considered as a conflict. Furthermore, at marked crosswalks, if pedestrian/s is/were waiting and vehicle yields then it was not considered as a conflict. The vehicle-vehicle conflicts were due to queued vehicles or vehicles stopped for pickup and drop off on east leg. The other reasons for conflicts were when the drivers tried to use the single lane dedicated right turn lane as two lanes before merging with traffic on the major road.

4.2. Simulated Conflicts for Existing Intersection (Before Intersection Improvement)

Vehicles and pedestrians' trajectories that were simulated in VISSIM environment were processed using SSAM. The trajectory file generated by VISSIM was analyzed to identify the two types of conflicts (i.e., vehicle-vehicle and pedestrian-vehicle conflicts). In general, SSAM identifies conflicts by tracking and processing space-time diagram of simulated trajectories. Several parameters are considered to identify type and severity of conflicts including time-to-collision (TTC), post-encroachment time (PET), change of speed and acceleration, and the conflict angles.

In this study, TTC and PET minimum values were adjusted so that the spatial distribution of resulted conflict are similar to those resulted by processing the recorded video footage. In particular, the TTC ranges between 0.05 and 1.0 second, while the PET ranges between 0.05 and 2.0 second. Fig. 5 shows the location of the simulated conflicts.

The comparison of observed conflicts shown in Fig. 4 and simulated conflicts shown in Fig. 5 disclosed that the locations and number of conflicts matched with reasonable accuracy. The figures indicate that well-calibrated VISSIM model can reasonably identify the location of vehicular conflicts, and overestimate the number of these conflicts. However, when pedestrians are involved in the conflicts, SSAM tends to underestimate these conflicts. This finding can be explained by the fact that modeling pedestrian movements in simulation environment is not highly detailed to reflect real pedestrians' movement. Remember that the proper modeling of pedestrians in VISSIM via VISWALK add-on module did not result in recording pedestrian trajectories. This observation indicates that VISSIM should consider this shortcoming in future release.

4.3. Simulated Conflicts for Future Intersection (After Intersection Improvement)

The conflicts were determined for a scenario in which the U turn on eastbound approach was shifted backward to provide an additional crosswalk. The backward shift of the U-turns allows the creation of pedestrian zebra crossing path so that pedestrians can easily move in the north-south directions, crossing the eastbound and the westbound. Traffic and pedestrian demands, along with signal timings are kept the same as the previously collected data.

The model was run for two hours and conflicts were determined using SSAM. The location of conflicts is shown in Fig. 6. A comparison of conflicts with Fig. 5 shows that the number of conflicts reduced significantly due to shifting of U-turn and provision of the additional crosswalk. Further, to reduce pedestrian-vehicle conflicts at right turn lanes, additional measure should be taken such as driver education, awareness and implementation of advanced warning signs.

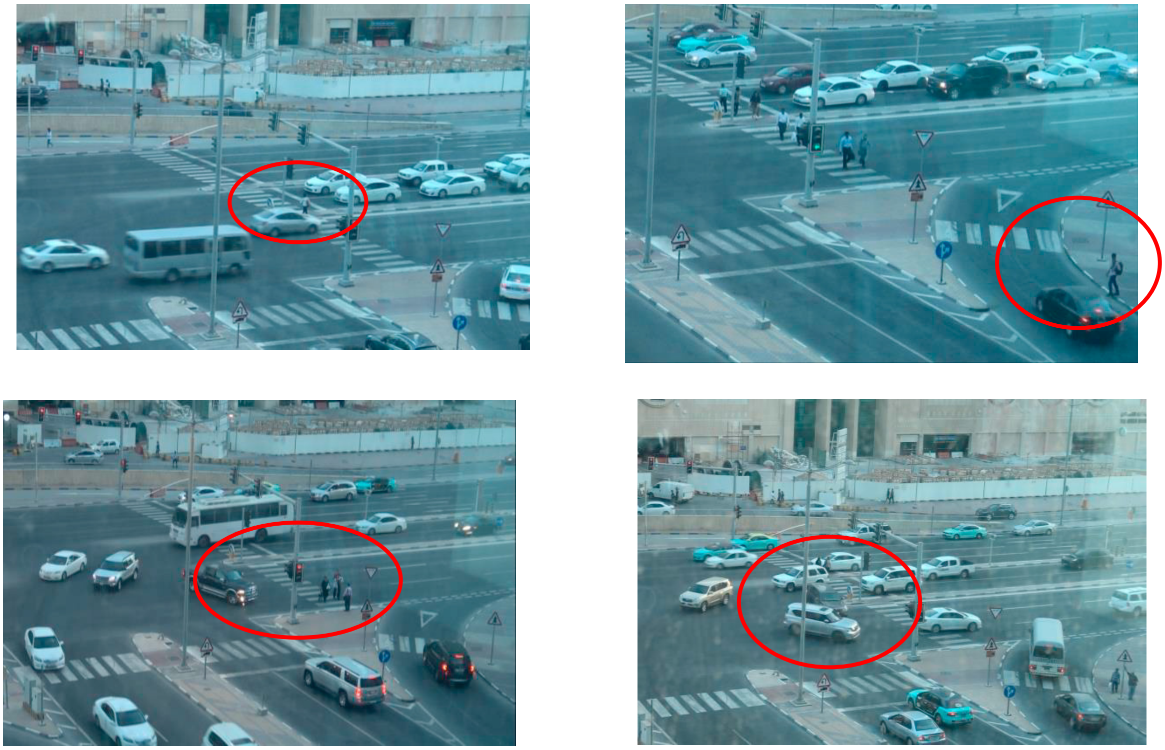

Fig. 3. Examples of observed conflicts

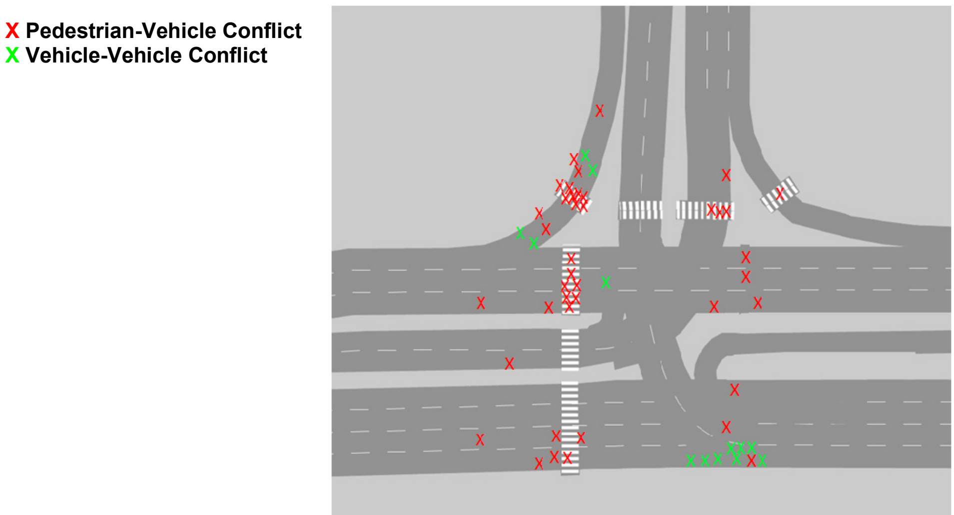

Fig. 4. Manually Observed Conflicts at the Study Site between 4:30 PM and 6:30 PM

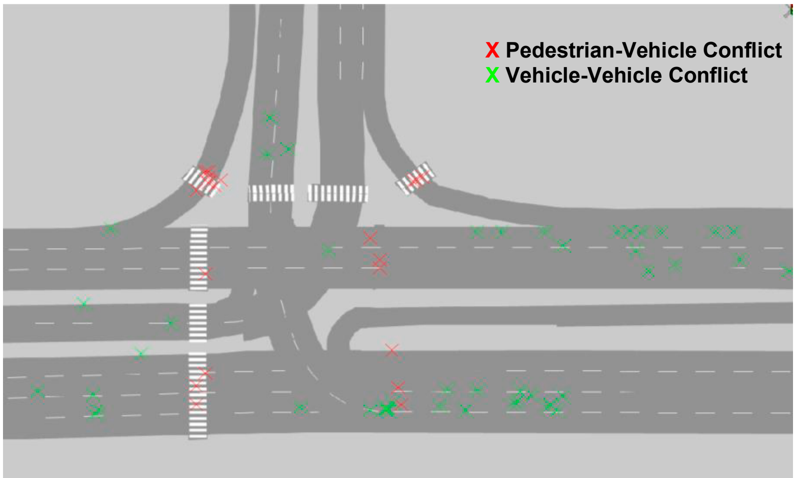

Fig 5. Number and location of conflicts observed at the study site from SSAM (Current Case)

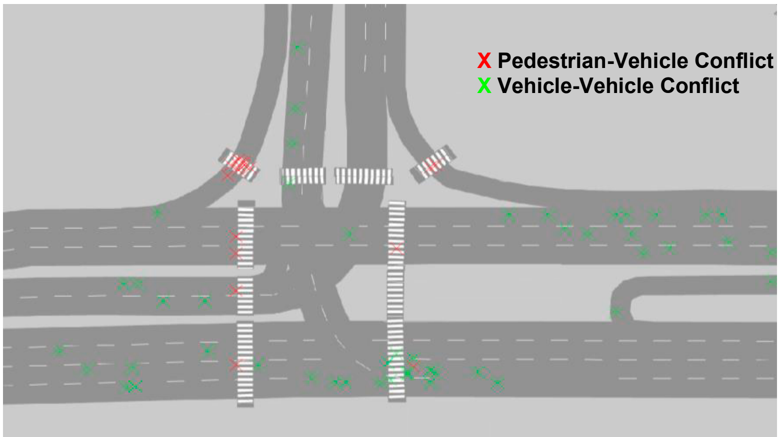

Fig. 6. Number and location of conflicts observed at the study site from SSAM (Improved Geometry)

5. Conclusions

Microscopic simulation is commonly used for analyzing operational performance of traffic networks while less attention is paid to use this technique to assess safety performance. In previous studies, SSAM was mainly used to identify vehicular conflicts. However, the result from this study showed that SSAM can be used to determine pedestrian-vehicle conflicts as well. The patterns of modeled conflicts matched closely with the observed conflicts. Besides, the scenario testing indicated that the conflicts reduced if an additional crosswalk is installed at the intersection with minor change to the current design. A similar approach can be used to design walkable roads in the State of Qatar. It is worth to mention that this is a typical intersection design near most of the popular shopping centers in the city which observes high vehicular and pedestrians' movements.

The limitation of the study is that the observed conflicts are determined qualitatively. Hence, the severity of conflicts is not checked. Additionally, the interaction between pedestrians is not modeled as VISSIM does not generate pedestrians' trajectories on areas that are modeled using VISWALK module.

In this case, this is acceptable because in the State of Qatar, low pedestrian activities are observed in general. This methodology should be used with caution for intersections with medium or heavy pedestrian flow.

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