Brock St & King St. E
Video-Based Conflict Analysis

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1. Background

Since 2005, there have been three vehicle-pedestrian collisions at Brock St and King St E – one on the crosswalk across Brock St (west leg), and two on the crosswalk across King St E (south leg). All three collisions involved left-turning vehicles.

There is no left turn phase for vehicles at this intersection – there are none in the entire downtown core, as the cycle length is only 80 seconds. Also, there is no dedicated pedestrian or scramble phase – the pedestrian signals come up at the same time as the parallel green phase for vehicles.

2. Objective

This report presents the results of a video-based conflict analysis (VBCA) study of the road safety concerns generated by vehicle-pedestrian interactions at the intersection of Brock St and King St E in Kingston, ON.

3. Conflict Scenarios

To analyze the vehicle-pedestrian interactions and safety issues at Brock St and King St E, the following conflict scenarios were studied (Fig. 1, Fig. 2):

Scenario 1: Vehicle-pedestrian conflicts between southbound vehicles turning right from King St E onto Brock St and pedestrians crossing Brock St.

Scenario 2: Vehicle-pedestrian conflicts between northbound vehicles turning left from King St onto Brock St and pedestrians crossing Brock St.

Scenario 3: Vehicle-pedestrian conflicts between westbound vehicles turning left from Brock St onto King St and pedestrians crossing King St.

Figure 1. Conflicts between vehicles turning (blue, red, and yellow arrows) and pedestrians crossing (green and purple arrows) at Brock St and King St E.

Scenario 1 Scenario 2 Scenario 3

Figure 2. Examples of vehicle-pedestrian interactions (conflicts) for each of the three scenarios.

4. Video Data Collection

Video data was collected over five days, 14 hours per day:

- Tuesday, September 12, 2017 (7:00 am to 9:00 pm)
- Wednesday, September 13, 2017 (7:00 am to 9:00 pm)
- Thursday, September 14, 2017 (7:00 am to 9:00 pm)
- Friday, September 15, 2017 (7:00 am to 9:00 pm)
- Saturday, September 16, 2017 (7:00 am to 9:00 pm)

These 70 hours included peak and off-peak traffic conditions. Traffic conditions are expected to be representative of regular days.

5. Methodology

Once video was obtained, video camera calibration and analyses were performed using the BriskLUMINA software. BriskLUMINA uses artificial intelligence and computer vision algorithms to automatically analyze traffic video, to detect, classify, and track the movements of road users.

Trajectory data was then used to perform surrogate analysis; two surrogate safety indicators were used: i) post encroachment time (PET) and ii) operating speed.

5.1 Post Encroachment Time and Speed

Post encroachment time is defined as the time between the first road user leaving the common spatial zone (where two road users could potentially collide) and the second road

user arriving to the common spatial zone.[1] In other words, the PET value determines how close, in time, the two objects were to colliding (Fig. 3). The lower the PET, the more dangerous the conflict.

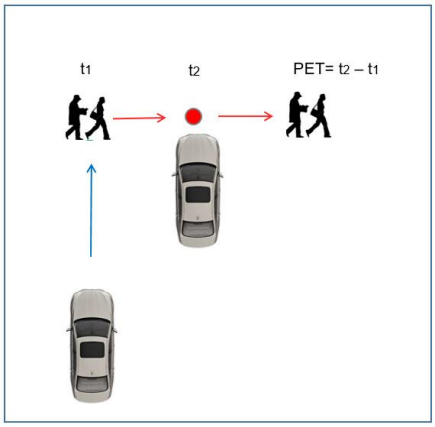


Figure 3. At time t2, the vehicle reaches the spatial zone that was occupied by the pedestrians at time t1. The post encroachment time (PET) is the time difference between t1 and t2.

To normalize the number of conflicts based on the exposure measurement – and to estimate the risk (conflict rates) – high-risk (PET ≤ 1 s), medium-risk (1 s < PET ≤ 3 s), and low-risk (3s < PET ≤ 5s) conflict rates were calculated as follows:

$$\text{Conflict rate} = \frac{(\text{PET per hour}) * 10^6}{\left(\text{RoadUser}_{\text{Type1}} \text{ per hour}\right) * \left(\text{RoadUser}_{\text{Type2}} \text{ per hour}\right)}$$

where, for a pair of road users:

- PET per hour = the number of vehicle-pedestrian conflicts per hour;
- $\text{RoadUser}_{\text{Type1}}$ per hour = the average number of one of the road user types (e.g., pedestrians) observed per hour over all hours in the study;
- $\text{RoadUser}_{\text{Type2}}$ per hour = the average number of the other road user type (e.g., vehicles) observed over all hours in the study.

Each road user's speed was measured as the 85th percentile of all speeds observed in that road user's individual trajectory.

[1] Gettman, D., Head, L. 2003. Surrogate safety measures from traffic simulation models. Transport. Res. Rec. 1840 (1), 104-105.

6. Results

For each conflict scenario, data was generated and reported in a spreadsheet containing analysis results and video clips for any conflicts identified. The results are summarized in Appendices **A** and **B**:

- **Appendix A** lists the outcomes files delivered
- **Appendix B** describes the tab in each report spreadsheet

6.1 Key Findings: Scenario 1

This scenario looks at vehicle-pedestrian conflicts between southbound vehicles turning right onto Brock St and pedestrians crossing Brock St. From the analysis, the following points can be highlighted:

- Over the five days of data collection, 4,059 vehicles and 30,355 pedestrians were identified. Of the three scenarios analyzed, this one is the second most intense in terms of vehicles flows and pedestrian activity.
- The vehicle trajectory heatmap (Fig. 4) shows vehicles making somewhat wide right turns onto Brock St. Right-turn vehicle speeds in this scenario are the highest. However, speeds as vehicles approach the traffic light – which may be lower – are not tracked in this study. Despite this potential bias, vehicle speed measures are relatively low (Fig. 5).

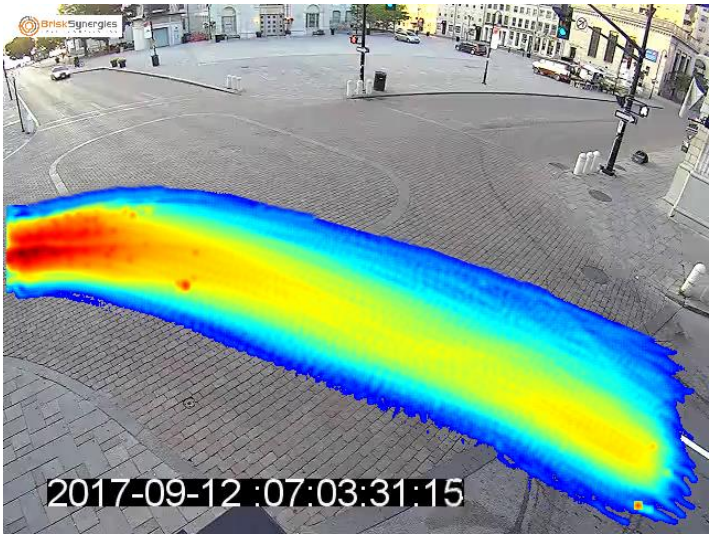


Figure 4. Vehicle trajectory heatmap for southbound vehicles turning right at Brock St and King St.

- An 85th percentile speed of 26.5 km/h (median = 21.6 km/h, average = 21.3 km/h, standard deviation = 5.1 km/h) does not indicate an issue with speeding (Fig. 5).

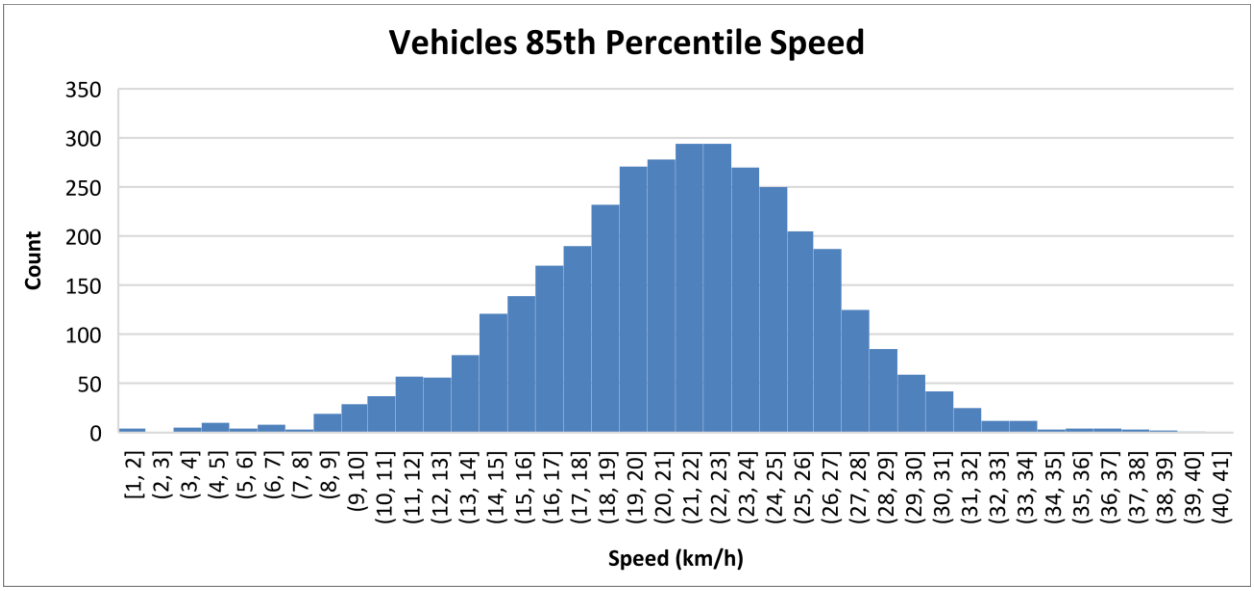


Figure 5. Speed distribution for southbound vehicles turning right at Brock St and King St.

- Of the total 1,258 conflicts identified, most (1,020) were low-risk. One high-risk and 237 medium-risk conflicts were detected (Fig. 6, Fig. 7). Despite the very low frequency of high-risk conflicts, this scenario is the most intense based on both the vehicle-pedestrian conflict frequency and rates.

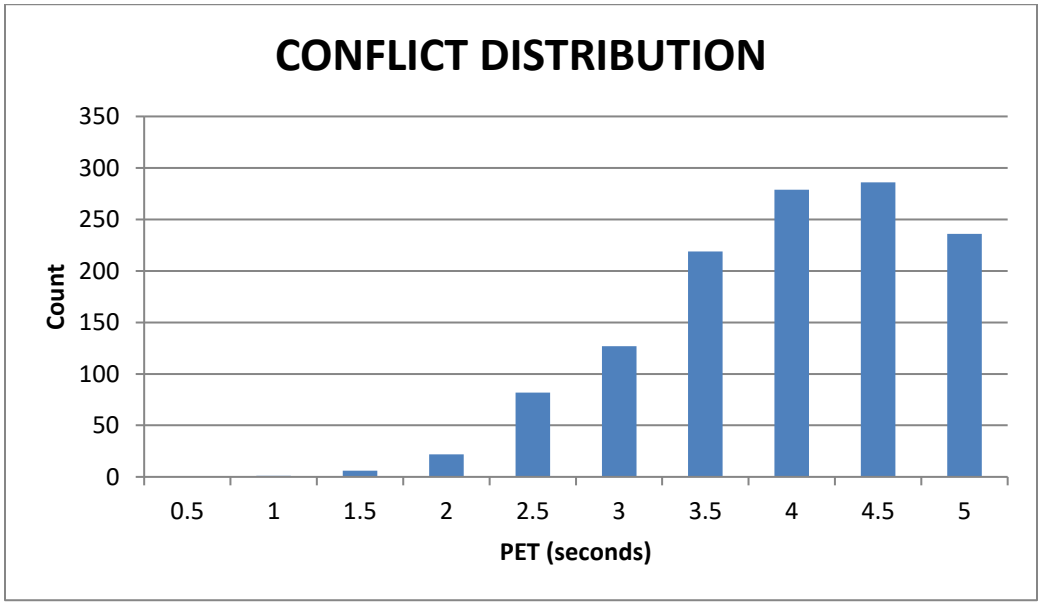
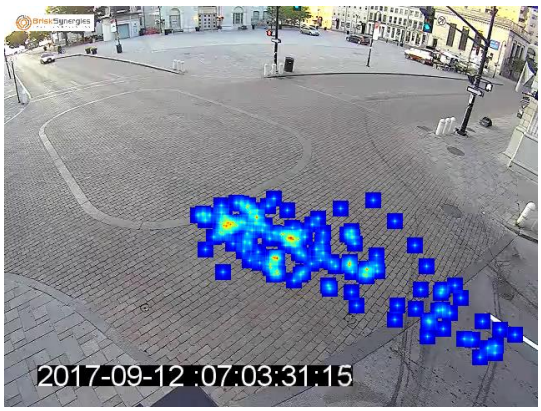


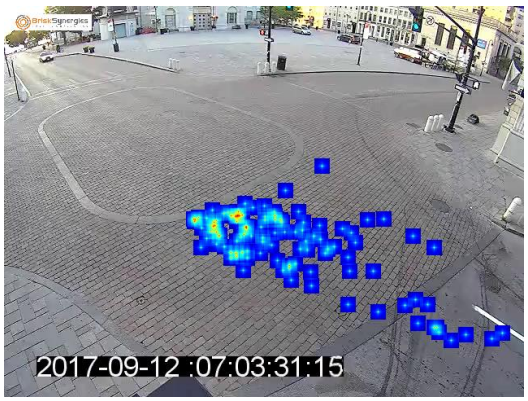
Figure 6. Distribution for conflicts between southbound vehicles turning right and pedestrians crossing on the west leg at Brock St and King St.

HIGH RISK CONFLICTS (vehicle arrived first), Total = 1

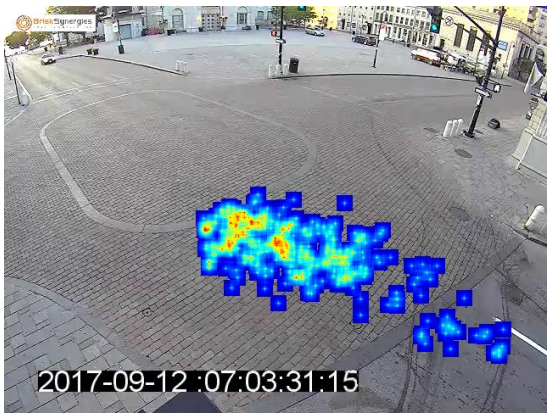
HIGH RISK CONFLICTS (pedestrian arrived first), Total = 0



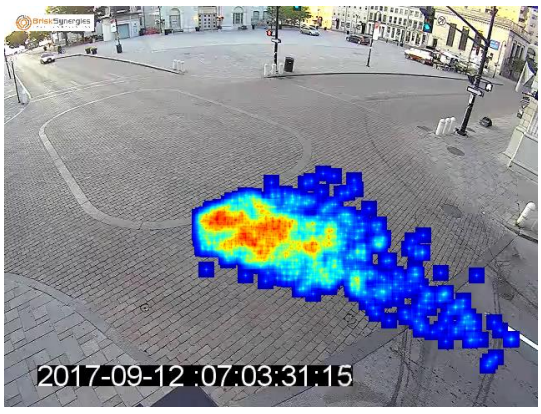
MEDIUM RISK CONFLICTS (vehicle arrived first), Total = 131



MEDIUM RISK CONFLICTS (pedestrian arrived first), Total = 106



LOW RISK CONFLICTS (vehicle arrived first), Total = 274



LOW RISK CONFLICTS (pedestrian arrived first), Total = 746

Figure 7. Heatmaps for conflicts between southbound vehicles turning right and pedestrians crossing on the west leg at Brock St and King St.

6.2 Key Findings: Scenario 2

This scenario looks at vehicle-pedestrian conflicts between northbound vehicles turning left from King St onto Brock St. From the analysis, the following points can be highlighted:

- This is the most intense scenario in terms of vehicle and pedestrian activity – over the five days of data collection, 7,405 vehicles and 30,355 pedestrians were identified. The vehicle trajectory heatmap (Fig. 8) shows vehicles making very angular left turns onto Brock St.

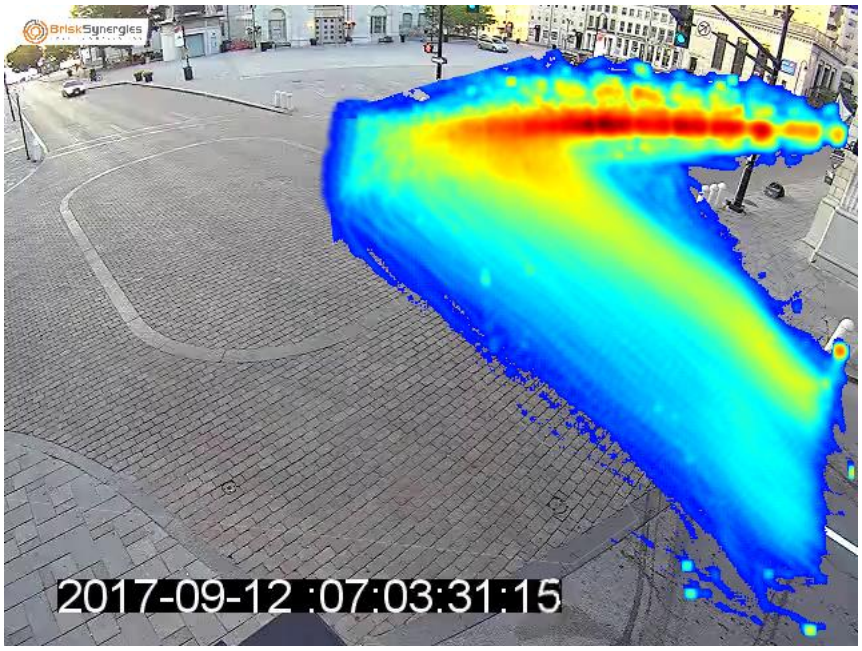


Figure 8. Vehicle trajectory heatmap for northbound vehicles turning left at Brock St and King St.

- Based on the speed distribution (Fig. 9) and the basic statistics (85th percentile speed = 18.2, median vehicle speed = 11.2 km/h, average =11.6 km/h, standard deviation = 6.7 km/h)), vehicle speeds are not an issue, and are much lower than in scenario 1.

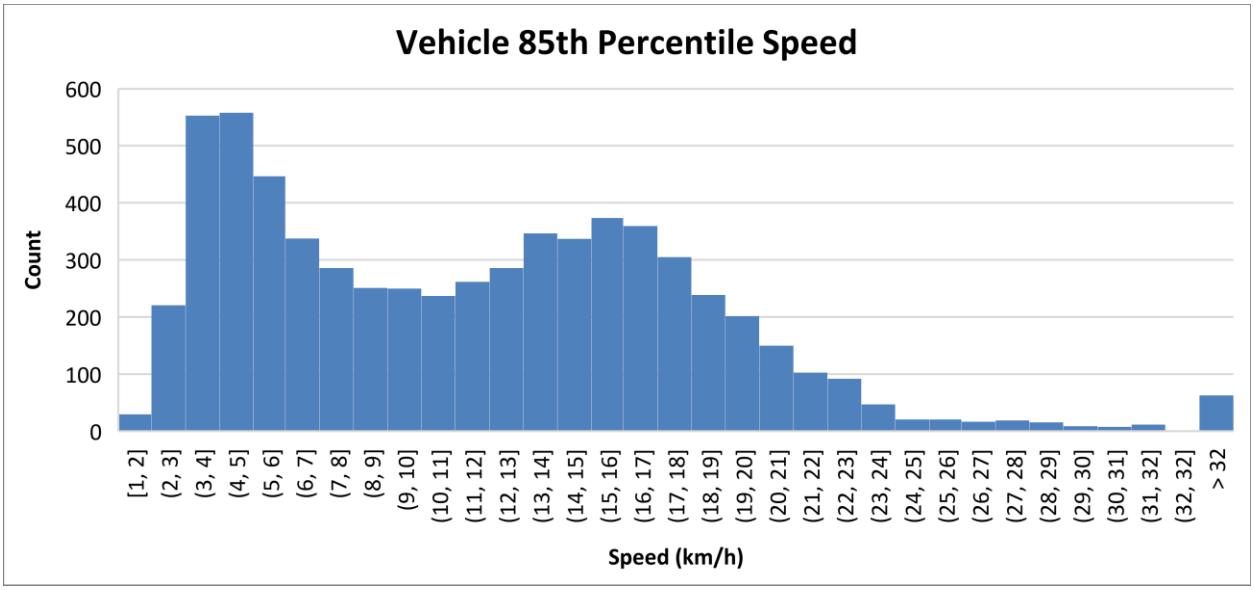


Figure 9. Speed distribution for northbound vehicles turning left at Brock St and King St.

- Of the total 1,101 conflicts identified, most (751) were low-risk. One high-risk and 349 medium-risk conflicts were detected (Fig. 10, Fig. 11). This is the second-most risky scenario based on the conflict frequency and rates.

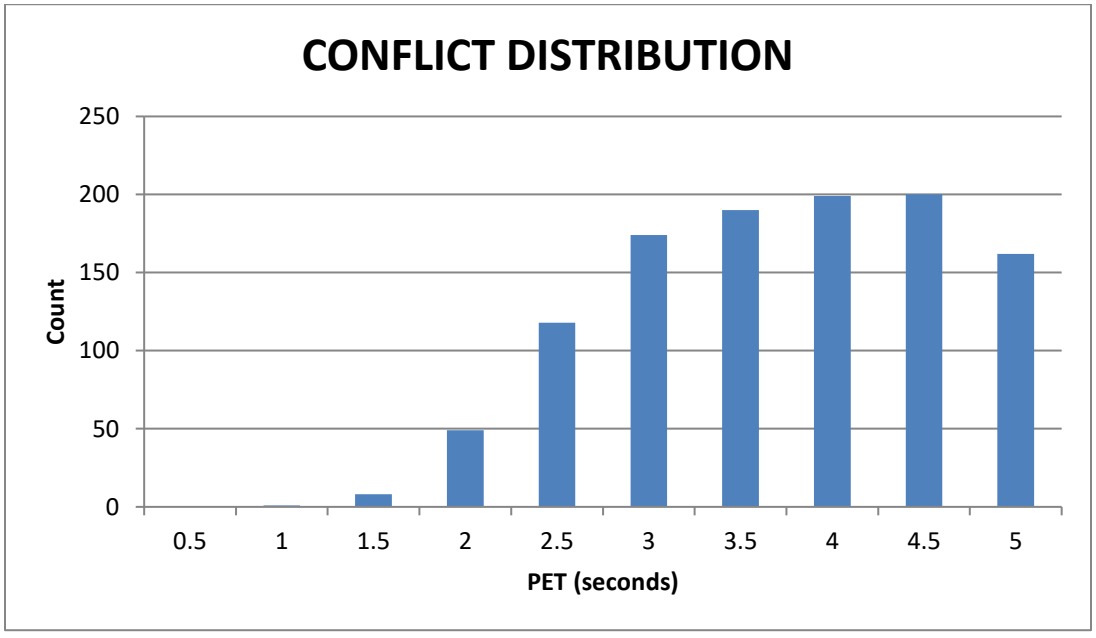
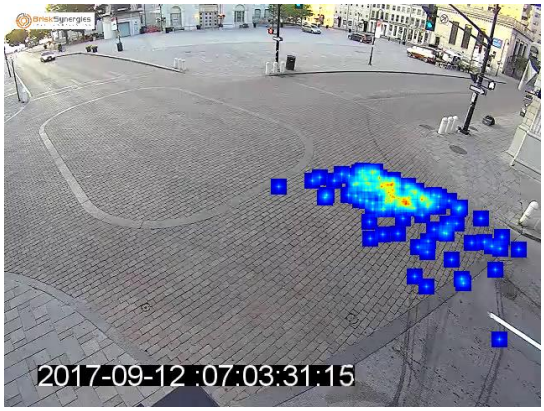


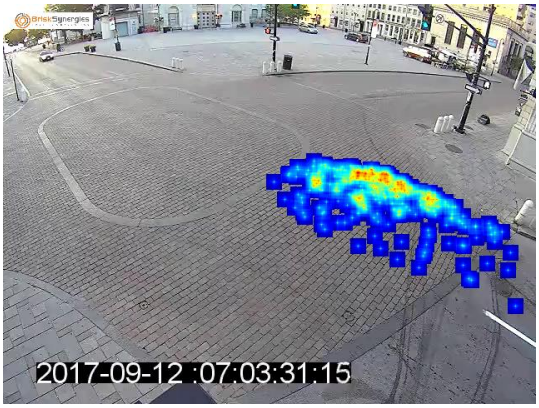
Figure 10. Distribution for conflicts between northbound vehicles turning left and pedestrians crossing on the west leg at Brock St and King St.

HIGH RISK CONFLICTS (vehicle arrived first), Total = 1

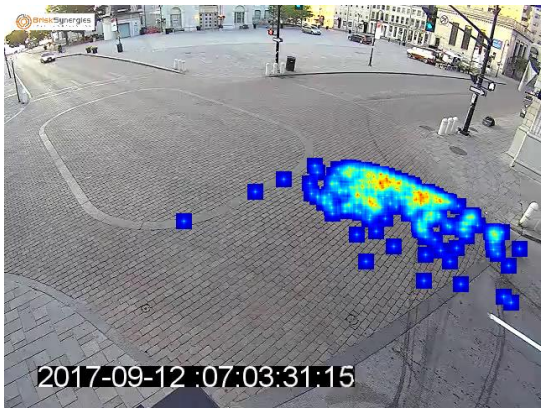
HIGH RISK CONFLICTS (pedestrian arrived first), Total = 0



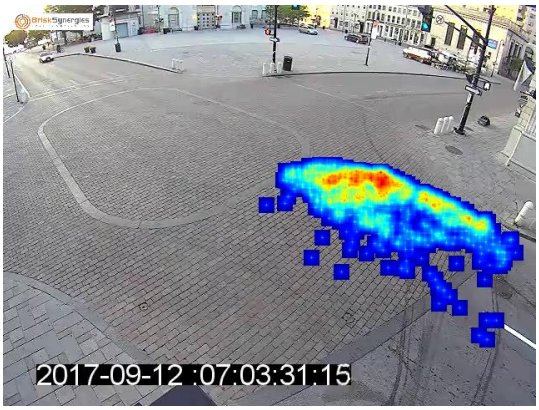
MEDIUM RISK CONFLICTS (vehicle arrived first), Total = 109



MEDIUM RISK CONFLICTS (pedestrian arrived first), Total = 240



LOW RISK CONFLICTS (vehicle arrived first), Total = 193



LOW RISK CONFLICTS (pedestrian arrived first), Total = 558

Figure 11. Heatmaps for conflicts between northbound vehicles turning left and pedestrians crossing on the west leg at Brock St and King St.

6.3 Key Findings: Scenario 3

This scenario looks at vehicle-pedestrian conflicts between westbound vehicles turning left from Brock St onto King St. From the analysis, the following points can be highlighted:

- Over the five days of data collection, 1,735 vehicles and 15,277 pedestrians were identified in this scenario. This intersection crosswalk has much less vehicle flow and pedestrian activity than scenarios 1 and 2.
- The vehicle trajectory heatmap (Fig. 12) shows vehicles making very angular left turns onto King St.

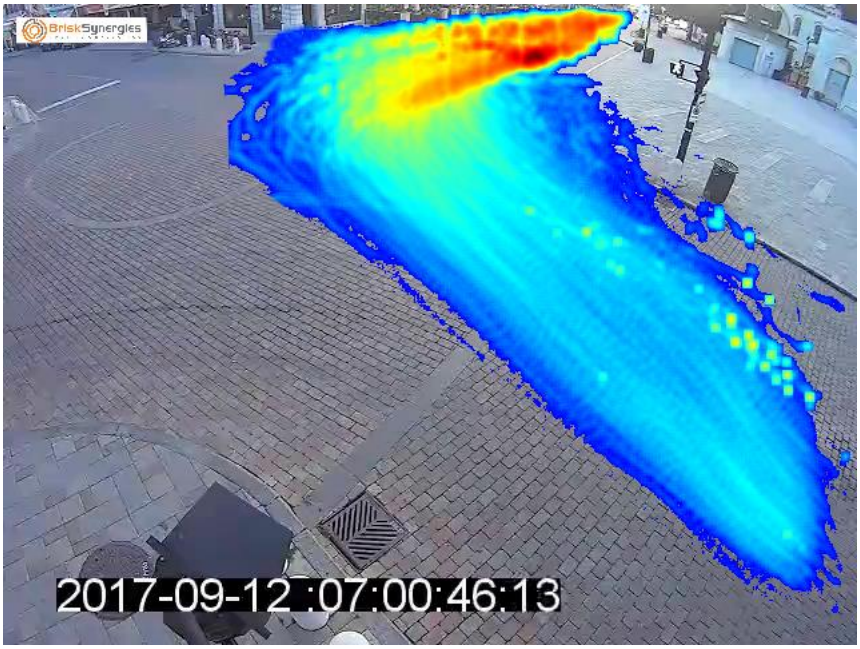


Figure 12. Vehicle trajectory heatmap for westbound vehicles turning left at Brock St and King St.

- As in scenario 2, the vehicle speeds in this approach are not high. An 85th percentile speed of 21.8 km/h (median = 14.6 km/h, average = 14.5 km/h, standard deviation = 6.7 km/h) does not indicate an issue with speeding (Fig. 13).

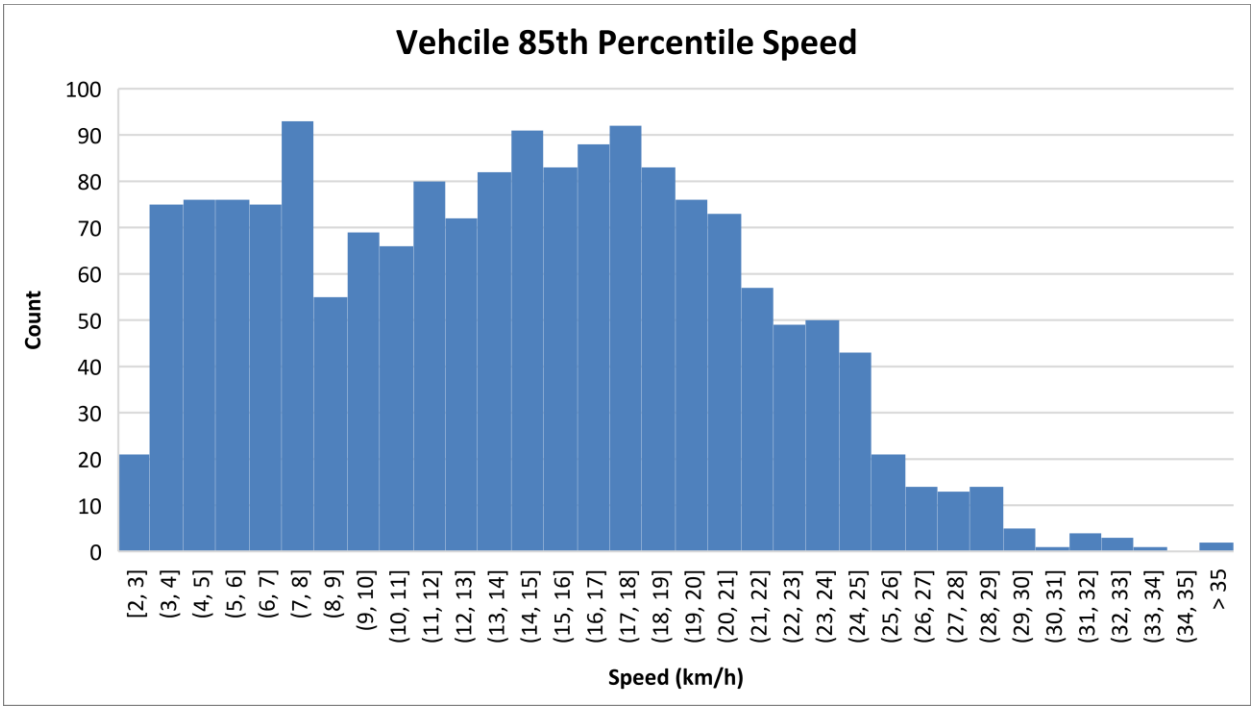


Figure 13. Speed distribution for westbound vehicles turning left at Brock St and King St.

- This scenario poses the least risk with respect to both conflict frequency and rates. Of the total 383 conflicts identified, most (347) were low-risk. There were no high-risk and 36 medium-risk conflicts (Fig. 14, Fig. 15).

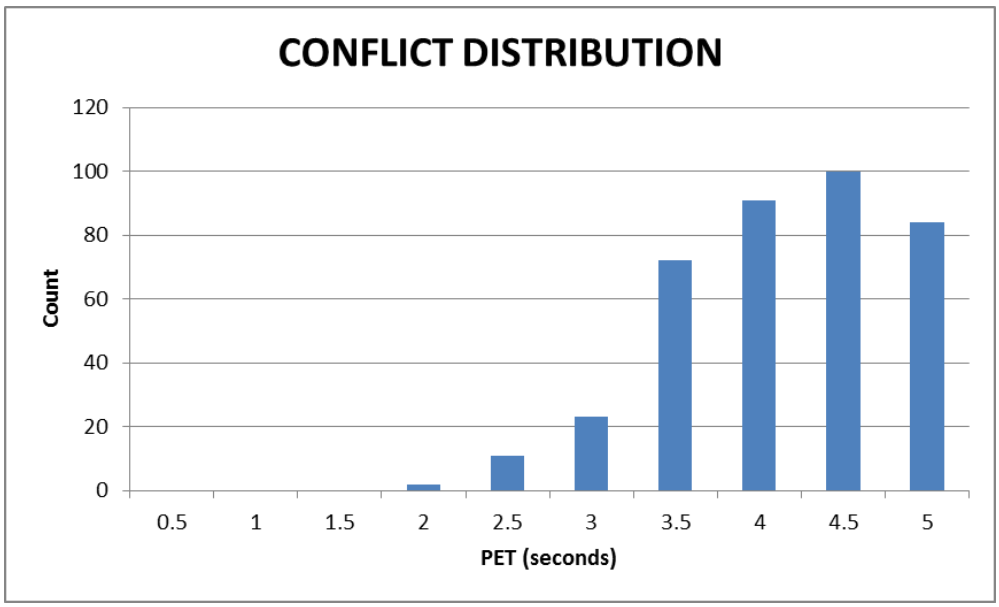


Figure 14. Distribution for conflicts between westbound vehicles turning left and pedestrians crossing on the south leg at Brock St and King St.

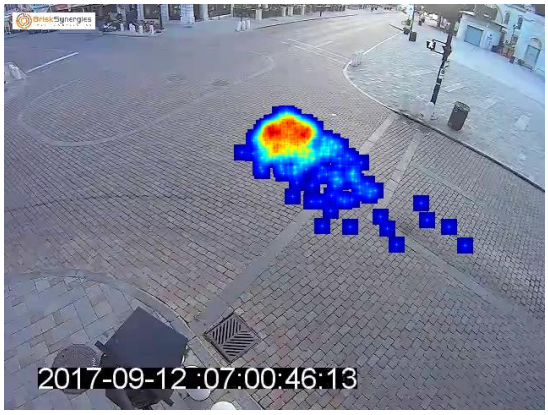
HIGH RISK CONFLICTS (vehicle arrived first), Total = 0

HIGH RISK CONFLICTS (pedestrian arrived first), Total = 0

MEDIUM RISK CONFLICTS (vehicle arrived first), Total = 9

MEDIUM RISK CONFLICTS (pedestrian arrived first), Total = 27

LOW RISK CONFLICTS (vehicle arrived first), Total = 39



LOW RISK CONFLICTS (pedestrian arrived first), Total = 308

Figure 15. Heatmaps for conflicts between westbound vehicles turning left and pedestrians crossing on the south leg at Brock St and King St.

6.4 Overall Conflict Rates

Scenario 1 (right-turning vehicles) had the highest frequency and rates of conflicts (medium- and high-risk), followed by scenario 2 (left-turning vehicles) (Table 1). This means that the safety issues at the crosswalk at Brock St are more serious than that safety issues at the King St crossing.

Table 1. Conflict risk estimate rates for the three scenarios investigated in this study

	Scenario 1 King to Brock (Right turn)	Scenario 2 King to Brock (Left turn)	Scenario 3 Brock to King (Left turn)
High-risk Conflict Rate	0.6	0.3	0
Medium-risk Conflict Rate	134.6	108.7	95.1
Low-risk Conflict Rate	579.5	233.9	916.4

7. General Remarks & Recommendations

Pedestrian volumes were higher than vehicle volumes in all three scenarios. Despite the fact that most of the conflicts happened at low speeds and are classified as medium-low risk, the number of interactions were high.

The vehicle-pedestrian interactions were particularly concentrated at the Brock St crosswalk (west leg).

Accordingly, the following improvements could be considered:

- A change in pedestrian timings at the Brock St crosswalk is recommended. This could be a leading pedestrian interval (LPI) or "pedestrian jump" which provides pedestrians with the opportunity to start crossing before vehicles are permitted to proceed. That is, pedestrians receive the walk indication (for 3-7 seconds) before the beginning of the green indication for turning vehicle movements. An LPI can enhance the visibility of pedestrians in the intersection, and reinforce their right-of-way over turning vehicles – especially in locations with a high frequency of pedestrian volumes and conflicts. According to National Association of Transportation Officials (NACTO) guidelines, LPIs have been shown to reduce

pedestrian-vehicle collisions by as much as 60%[2]. For its implementation, some guidelines could be consulted[3].

- For northbound vehicles turning left from King St onto Brock St (scenario 2) – given the intensity of the left-turn flow and the very high pedestrian volumes/conflicts, there are very few gaps in traffic for vehicles to execute the left turn. This situation could justify the implementation of a left-turn phase (fully protected or protected/permissive). In a protected left-turn phase, vehicles can turn left (as indicated by a green arrow signal), which provides the right-of-way to vehicles with no conflicting movements with pedestrians. There are several types of protected/permissive left-turn and fully protected phases.

Note that as the cycle is only 80 seconds, adding a left-turn phase could require increases to the cycle length or changes in the traffic signal timing. This would also eliminate traffic signal coordination with adjacent intersections.

[2] https://nacto.org/publication/urban-street-design-guide/intersection-design-elements/traffic-signals/leading-pedestrian-interval/

[3] For instance, refer to S. Saneinejad & J. Lo (2010). Leading Pedestrian Interval: Assessment and Implementation Guidelines. *Transportation Research Record: Journal of the Transportation Research Board, No. 2519*, Transportation Research Board, Washington, D.C., 2015, pp. 85–94. DOI: 10.3141/2519-10

Appendix A. Report files and video clips

Folder	Subfolder	Description
Camera 1	RightTurningVehicle_Pedestrian	Report spreadsheet (report.xlsx) and video clips (vehicle_arrivedFirst, pedestrian_arriveFirst) for conflicts between southbound vehicles turning right and pedestrians crossing on the west leg at Brock St and King St.
	LeftTurningVehicle_Pedestrian	Report spreadsheet (report.xlsx) and video clips (vehicle_arrivedFirst, pedestrian_arriveFirst) for conflicts between northbound vehicles turning left and pedestrians crossing on the west leg at Brock St and King St.
Camera 2	LeftTurningVehicle_Pedestrian	Report spreadsheet (report.xlsx) and video clips (vehicle_arrivedFirst, pedestrian_arriveFirst) for conflicts between westbound vehicles turning left and pedestrians crossing on the south leg at Brock St and King St.

Appendix B. Report spreadsheet tab descriptions

Tab	Description
General Information	This tab contains general information about the project.
Trajectory Heatmaps	This tab shows heatmaps for each road user/movement in the conflict scenario. Volume heatmaps are an effective way of showing the overall movements of a type of road user in one single image. Density map colors range from blue (least used location) to red (most used location), passing through cyan, yellow, and orange.
Speed Distribution	This tab shows charts corresponding to the speed distribution of the road users involved in the scenario, as well as the average and median speeds, and the standard deviation. A low standard deviation means that most of the numbers are very close to the average. A high standard deviation means that the numbers are spread out
Time Distribution	This tab shows charts corresponding to the 15-minute time intervals counts of the road users involved in the scenario.
Conflict Distribution	This tab shows the distribution of the conflicts with Post Encroachment Time (PET) less than 5 seconds. PET is defined as the time between a first road user leaving a common spatial zone (where two road users could potentially collide) and a second road user arriving to the common spatial zone. PET value determines how close, in time, the two objects were to colliding. The lower the PET, the more dangerous the conflict. For example, the following figure shows the PET between pedestrians and a vehicle.
Conflict Heatmaps	Each conflict is classified by severity level based on PET: - High-risk: $0\ s \leq PET \leq 1\ s$ - Medium-risk: $1\ s < PET \leq 3\ s$ - Low-risk: $3\ s < PET \leq 5\ s$ Each conflict is also classified based on which road user arrived to the conflict point first. This is a useful way to determine if the road users involved in the conflict complied to the right of way or not.

Tab	Description
	The heatmaps on this tab show conflict locations based on the severity and which road user arrived to the conflict point first.
Raw Speed Data	This tab shows the median speed of each road user.
Raw PET Data	This tab shows the PETs calculated for the road user interactions.