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Networkwide Traffic Data and Safety Analysis in Bellevue (WA)

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Abstract
This research partnership leveraged surrogate safety measures at 75 intersections in the city of Bellevue, Washington to inform Vision Zero safety improvements and evaluate countermeasure outcomes. Data on traffic volumes, speeds, and near-misses was obtained using video analytics and thousands of hours of footage collected over several months. Near-misses were measured using post encroachment time (PET), defined as the time between when the first road user and the second road user arrive at the same point. The safety analysis flagged intersections with a high occurrence of conflicts (PETs less than 1.5 seconds) between road users. The intersections with the highest number of pedestrian-driver conflicts were in the downtown area. The intersections with the highest number of driver-driver conflicts were more dispersed. Additionally, the conflict analysis was tested in a preliminary before and after case study at one of the study intersections.

Keywords:
VISION ZERO, SAFETY, VIDEO ANALYTICS

Introduction

As pedestrian and bicycle fatalities continue to rise nationwide, there is a need for improved data driven approaches to achieve our collective goal of Vision Zero – eliminating traffic fatalities and serious injuries to ensuring that everyone can safely move around in our communities. Between 2009 and 2018, 66% of all fatal and serious-injury collisions in the City of Bellevue, Washington occurred along just 9% of streets (Breiland, C., Weissman, D., Saviskas, S., & Wasserman, D., 2019). Vulnerable road users (people walking and bicycling) made up 5% of all collisions during this time but comprised 46% of all serious injuries and fatalities. An analysis of the collisions indicates that five road user behaviors contributed to 70% of all fatal and serious injuries. These five behaviors were drivers' failure to yield to a pedestrian, failure to grant right-of-way to a motorist, and driver distraction, intoxication, and speeding.

In response to these road safety concerns, the City of Bellevue passed a Vision Zero resolution in 2015 to strive to achieve zero traffic fatalities and serious injuries by 2030. In 2018, the City of Bellevue partnered with Brisk Synergies to conduct a citywide network screening analysis to better understand the factors that impact the safety of its transportation system and leverage this insight to identify improvements and evaluate outcomes.

BriskLUMINA, a product of Brisk Synergies, uses computer vision and artificial intelligence to analyze traffic video using non-intrusive data collection methods. Camera footage is analyzed to obtain data about surrogate safety indicators including road user speeds and near-misses. BriskLUMINA can detect and obtain aggregate information about a variety of road user classifications including cars, busses, trucks, motorcycles, bicycles, and pedestrians. Results are often used to validate road improvements, determine high-risk locations, and determine the most severe conflicts and interactions at an intersection, roundabout, or road segment.

The objective of this paper is to use video analytics and camera footage from existing infrastructure to perform a networkwide screening of the city of Bellevue. This screening provides the City with data on where volumes are high for motorized and vulnerable road users, speeds of road users, and frequency of near-misses. This data can be correlated with location, land use, and urban density. All of this information can be used by the City in safety diagnosis, risk factor identification, and treatment assessment.

Conflicts as a Safety Indicator

Many governmental agencies continue to rely on traditional traffic safety approaches. They intervene only after enough police crash reports are filed to trigger a High Crash Corridor designation. This reactive approach to prevent crash recurrence has well documented limitations.

- Studying collision data is reactive; safety evaluation takes place after collisions occur, making it difficult to achieve the goal of zero traffic deaths and serious injury collisions;
- The infrequent nature of traffic collisions necessitates years of observation to achieve statistical significance — up to 5 or even 10 years of data in the cases of studies involving single sites and/or low-traffic volume locations.
- It is well-documented that traffic crashes and injuries are under-reported in many localities and
- There are societal barriers in using the general public to test unknown safety countermeasures.

Although traffic collisions can happen anywhere, conflicts at specific locations are often early warning signs - e.g. recurring instances where a driver abruptly stops because a bicyclist veered in front of them, a pedestrian steps into the path of a bicyclist, or one bicyclist or driver passes by another or a static object at very close spacing. These surrogate warning indicators provide insight into when, where, and why crashes are most likely to occur. Understanding the root causes for traffic conflicts enables local agencies to take proactive, corrective actions to reduce the potential for future crashes.

Project Details

Video footage was recorded at 75 signalized intersections from January to July of 2019. The location of these intersections is indicated in Figure 1. For the majority of intersections, footage was taken during the afternoon peak hours, from 3 PM to 6 PM for 5 consecutive weekdays each month. On average, more than a hundred hours of footage was collected at each intersection.

The analytic approach was structured to gain insight on whether differences might be observed among varying land use characteristics in the city of Bellevue. The majority of study intersections were located outside of Bellevue’s downtown core, defined as the area between Main St. and NE 12th, and 100th Ave to 112th Ave. 19 intersections (25%) were located in the downtown core. 48 intersections (64%) were located in commercial areas while 27 intersections (36%) were in residential areas. Over 70% were of medium density areas with suburbs and big-box stores. About 25% are high density intersections, containing multi-story dwellings, businesses, and/or 10+ story buildings.

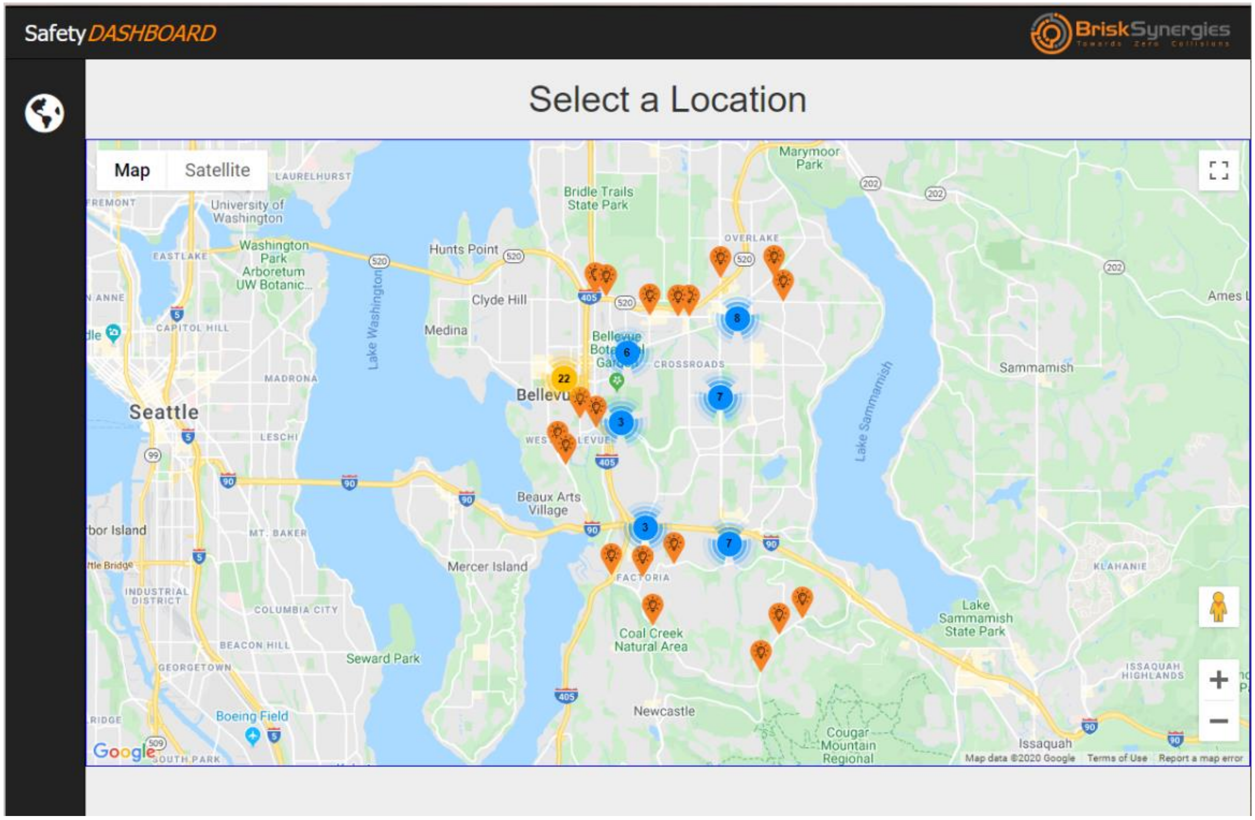

Figure 1 – Intersections Included in Analysis

Results and Analysis

BriskLUMINA produces a variety of datasets, including road user counts by classification, road user speeds, and conflict occurrence. Road user speeds are defined as the median non-zero speeds of road users while they are present in the camera frame. Conflicts or interactions are detected using post encroachment time (PET) **-** the time between when the first road user and the second road user arrive at the same point. A lower PET indicates a situation where a collision is more likely to occur. The analysis breaks down the PETs into thresholds of 1.5 seconds, 2s, 3s, 5s, and 10s to observe various trends. PETs below 1.5s are considered events of concern, as 1.5s is considered to be the standard human reaction time (Taoka, G., 1989). PETs between 5 and 10 seconds, generally speaking, are simply considered interactions.

Road User Results

The total number of road users observed was over 17.7 million, 96% of which were drivers. Pedestrians were predominantly observed within the downtown core (81% of all pedestrians). 96% of all pedestrians were observed at commercial locations and 81% of all pedestrians were observed at locations with high population density. Approximately 70% of all pedestrians were located at just nine of the downtown intersections. The majority of the sites (83%) have pedestrian volumes below 5% of their total intersection volume.

The intersections along NE 4th St and NE 8th St are of particular interest. A total of 15 intersections were analyzed there, making up 20% of the total number of intersections. The total road user volumes on these two streets was 30% of the total; however, pedestrian volumes along these 2 corridors made up 67% of the total pedestrian volumes among the 75 intersections in the study.

Speed Results and Analysis

An exploratory analysis was performed on driver speeds. Speeds at all intersections were averaged, and median speeds for through movements was calculated. Through movements include all drivers traveling straight through the intersections. Comparing average speeds is useful to determine where speeds are higher, and median speeds are useful to compare which road users and movements have higher speeds. This was done for downtown, non-downtown, commercial, residential, high density, and medium density intersections.

The average speeds were 24% higher outside of the downtown and were 22% higher at residential locations. Average speeds at locations with higher population densities were 16% slower than those with lower population densities. Median speeds were 15% higher outside of the downtown and 11% higher in residential areas. In addition, speeds at locations with higher population densities were 19% slower.

Further analyses can be performed on other speed values such as the 15th and 85th percentile speeds. In addition, data concerning speeding and speed limits will be obtained and analyzed in the future. This is of particular interest to the City and their speed management program.

Conflict Results and Analysis

The following conflict analysis is based on post encroachment time (PET). The analysis was performed on PETs < 1.5s, 1.5s < PETs < 2s, 2s < PETs < 3s, 3s < PETs < 5s, and 5s < PETs < 10s. Cases where the PET is between 5 and 10s are not cause for concern. PETs below 1.5s are the most critical. The remainder of PET values could be critical depending on factors such as the types of road users involved, speeds, types of interactions, etc. Figure 2 shows how many interactions were observed at each PET value.

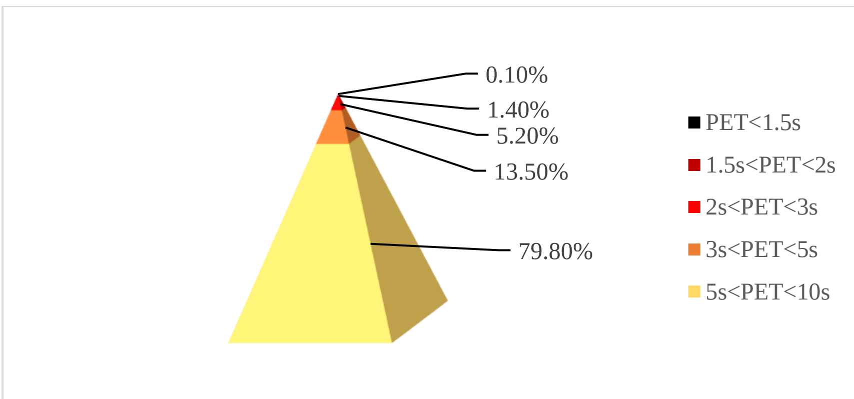

Figure 2 - Frequency of Interactions with Different PET Values

Several categories of conflicts exist. These categories are divided into conflicts between vulnerable road users and motorized road users and motorized road users with each other. Motorized road user conflicts can further be divided into through vs through movements, left turning vs through movements, and merging movements. Examples of these motorized road user movements are illustrated in Figure 3.

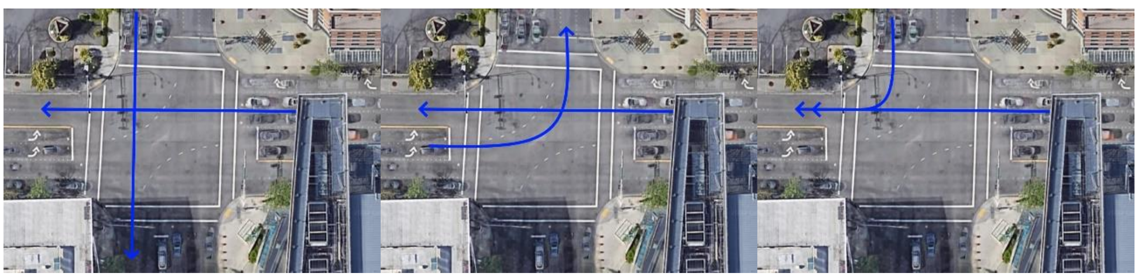

Figure 3 – Examples of Different Types of Road User Interactions

Network-wide, the most common conflict across all PET values was between left turn and through movements. For PETs < 1.5s, 1.5s < PETs < 2s, and 2s < PETs < 3s, these conflicts comprise about 90% of all conflicts. Figure 4 displays the prominence of each conflict type at PET < 1.5s. Merging scenarios, through and through movements, and interactions with bicyclists are under the “Other” category.

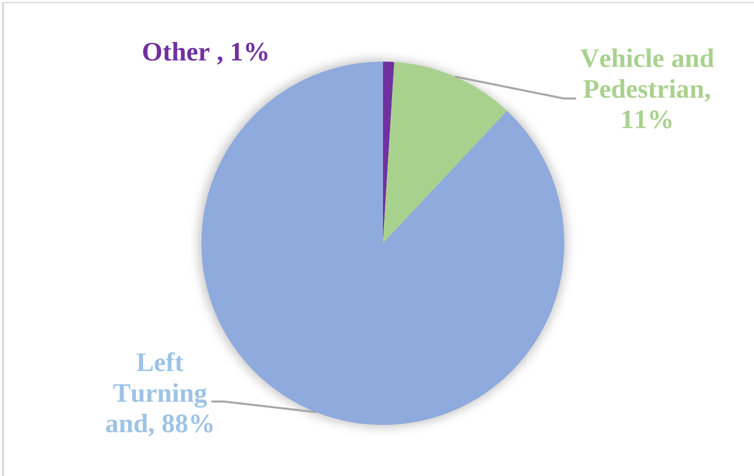

Figure 4 – Frequency of Each Conflict Type Throughout the Network for PET < 1.5s

The intersections with the highest number of severe conflicts for both pedestrians and drivers are listed. These lists were then compared to the High Injury Network (HIN), as defined a City of Bellevue study by Fehr and Peers, WA (Breiland, C., Weissman, D., Saviskas, S., & Wasserman, D., 2019).

Table 1 lists the 10 intersections with the highest number of conflicts with PETs < 1.5s involving pedestrians. These 10 intersections account for 58% of all PETs < 1.5s observed for pedestrians. The table shows that the majority of critical interactions at these intersections involve drivers and pedestrians. Based on this initial screening further analysis can be conducted at these intersections. Across all study intersections, pedestrians were involved in 11.10% of all conflicts with PETs < 1.5s even though they make up only 4% of all road users. As the majority of pedestrian travel is within the downtown core, the majority of the PETs < 1.5s involving a pedestrian (61%) were found in downtown commercial locations with high population density.

Table 1 – Top 10 Intersections by Total Number of Severe Conflicts for Pedestrians (PET<1.5s)

Rank	Site Name	Downtown	HIN	PETs<1.5s involving pedestrians
1	NE 8th St & 106th Ave NE	Yes	Yes	100%
2	NE 8th St & 110th Ave NE	Yes	Yes	79%
3	NE 8th St & Bellevue Way NE	Yes	Yes	100%
4	NE 8th St & 120th Ave NE	No	Yes	100%
5	Main St & Bellevue Way NE	Yes	Yes	100%
6	NE 4th St & 110th Ave NE	Yes	Yes	52%
7	SE 36th St & Factoria Blvd SE	No	Yes	100%
8	NE 8th St & 112th Ave NE	Yes	Yes	100%
9	NE 8th St & 108th Ave NE	Yes	Yes	79%
10	NE 6th St & 110th Ave NE	Yes	Yes	100%

Table 2 lists the 10 intersections with the highest number of conflicts with PETs < 1.5s involving only drivers (i.e. left turns & through conflicts, through & through conflicts, and merging). These 10 intersections account for 53% of all PETs < 1.5s observed for drivers. At these intersections, between 93%

to 100% of conflicts with PETs < 1.5s involved two drivers. Based on this initial screening further analysis can be conducted at these intersections.

Table 2 – Top 10 Intersections by Total Number of Severe Conflicts for Drivers

Rank	Site Name	Downtown	HIN	PETs<1.5s involving Drivers
1	NE 24th St & Northup Way	No	Yes	100%
2	Lakemont Blvd SE. St & 164th Ave SE	No	No	99%
3	NE 20th St & 116th Ave NE	No	No	99%
4	NE 8th St & 124th Ave NE	No	Yes	99%
5	NE 20th St & 130th Ave NE	No	Yes	99%
6	NE 30th St & Bel-Red Rd	No	No	98%
7	SE Newport Way & 150th Ave SE	No	No	99%
8	SE 26th St & Richards Rd	No	Yes	99%
9	NE 12th St & 112th Ave NE	Yes	Yes	97%
10	Main St & 106th Ave NE	Yes	Yes	93%

Figure 5 shows the location of these intersections. The red pins mark intersections that have a high number of severe interactions between pedestrians and drivers and the black pins mark intersections that have a high number of severe interactions between two drivers. The downtown area is highlighted in orange.

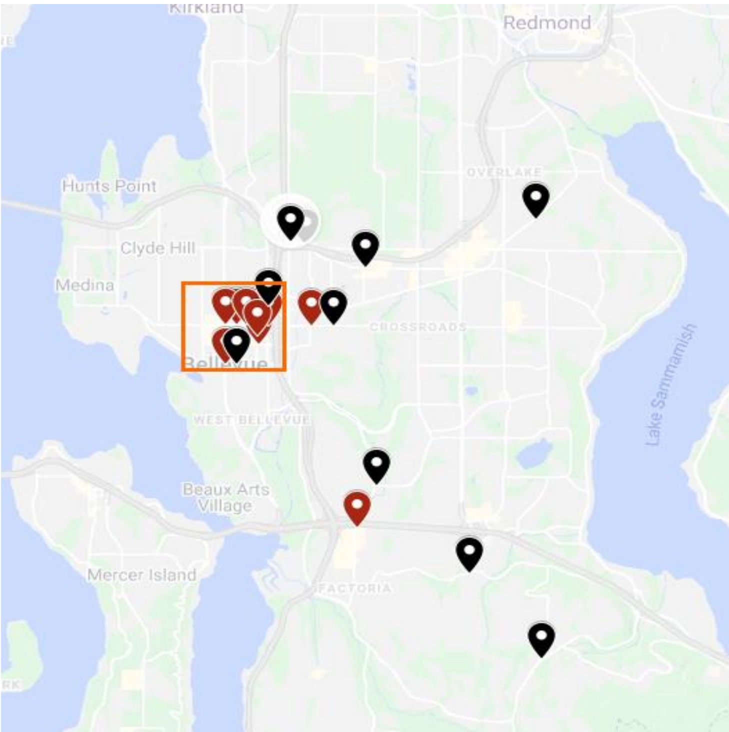

Figure 5 –Intersections with Severe Interactions

Before/After Case Study: How Signalization Changes Affect Cyclist Safety

The use of surrogate safety measures allows one to compare the effectiveness of a treatment almost immediately after implementation. The use of road use behavior means that there is no need to wait for crashes to happen. In late September 2019, the City of Bellevue implemented signalization changes to enhance safety at Main St and 108th Ave.

Description of the Site

Where Main St and 108th Ave intersect, Main St has 2 lanes in each direction plus one additional left-turn lane in each direction. Along 108th Ave, the southbound through movement is prohibited so there is one left turn and one right turn lane. Northbound on 108th Ave has one vehicle lane, in addition to one painted bike line. There is a green-painted bike box for both northbound and southbound bicyclists. The intersection is in a commercial area at the edge of the downtown area. Pedestrian volumes are in the top 30th percentile compared to all other sites analyzed in Bellevue. Motorist volumes, however, are in the bottom 35th percentile compared to all other sites analyzed in Bellevue.

Description of Change Implemented

Before the change in signalization at 108th Ave and Main St, the southbound left-turn movement had a permissive left turn signal, meaning drivers turning left were required to yield to through traffic, as well as to pedestrians and bicyclists in the opposite direction at all times. In late September 2019, the City of Bellevue implemented a leading protected left turn signal phase (green arrow) for the southbound left-turn movement. If a pedestrian has activated the push button to receive the walk, the southbound left-turn signal phase ends and remains red. Otherwise, the movement receives a flashing yellow arrow signal phase, meaning drivers can still turn left but must yield to the northbound through movement, bicyclists, and pedestrians.

Results

A limited study was performed using three days of before and after data over three hours (3 to 6 PM) comparing July to October. Overall 992 indicators of PET were observed. Figure 6 below shows the 50 worst interactions both before and after based on PET. Figure 6 shows that the closest interactions had a PET of between 1.5 and 3 seconds.

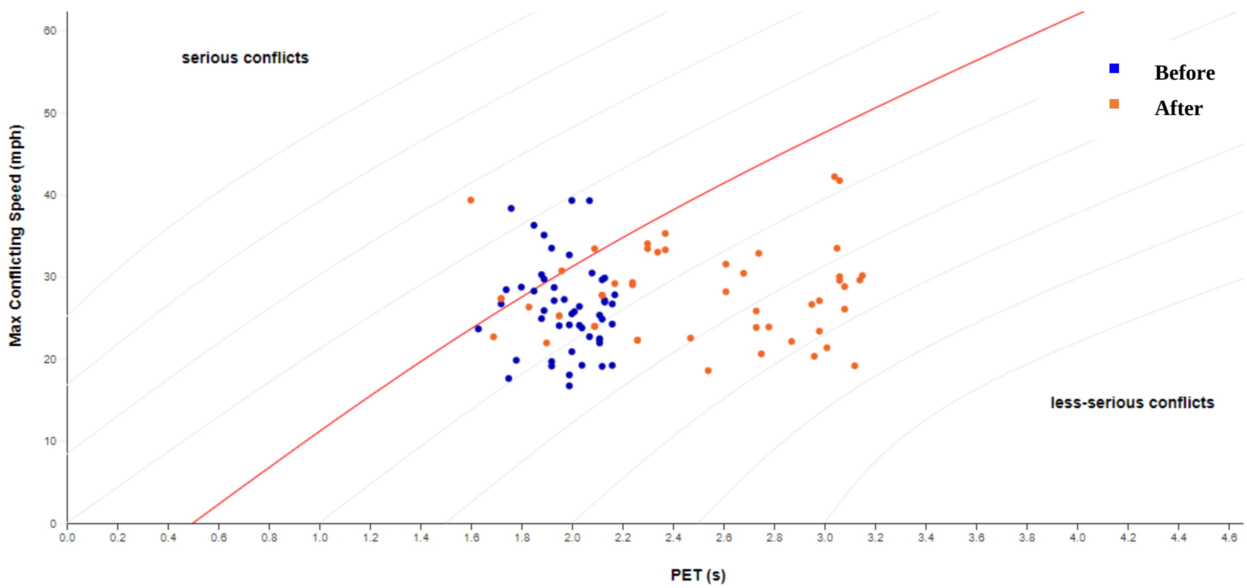

Figure 6 – 50 Worst PET Interactions of Southbound Left vs Northbound Through

Specifically related to the southbound left turn improvement, the number of interactions involving a southbound driver turning left were reduced. The volume of southbound left turns per hour changed from 105 per hour before and to 93 per hour after (12% decrease). Before, there were 52 instances with a PET < 5s and 13 instances with a PET <3s where a driver turned left immediately in front of a through driver. After, it was reduced to 7 with PET < 5s and 1 with PET <3s, a reduction of over 90%. For southbound left turn vs pedestrian interactions, the number of interactions with PET < 3s was reduced from 7 to 0 and instances of PET <5s was reduced from 38 to 3. The number of interactions involving a southbound driver turning left immediately after a northbound driver (PET <5s) was also reduced by about 90%. Overall the percent of interactions with PET < 3s per left turn was reduced from 2.1% to 0.1% and for PET < 5s from 13.2% to 1.2%.

In terms of driver speeds, the average median speed of northbound through motorists decreased slightly from before to after (9.63 mph to 8.39 mph). However, the average median speed of southbound left-turning drivers increased slightly from before to after, going from 9.32 mph to 10.87 mph. Given that the signalization changed from a permissive left to a protected left, left-turning drivers feel more comfortable making their turn at a slightly faster speed.

Conclusion

This work introduces a unique application of a large-scale network screening using video data from traffic surveillance cameras and LUMINA, a specialized automated-road-safety platform. Traffic volumes, speeds, and near misses were analyzed at intersections all around the city, using video analytics. This demonstrates the scalability of the platform. By taking advantage of existing infrastructure, this analytics solution can support Vision Zero programs.

75 intersections with varied population densities and land use were analyzed. Results showed that pedestrian volumes are much higher in the downtown region than in surrounding areas and that the majority of the road users were drivers. Speed analysis showed that driver speeds tended to be higher outside of the downtown, probably due to the lower pedestrian density, and that they were lower in more commercial areas. Conflict analysis varied by road user type. The intersections with the most severe conflicts for pedestrians and drivers were located in the downtown. The intersections with the most severe conflicts for drivers were more dispersed throughout the city and were generally not in the downtown area. On a network-wide scale, the most serious and common interactions found were between left turning motorists and through drivers.

Future Work

The second phase of this project is in process. It focuses on a subset of the intersections in this paper. The intersections were selected according to their location on the HIN. The video footage recorded for these intersections was continuous for 2 months. This data will be used to expand our understanding of the relationship between road user conflicts and crashes and to obtain more data on speeding.

References

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