Jacobs

Evaluation of Leading Pedestrian Intervals Using Video Analytics

In partnership with City of Bellevue, Microsoft, and Advanced Mobility Analytics Group

March 2022

Evaluation of Leading Pedestrian Intervals Using Video Analytics

Client name: City of Bellevue, Microsoft, and Advanced Mobility Analytics Group

Date: March 2022 **Prepared by:** Mark Bandy, PE and Erica Tran, PE

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1. Introduction

This report summarizes the application of video analytics to evaluate the pilot deployment of leading pedestrian intervals (LPI) in the City of Bellevue, Washington.The pilot deployment and evaluation through video analytics is the result of a partnership between the City of Bellevue, Advanced Mobility Analytics Group, Jacobs, and Microsoft. The partners believed that insight into the data derived from the effort had the potential to enhance the transportation industries' understanding of road user behaviors that contribute to crashed and that with predictive insights would be able to implement countermeasures to reduce conflicts and crashes. Additionally, specific to LPI, the partners' hope is thatthe evaluation would provide information that could inform t he City of Bellevue's LPI implementation guidance as well as its on-going Vision Zero program.

A Leading Pedestrian Interval (LPI) is a treatment at signalized intersections where a walk phase is started 3 to 7 seconds prior to the corresponding vehicular green phase. The treatment is identified by the Federal Highway Administration as a countermeasure to reduce conflicts between vehicles and pedestrians at signalized intersections, with studies showing it can reduce pedestrian crashes by 13%. (see https:/ /safety.fhwa.dot.gov/provencountermeasures/fhwasa18029/ch13.cfm)

Shown below is avisualization of how a leading pedestrian interval functions.

Source: Federal Highway Administration, STEP Countermeasure Tech Sheet, https://rosap.ntl.bts.gov/view/dot/55633

2. Study Locations and Data Collection

The City of Bellevue (City) identified 20 intersections within the Downtown and Crossroads areas for the before-after safety assessment of LPIs. These 20 intersections were selected to assess the LPI effects across varying land-use contexts, pedestrian volumes and signal phasing. Many of the intersections are also designated as a part of the City's High Injury Network.

The study intersections are shown in Figure 1.

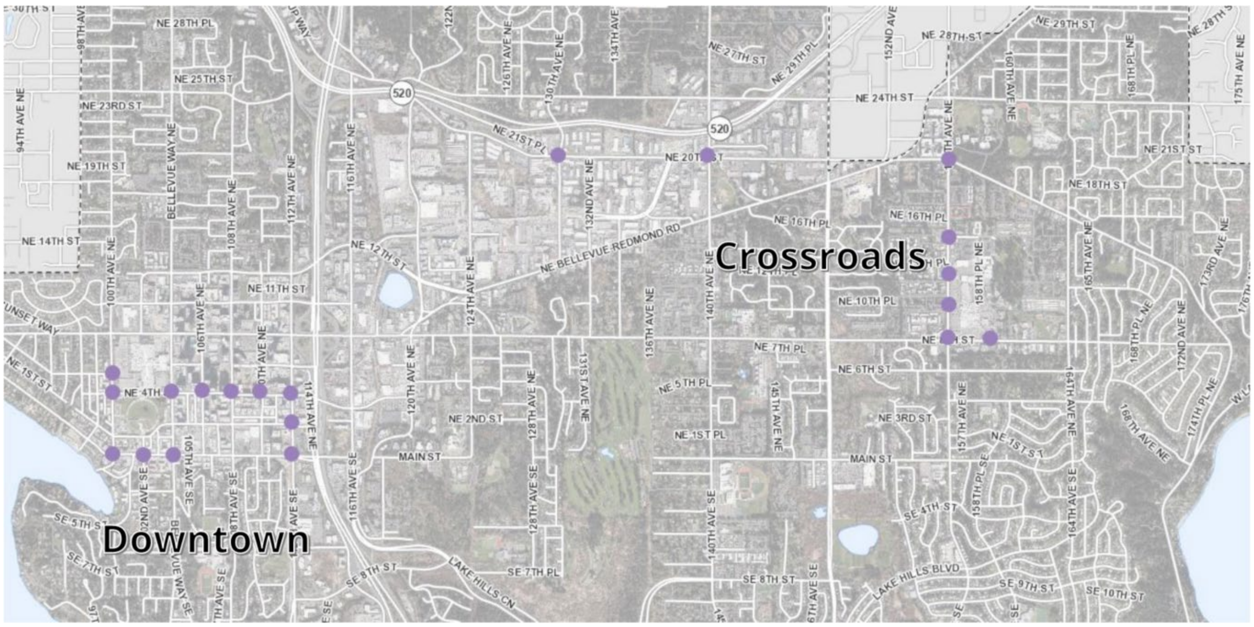

Figure 1. Study Intersection Locations

The study intersections have a variety of left-turn signal phasing, such as permissive, protected and protected-permissive. In addition, some locations have right turn pockets whereas other locations have a shared thru-right curb lane.

The City's approach was to implement LPI treatments in pairs (e.g. both north-south crossings or both east/west crossings) for this study. An LPI duration of 5 seconds was implemented, which aligns with the City's typical walk phase duration. Table 1 shows the crossings where LPI treatments were added at each study intersection.

Table 1. LPI Treatments at Study Intersections

ID	Intersection	Intersection Approach with Added LPI
1	100th Avenue and Main Street	North, South
2	102nd Avenue and Main Street	North, South
3	Bellevue Way NE and NE 4th Street	North, South
4	Bellevue Way and Main Street	North, South
5	106th Avenue NE and NE 4th Street	East, West
6	130th Avenue NE and NE 20th Street	North, South, East
7	108th Avenue NE and NE 4th Street	West
8	156th Avenue NE and Northup Way	North, South, East, West
9	112th Avenue and Main Street	North, South, East, West
10	112th Avenue NE and NE 4th Street	North, South, East
11	100th Avenue NE and NE 4th Street	East,West
12	112th Avenue NE and NE 2nd Street	South
13	100th Avenue NE and NE 5th Street	North
14	140th Avenue NE and NE 20th Street	East, West
15	110th Avenue NE and NE 4th Street	East, West
16	156th Avenue NE and NE 8th Street	North, South
17	156th Avenue NE and NE 15th Street	North, South
18	156th Avenue NE and NE 10th Street	*Existing LPI on North/South crossing
19	156th Avenue NE and NE 13th Street	North, South
20	158th Avenue NE and NE 8th Street	West

The City of Bellevue implemented LPI at all twenty study locations on October 25th, 2020. Video from City of Bellevue traffic monitoring cameras was processed by Microsoft using its Edge Video Services (EVS) to classify road users and their trajectories. This information was then provided to AMAG for analysis of conflicts in their SMART Transport Analytics Platform. For the full set of study intersections, before-LPI implementation video was collected on October 9, 2020 and October 14, 2020 and after-LPI implementation video on October 28, 2020 and October 30, 2020.

The COVID-19 pandemic significantly reduced travel, of all road users, at the study intersections and elsewhere during the study period. This resulted in a smaller than desired sample size from the initial before and after period video. With the intent of developing a sufficient data set, a larger sample of before and after video was processed for a subset of the study intersections. For locations 3, 5, and 7 in Table 1, the before period and after period samples were increased to October 9th to 15th and October 30th to November 5th, respectively.

3. Video Analytics Platform

The SMART Transport Analytics Platform was developed by AMAG and uses AI powered video analytics to identify road user conflicts. The platform can generate visualizations, conflict video clips and other metrics such as crash predictions, conflict rates and conflict distributions by crash type. Figure 2 shows the SMART Platform dashboard for this study.

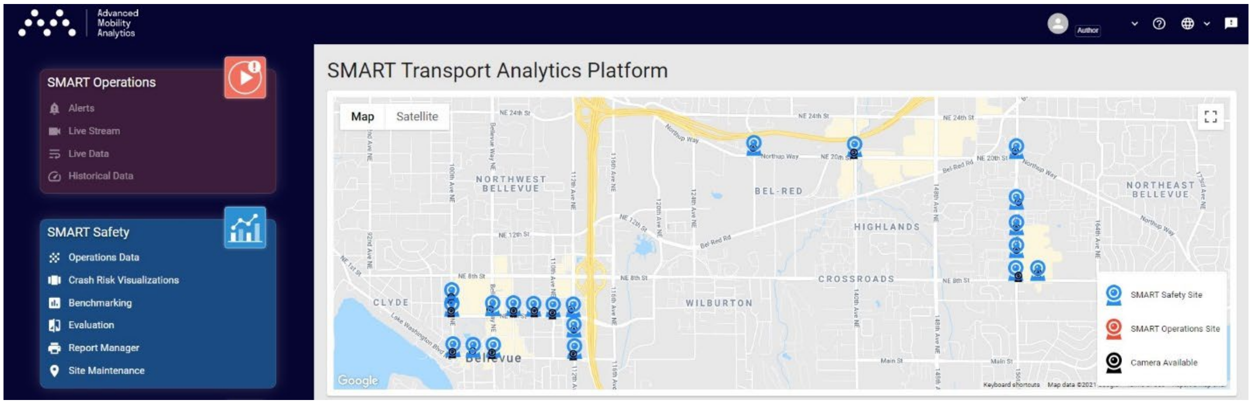

Figure 2. The SMART Transport Analytics Platform

3.1 Examples of SMART Platform Capabilities

In addition to tabular data summaries, the SMART Transport Analytics Platform provides two visualization outputs that are helpful to understand road user behavior and potential conflicts – (a) conflict heat maps and (b) speed and trajectory maps. Visualizations, overlaid on an image of the actual road space, can be a powerful technique to easily understand and convey how behavior of road users can vary at different locations or at the same location under differing conditions.

Both the conflict heat map and speed and trajectory maps were reviewed as part of this effort. Below are examples, with interpretations, using the Bellevue Way NE and NE 4th Street study intersection. Other sample outputs from the platform are included in Appendix A.

At the Bellevue Way NE and NE 4th Street intersection in Downtown Bellevue, LPIs were added on the north and south pedestrian crossing. Figures 3 and 4, below, show before and after conflict heat maps for all conflict types involving pedestrians. Comparing the two images, one can note how the intensity of the conflict heat maps appears reduced after the adding the LPI treatment.

Figure 3. Conflict Heat Map - Bellevue Way NE and NE 4th Street– Before LPI Treatment

Figure 4. Conflict Heat Map - Bellevue Way NE and NE 4th Street– After LPI Treatment

An example of comparing a location using the Speed and Trajectory mapsat the same intersection is shown in Figures 5 and 6. In these images the camera view is looking to the north. Comparing the westbound right-turn speeds it appears that the range of speeds is lower in the after condition. This could be a result of right turning vehicles stopping for or yielding to pedestrians in the crosswalk on the north leg post-LPI.

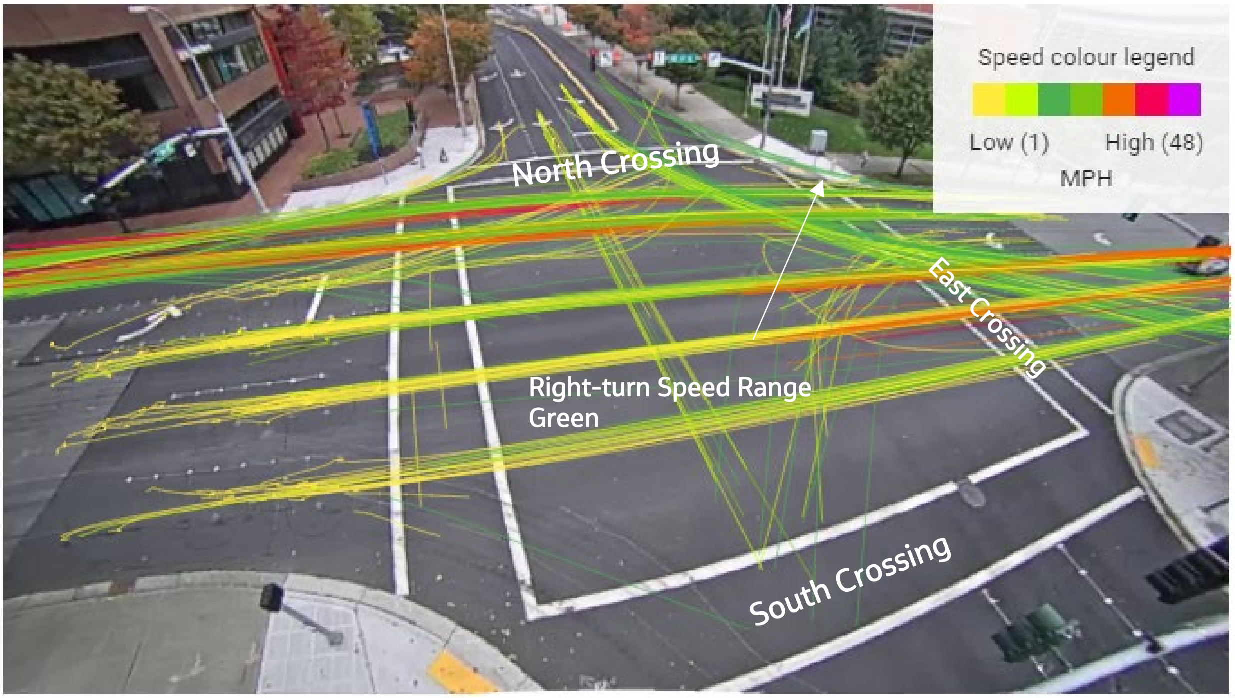

Figure 5. Speed and Trajectory Map - 110th Ave NE and NE 4th Street - Before LPI (10/ 14/20 at 5pm)

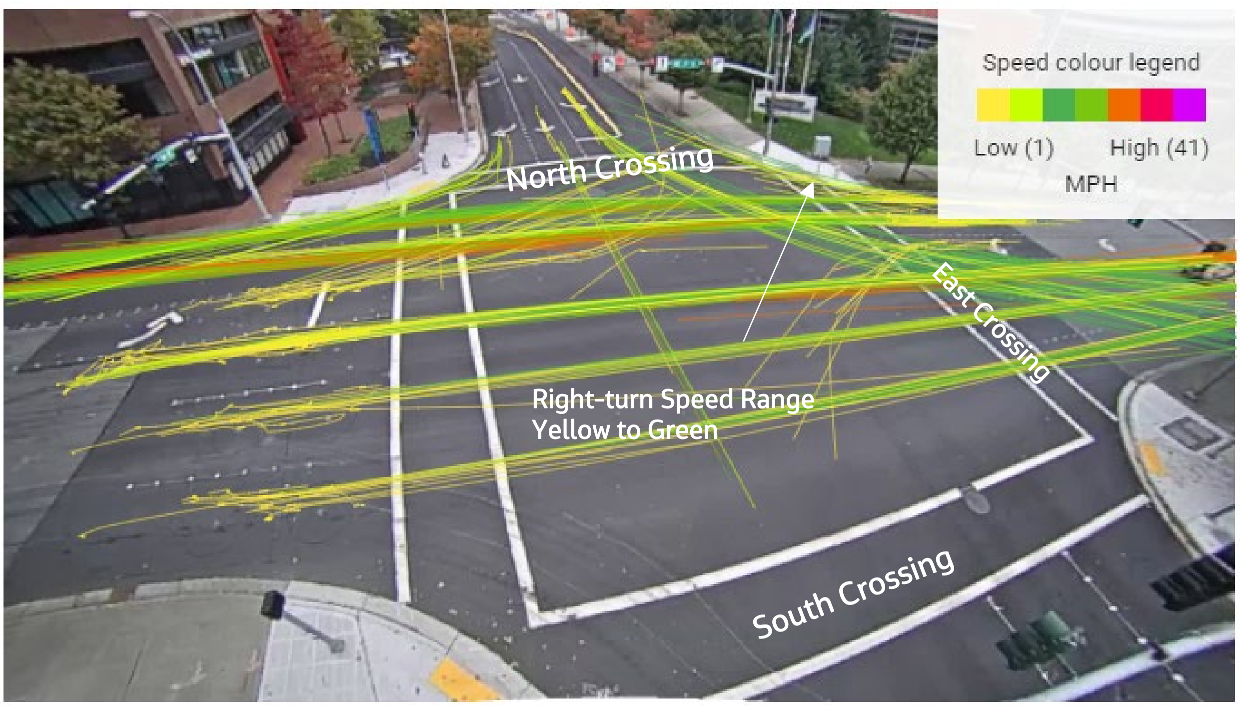

Figure 6. Speed and Trajectory Map- 110th Ave NE and NE 4th Street - After LPI (10/ 28/20 at 5pm)
[Note: background intersection image is for reference]

4. Evaluation

4.1 Approach

The approach to evaluating LPI was comprised of comparing the rate of conflicts, vehicle speeds, and modeled intersection operations. As mentioned earlier, the COVID-19 pandemic had an impact on the approach to the evaluation and likely impeded the ability to draw out some more discrete conclusions, for example, between different intersection geometries.

A fundamental aspect of this evaluation, which is facilitated through video analytics, is the comparison of conflict data rather than collision data. Conflict analyses have been part of transportation engineers' investigative methods for years, but the introduction of video analytics and related AI applications enables the development of richer data sets and more detailed assessments. Conflicts are identified in the SMART Transport Analytics Platform by analyzing post-encroachment time (PET), time-to-collision (TTC), and other factors.

4.2 Before-After Conflict Comparison

The top-level comparisons were to look at vehicle-pedestrian and vehicle-vehicle conflicts for the entire study set before and after the implementation of LPI. The SMART Transport Analytics Platform produces charts that facilitate this comparison.

Figure 7 shows the before and after rate of conflict for vehicle-pedestrian conflicts. The platform uses the term 'corrected for exposure', which is synonymous with 'rate'. At a high level this chart indicates that LPI may have reduced the rate of conflict but, being conscious of the small sample size of pedestrians and overall low rate of conflicts to begin with, couldn't be determined as conclusive.

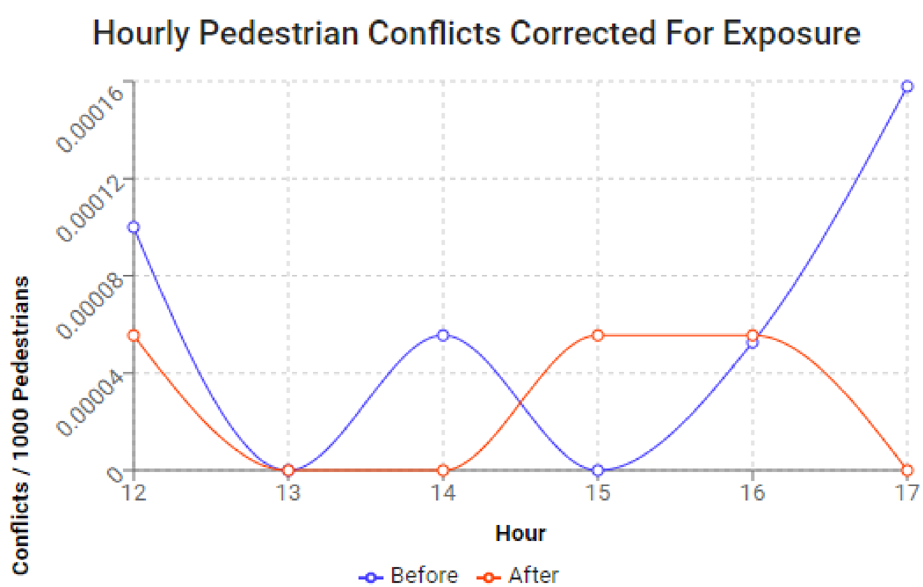

Figure 7. Pedestrian Conflict Rate Before and After

Figure 8 shows the before and after rate of conflict for vehicle-vehicle conflicts. At a high level, this suggests that the implementation of LPI has potentially reduced conflicts for all users. The sample size of vehicle traffic was considerably higher than that of pedestrians, and while this chart doesn't allow for a statistical conclusion, the before and after comparison of conflicts appears to indicate that the implementation of LPI is unlikely to increase overall conflicts.

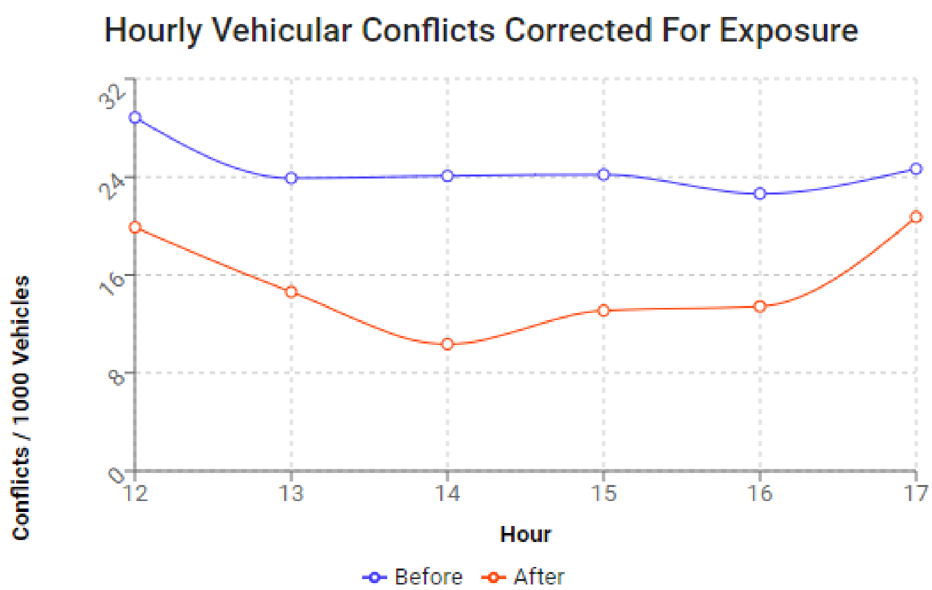

Figure 8. Vehicle Conflict Rate Before and After

4.3 Intersection Subset Comparison

As noted, three study intersections were evaluated in more detail, both in terms of before-after data collection and in statistical analysis. The intersections were evaluated using a Peak Over Threshold approach, which is documented in a separate paper, to be published in the near future. The findings of this analysis were that the implementation of LPI reduced vehicle-pedestrian conflicts by 42.3% and did not increase crash risk for other crash types.

4.4 Comparison of Change in Vehicle Turning Speed

Vehicle speed data from the video analytics was reviewed to see if LPI had an effect on vehicle turning speeds based on turn type (i.e. left turn versus right turn) or the presence of a right turn pocket. Table 2 shows the change in vehicle speed across the twenty study locations. For the purposes of this comparison, a change of less than 0.5 mph was considered to be the same and a change of more than 0.5 mph was considered a decrease or increase.

Table 2 Comparison of Turning Speeds

ID	Intersection	Intersection Crossing with Added LPI	Right Turn Pocket?	RT Pocket and LPI?	Change in Turning Speed (After - Before)							
					NBL	NBR	SBL	SBR	EBL	EBR	WBL	WBR
1	100th Avenue and Main Street	North, South	WBR	yes					-1	0	-1.1	0
2	102nd Avenue and Main Street	North, South	None	no					n/a	n/a	n/a	n/a
3	Bellevue Way NE and NE 4th Street	North, South	WBR	yes					-2.3	4.1	-1.9	-1.3
4	Bellevue Way and Main Street	North, South	EBR/WBR	yes					-0.5	1	n/a	n/a
5	106th Avenue NE and NE 4th Street	East, West	SBR	yes	-0.2	0.3	1.1	0.2				
6	130th Avenue NE and NE 20th Street	North, South, East	NBR/SBR	yes		-0.2	1.1		-0.2	1.1	-0.1	0.3
7	108th Avenue NE and NE 4th Street	West	SBR/WBR	yes	-1.1			-0.3				
8	156th Avenue NE and Northup Way	North, South, East, West	EBR	yes	0.6	0.6	-0.1	0.2	0.5	-0.1	0.3	1.1
9	112th Avenue and Main Street	North, South, East, West	None	no	-0.4		1.8	-1	0.1	-1.1	0.1	-0.7
10	112th Avenue NE and NE 4th Street	North, South, East	NBR/WBR	yes		-1.6	0.1		-1.3	0	n/a	n/a
11	100th Avenue NE and NE 4th Street	East, West	WBR	no	0	-0.3	-0.4	0				
12	112th Avenue NE and NE 2nd Street	South	None	no						1.5	2	
13	100th Avenue NE and NE 5th Street	North	None	no					-0.2			-0.8
14	140th Avenue NE and NE 20th Street	East, West	SBR	yes	1	0.6	n/a	1				
15	110th Avenue NE and NE 4th Street	East, West	NBR/SBR	yes	0.6	1.9	0.3	-0.7				
16	156th Avenue NE and NE 8th Street	North, South	SBR	no					2.1	0	-0.4	-1.4
17	156th Avenue NE and NE 15th Street	North, South	None	no					0.8	0.4	2.4	0
18	156th Avenue NE and NE 10th Street	*North, South	None	no					1.4	-0.6	0.2	-0.2
19	156th Avenue NE and NE 13th Street	North, South	None	no					0.4	0	0.1	-0.2
20	158th Avenue NE and NE 8th Street	West	SBR	yes	-0.1			-0.3				

* Existing LPI

Yellow = No Change; Green = Decrease; Red = Increase

Tables 3 and 4, below, show the breakdown of whether speeds remained the same, decreased, or increased. No apparent trends were identified, with the majority remaining the same.

Table 3. Change in Speed by Turn Type

Comparison of Speed by Turn Type			
	Same	Decrease	Increase
Left Turn	25	6	10
Right Turn	23	9	10

Table 4. Change in Speed by Presence of Turn Pocket

Comparison of Speed by Right Turn Pocket			
	Same	Decrease	Increase
Pocket	7	1	3
No Pocket	16	8	7

4.5 Operational Analysis

City of Bellevue staff analyzed the potential traffic delay effects of adding LPIs by modeling a subset of the study intersections and other intersections representing 'typical' intersections with the Synchro traffic analysis software.

The intersections modeled included:

- Bellevue Way NE and NE 4th St
- Bellevue Way NE and NE 8th St
- 108th Ave NE and NE 8th St
- 108th Ave NE and NE 10th St
- 108th Ave NE and NE 12th St
- 112th Ave NE and NE 2nd St
- 148th Ave NE and Main St

Overall, this analysis found that intersection delay, measured in seconds per vehicle, changed by less than five seconds and queue lengths by less than two vehicle-lengths. This amount of change is typically considered negligible, meaning the intersection operations can be viewed as equivalent with and without LPI. The analysis methodology and results are described in more detail in a technical memorandum, included as Appendix B.

5. Conclusions

5.1 Considerations for Further LPI in Bellevue

The comparison of before and after conditions across the twenty study intersections showed the potential for LPI to reduce the rate of vehicle-pedestrian conflicts, but the small data set did not enable this to be a firm conclusion. However, the additional analysis on three of the sites was able to show that LPI reduced vehicle-pedestrian conflicts by 42.3%.

The investigation of any differences in the effectiveness of LPI by turn type, presence of turn pocket, and intersection geometry were inconclusive. The expectation is that this is due to a small data set to compare across and that it is an area of potential further study, particularly with tools that can show road user trajectory and speed, such as that used in this study.

With the overall demonstrated benefit in conflict reduction and negligible change in intersection delay, deployment of LPI at other intersections appears to be a treatment worth considering.

5.2 Other Observations

Through the partners work on this study, several observations are shared for the benefit of others wishing to conduct similar studies with video analytics for conflict assessments

- Bellevue's permanent traffic camera system, fiber network, and ability to push digital video files to a server simplified site selection and the before and after video data collection.
- Video analytics tools that can compile road user trajectories, speeds, and potential conflicts can help practitioners understand infrastructure and operational treatments in new ways. Potential examples include:
  - Bicycle infrastructure elements such as bike boxes, buffer widths, and buffer treatments
  - Intersection elements such as corner radii and centerline extensions
  - Crosswalk approach elements such as RRFB, yield lines, and zigzag lines

Appendix A. Sample Reports from AMAG SMART Safety Application Platform

Flow Comparison Before/After at All 20 Sites

SMART Safety

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Compare Flows: Bellevue 20 Sites LPI Before-After

NEW FILTER | SAVED FILTERS | ADD TO REPORT

Filter type: Before/After

Average Flows (by road user in total entering volumes per hour)

Site	Ute/Pickup truck	Van	Passenger Car	Bus	Double Trailer	Pedestrian	Motorbike	Rigid Truck	Articulated Truck	Commercial Vehicle	Bicycle	Triple Trailer	Car/Ute With Trailer
Before			23917.7	307.5		360.3	7.2			149.1	19.9		
After		0.4	20784.2	289.6		264.3	6.4			110.0	10.6		
Difference	0%	0%	-13.10%	-5.82%	0%	-26.64%	-11.11%	0%	0%	-26.22%	-46.73%	0%	0%

Before: 4 - BELLEVUE WAY NE/MAIN ST (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 17 - 156TH/NE 15TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 1 - 100TH/MAIN (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 3 - BELLEVUE WAY/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 2 - 102ND/MAIN (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 12 - 112TH/NE 2ND (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 16 - 156TH/NE 8TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 18 - 156TH/NE 10TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 20 - 158TH/NE 8TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 17:00) 7 - 108TH/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 5 - 106TH/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 19 - 156TH/NE 13TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 17:00) 15 - 110TH/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 8 - 156TH/NE 20TH (Thu Oct 08 2020 - Wed Oct 14 2020) (11:00 - 18:00) 10 - 112TH/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 9 - 112TH/MAIN (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 14 - 140TH/NE 20TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 11 - 100TH/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 13 - 100TH/NE 5TH (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 6 - 130TH/NE 20TH (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00)

After: 4 - BELLEVUE WAY NE/MAIN ST (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 17 - 156TH/NE 15TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 1 - 100TH/MAIN (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 3 - BELLEVUE WAY/NE 4TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 2 - 102ND/MAIN (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 12 - 112TH/NE 2ND (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 16 - 156TH/NE 8TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 18 - 156TH/NE 10TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 20 - 158TH/NE 8TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 7 - 108TH/NE 4TH (Tue Oct 27 2020 - Thu Oct 29 2020) (8:00 - 17:00) 5 - 106TH/NE 4TH (Tue Oct 27 2020 - Thu Oct 29 2020) (10:00 - 17:00) 19 - 156TH/NE 13TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 15 - 110TH/NE 4TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 8 - 156TH/NE 20TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 16:00) 10 - 112TH/NE 4TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 9 - 112TH/MAIN (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 14 - 140TH/NE 20TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 16:00) 11 - 100TH/NE 4TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 13 - 100TH/NE 5TH (Tue Oct 27 2020 - Thu Oct 29 2020) (11:00 - 17:00) 6 - 130TH/NE 20TH (Tue Oct 27 2020 - Thu Oct 29 2020) (10:00 - 17:00)

Conflict Rate Comparison Before/After at All 20 Sites

SMART Safety

MARK BANDY

Compare Conflict Rate: Bellevue 20 Sites LPI Before-After

NEW FILTER | SAVED FILTERS | ADD TO REPORT

Filter type: Before/After

Conflict Rate Per 1000 Road Users

Site	U-Turn	Hit-Parked-Car	Opposing-Approaches	Head-On	Shared-Path	Pedestrian	Rear-End	Bicycle	Parallel-Lanes-Turning	Adjacent-Approaches	Side-Swipe	Off-Path
Before	0	0	10.8818	0	0	0.0528	7.8674	0.0151	0.0038	3.0181	1.0324	0
After	0	0	9.5742	0	0	0.0296	5.3712	0	0	2.3237	0.6434	0
Difference	**0%**	**0%**	**-12.02%**	**0%**	**0%**	**-43.83%**	**-31.73%**	**-100.00%**	**-100.00%**	**-23.01%**	**-37.68%**	**0%**

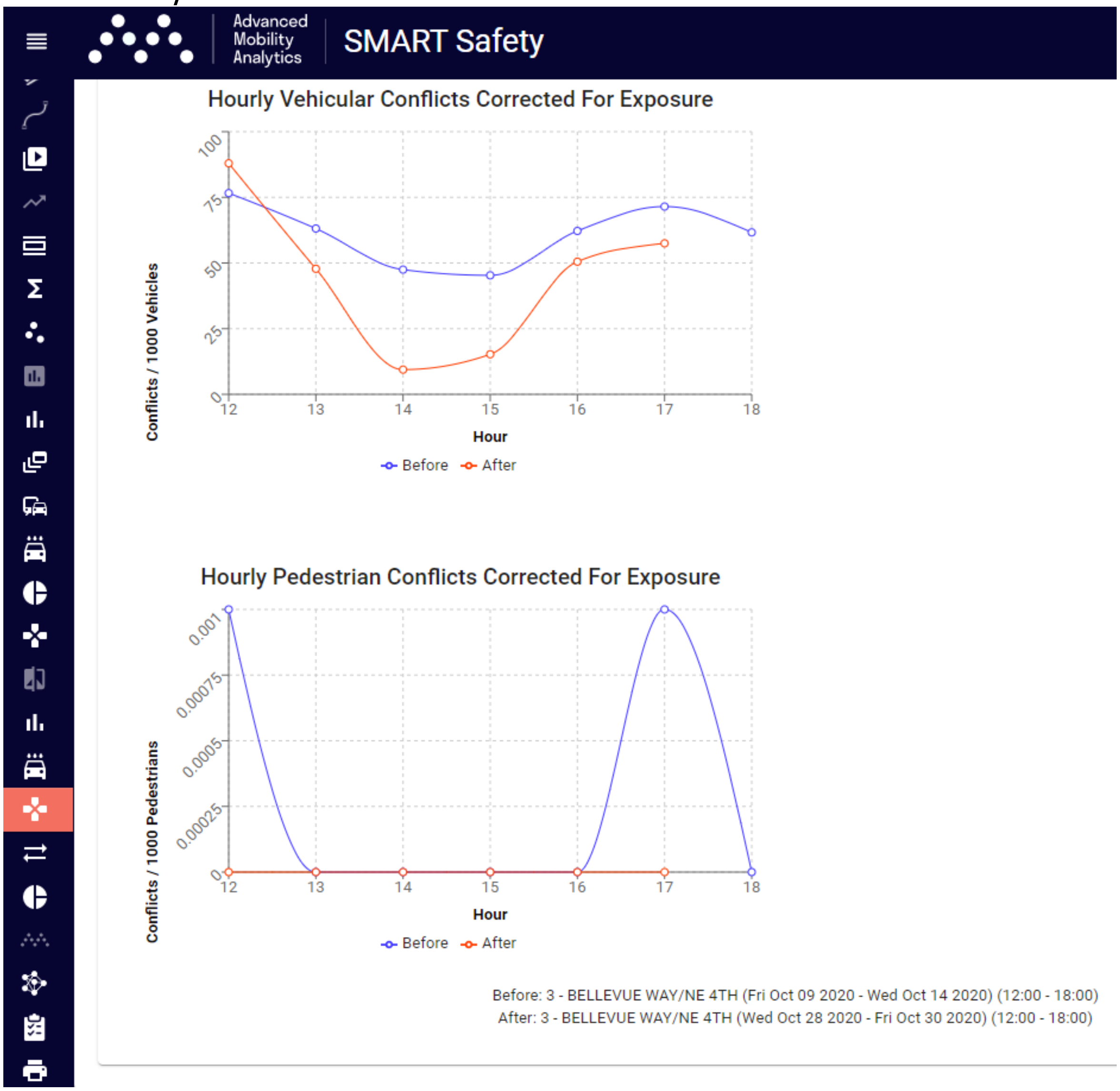
Conflict Count

Site	U-Turn	Hit-Parked-Car	Opposing-Approaches	Head-On	Shared-Path	Pedestrian	Rear-End	Bicycle	Parallel-Lanes-Turning	Adjacent-Approaches	Side-Swipe	Off-Path
Before	0	0	2888	0	0	14	2088	4	1	801	274	0
After	0	0	2262	0	0	7	1269	0	0	549	152	0
Difference	**0%**	**0%**	**-21.68%**	**0%**	**0%**	**-50.00%**	**-39.22%**	**-100.00%**	**-100.00%**	**-31.46%**	**-44.53%**	**0%**

Before: 4 - BELLEVUE WAY NE/MAIN ST (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 17 - 156TH/NE 15TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 1 - 100TH/MAIN (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 3 - BELLEVUE WAY/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 2 - 102ND/MAIN (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 12 - 112TH/NE 2ND (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 16 - 156TH/NE 8TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 18 - 156TH/NE 10TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 20 - 158TH/NE 8TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 17:00) 7 - 108TH/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 5 - 106TH/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 19 - 156TH/NE 13TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 17:00) 15 - 110TH/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 8 - 156TH/NE 20TH (Thu Oct 08 2020 - Wed Oct 14 2020) (11:00 - 18:00) 10 - 112TH/NE 4TH (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 9 - 112TH/MAIN (Thu Oct 08 2020 - Tue Oct 13 2020) (12:00 - 18:00) 14 - 140TH/NE 20TH (Thu Oct 08 2020 - Tue Oct 13 2020) (11:00 - 18:00) 11 - 100TH/NE 4TH (Thu Oct 08

Bellevue Way NE @ NE 4th Street

Conflict Exposure Before/After



Conflict Rate Before/After

Filter type: Before/After

Conflict Rate Per 1000 Road Users

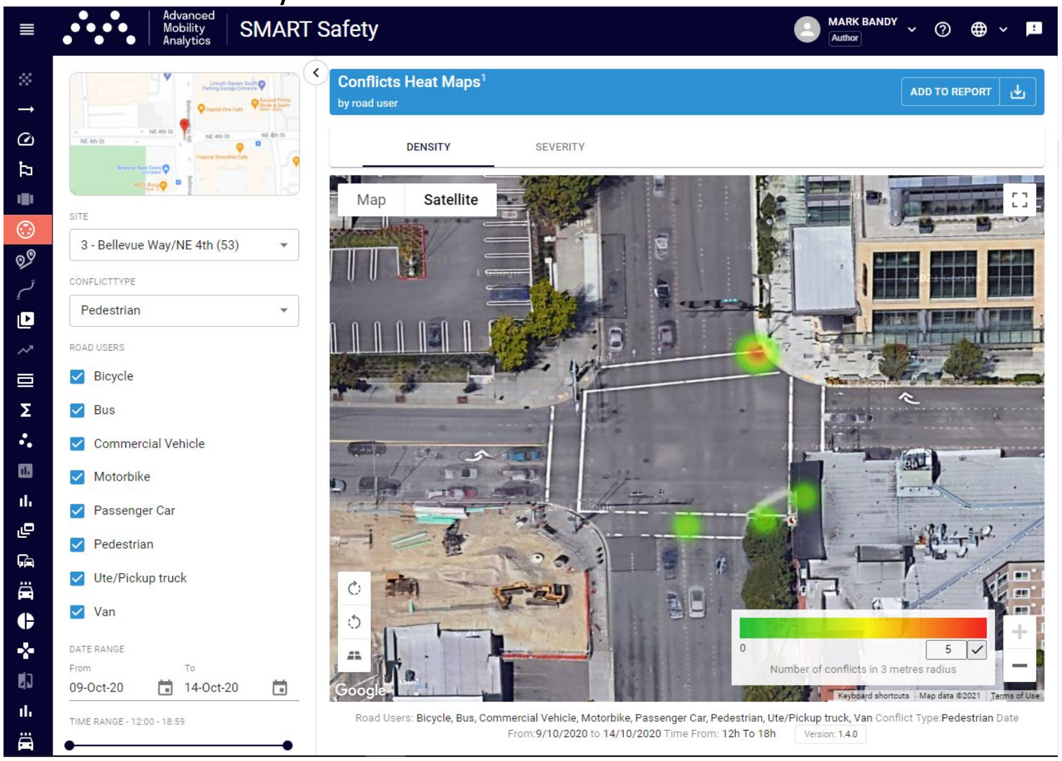
Site	U-Turn	Hit-Parked-Car	Opposing-Approaches	Head-On	Pedestrian	Rear-End	Bicycle	Parallel-Lanes-Turning	Adjacent-Approaches	Side-Swipe
Before	0	0	1.5950	0	0.2835	47.4587	0.0709	0	1.9848	7.7267
After	0	0	1.7008	0	0.0347	35.2655	0	0	1.2149	5.7619
Difference	**0%**	**0%**	**6.64%**	**0%**	**-87.76%**	**-25.69%**	**-100.00%**	**0%**	**-38.79%**	**-25.43%**

Conflict Count

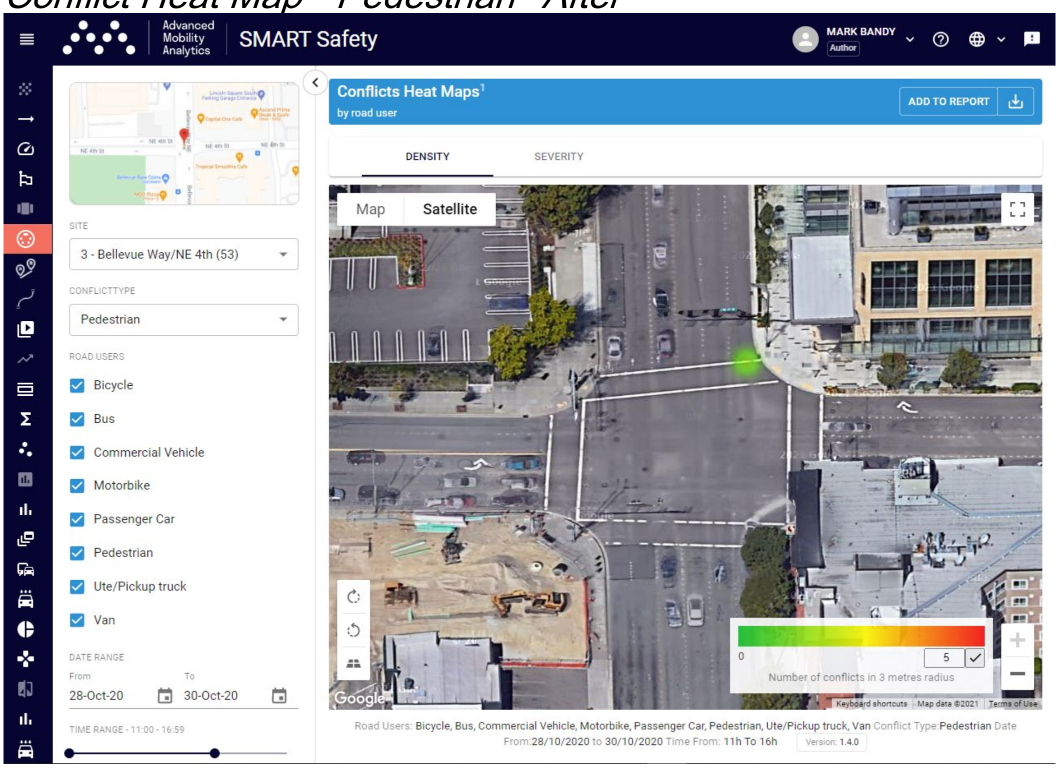
Site	U-Turn	Hit-Parked-Car	Opposing-Approaches	Head-On	Pedestrian	Rear-End	Bicycle	Parallel-Lanes-Turning	Adjacent-Approaches	Side-Swipe
Before	0	0	45	0	8	1339	2	0	56	218
After	0	0	49	0	1	1016	0	0	35	166
Difference	**0%**	**0%**	**8.89%**	**0%**	**-87.50%**	**-24.12%**	**-100.00%**	**0%**	**-37.50%**	**-23.85%**

Before: 3 - BELLEVUE WAY/NE 4TH (Fri Oct 09 2020 - Wed Oct 14 2020) (12:00 - 18:00)
After: 3 - BELLEVUE WAY/NE 4TH (Wed Oct 28 2020 - Fri Oct 30 2020) (12:00 - 18:00)

Conflict Heat Map – Pedestrian - Before



Conflict Heat Map – Pedestrian - After



156th Ave NE @ NE 8th Street

Conflict Exposure – Before/After

Conflict Rate Before/After

Filter type: Before/After

Conflict Rate Per 1000 Road Users

Site	U-Turn	Hit-Parked-Car	Opposing-Approaches	Head-On	Pedestrian	Rear-End	Bicycle	Parallel-Lanes-Turning	Adjacent-Approaches	Side-Swipe
Before	0	0	22.5642	0	0	7.1406	0	0	2.7134	0.5712
After	0	0	20.2124	0	0	4.3251	0	0	2.3124	0.1285
Difference	**0%**	**0%**	**-10.42%**	**0%**	**0%**	**-39.43%**	**0%**	**0%**	**-14.78%**	**-77.51%**

Conflict Count

Site	U-Turn	Hit-Parked-Car	Opposing-Approaches	Head-On	Pedestrian	Rear-End	Bicycle	Parallel-Lanes-Turning	Adjacent-Approaches	Side-Swipe
Before	0	0	632	0	0	200	0	0	76	16
After	0	0	472	0	0	101	0	0	54	3
Difference	**0%**	**0%**	**-25.32%**	**0%**	**0%**	**-49.50%**	**0%**	**0%**	**-28.95%**	**-81.25%**

Before: 16 - 156TH/NE 8TH (Fri Oct 09 2020 - Wed Oct 14 2020) (12:00 - 18:00)
After: 16 - 156TH/NE 8TH (Wed Oct 28 2020 - Fri Oct 30 2020) (12:00 - 18:00)

Appendix B. City of Bellevue Operational Analysis Tech Memo

Technical Memorandum

FROM: Darcy Akers, PE – City of Bellevue

DATE: March 15, 2022

RE: Operational Analysis of Leading Pedestrian Intervals

Background

The following summarizes operational analysis of Leading Pedestrian Intervals (LPI) at a sample of intersections in Bellevue. The modeling was conducted using microsimulation to estimate the impact of installing LPI on signal operation to supplement a larger study of LPI using video analytics and conflict data. More information on Bellevue's Vision Zero Video Analytics Partnerships can be found the city website for progress reporting.

Intersections

The following intersections were used because they represent a variety of intersection characteristics, including volumes, number of lanes and phasing. Except for one location, all the intersections are located in the Downtown Bellevue area, which was the primary focus of the LPI study. 148th Ave and Main St was chosen to represent an intersection on a low-density arterial not in the downtown area. Additional information on these intersections can be found in Table 2.

Intersections included in study:

- Bellevue Way and NE 4th St
- Bellevue Way and NE 8th St
- 108th Ave NE and NE 8th St
- 108th Ave NE and NE 10th St
- 108th Ave NE and NE 12th St
- 112th Ave NE and NE 2nd St
- 148th Ave and Main St

Modeling assumptions

Synchro and SimTraffic were used to model the impact of adding leading pedestrian intervals for signal operation. This software does not have defined method for implementing LPI so a "HOLD" or "PED" phase was used to simulate the delay in vehicle phase starting. Both the HOLD and PED phase is equivalent to an All-Red phase. This has two differences from actual operation – first, it must be modeled to occur every cycle, not just when a pedestrian is present and second the pedestrian phase does not begin until the vehicle phase turns green so it does not account for the 5 seconds the pedestrian could be clearing the road during LPI. Therefore, the modeling is likely over calculating the impact of LPI, especially for intersections where the pedestrian phase is not usually activated every cycle.

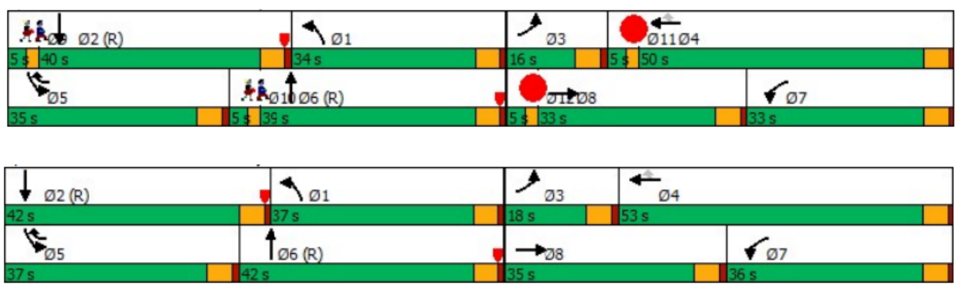
Additional modelling assumptions include:

- Alternatives are **With LPI** and **No LPI** for both the **AM peak** and **PM peak**.
- Volumes are based on pre-pandemic volumes for both pedestrians and vehicles for the highest peak hour between 7-9 AM and 4-6 PM. Right turn and left turn conflicting pedestrian volumes were entered to capture impact on permissive movement delay.
- Signal timing is based on existing signal timing, phasing and cycle length. Cycle lengths were maintained across alternatives.
- Signal splits were optimized in Synchro for all scenarios.
- For "With LPI" alternatives, the LPI is applied as a 5 second HOLD phase and has a min recall.
- The HOLD/PED phases for LPI were added to the ring barrier diagram as phases 9, 10, 11 and 12. They and could run concurrently with non-conflicting left turn phases as shown in Figure 1 below.
- 4 model runs were averaged for the SimTraffic report outputs.

Figure 1. Example of Signal Phasing in Synchro

With LPI

Without LPI



Summary of Results

On average, LPI increased intersection delay (seconds per vehicle) by less than 5 seconds. In comparing the average queue length, the maximum increase was less than 40 feet typically, which roughly equates to 1 or 2 cars. 148th Ave and Main St was the exception for both these measures.

As noted in modeling assumptions, there are limitations in modeling LPI in Synchro– the LPI phase needs to be modeled every cycle. Even though the pedestrian phases were placed on recall to provide a more direct comparison, it did not have much impact on delay and less of an impact than running the LPI phase (which is a HOLD/all red). This may be attributed to the pedestrian phase running concurrently with the vehicle phase.

The change in delay was smaller at locations with higher pedestrian volumes. This may be because the right turn movement experience delay from the pedestrians in the existing conditions. Locations that have protected left turn phasing also showed a smaller change in delay. Permissive left turn phasing may have had a larger impact because the permissive phase cannot run concurrently with the LPI phase, but a protected left turn phase can (as shown in Figure 1).

Location with lower pedestrian volumes and permissive movements showed a larger change in delay, but also had the lowest overall delay to start with, typically a level of service of B. While some locations with higher volumes showed limited change in delay, other locations did. In comparing locations of higher volume in the PM peak (3000-4000 vehicles in an hour), the locations with less change in delay had more balanced turning movement volumes and higher pedestrian volumes. 148th Ave and Main St showed the highest change in delay. It also has more directional volumes (high percent of volume traveling on the major through movement) and lower pedestrian volumes.

Table 1. Summary of Results

Intersection	Change in Delay (s/veh) AM/PM	Change in Avg Queue Length (ft) AM/PM
108th Ave NE and NE 8th St	3.4/2.3	29/41
108th Ave NE and NE 10th St	3.6/2.0	18/35
108th Ave NE and NE 12th St	3.6/4.6	27/40
112th Ave NE and NE 2nd St	2.7/4.1	22/29
Bellevue Way and NE 4th St	3.2/2.4	22/14
Bellevue Way and NE 8th St	3.0/3.6	26/26
148th Ave and Main St	9.2/13.9	98/145

Limitations and Further Study

This study includes a small sample size of intersections. Supplementary work could include more intersections with a variety of signal phasing and traffic volumes. Although SimTraffic was used in calculating delay and queue length, driver behavior and yielding was not calibrated in SimTraffic (default values were used) and could be further refined. There are also some assumptions to the signal timing and phasing that had to be made in order to include the LPI phase which do not match real world conditions. Additionally, the City of Bellevue operates an adaptive signal system. As a result, the signal splits and cycle lengths actually deployed in a before-after condition may likely vary from the optimized splits and assumed cycle length.

Intersection Characteristics

Table 2. Summary of Intersection Data

Intersection	Left Turn Phasing	Walk	Cycle Length AM/PM	FDW[2] Times (Peds 2/4/6/8)	Total Hourly Veh Volume AM/PM	Total Hourly Ped Crossings AM/PM
Bellevue Way and NE 4th St	Protected Only	Timed	130/150	13/16/16/16	1885*/2641	687*/687
Bellevue Way and NE 8th St	Protected Only	Timed	130/150	16/20/16/20	2380*/3548	746*/746
108th Ave NE and NE 8th St	Protected Only	Rest in Walk	135/150	14/20/13/20	2418/3388	384/481
108th Ave NE and NE 10th St	FYA with Ped Minus[1]	Timed	90/135	11/14/14/14	1214/1784	192/221
108th Ave NE and NE 12th St	FYA with Ped Minus[1] & Permissive Only	Timed	70/130	15/18/15/18	1700/2801	54/81
112th Ave NE and NE 2nd St	Permissive Only	Timed	130/130	12/16/10/15	1465*/2366	79*/79
148th Ave and Main St	Protected Only & FYA with Ped Minus[1]	Timed	150/150	10/19/9/21	3647/4015	73/130

1. "Ped Minus" means the permissive phase (FYA) does not run pedestrian phase. It remains protected until after pedestrian phase has cleared.
2. FDW = "Flashing Don't Walk", the pedestrian clearance time based on the width of the roadway

* Location where SCATS detector data and historical volumes were used to estimate AM peak volumes

Additional Results

Table 3 shows the average delay for the intersection in total for both with LPI and without LPI. Table 3 also include the total hours of delay, which accounts for the volume of vehicles in calculating the total amount of delay at the intersection for the given hour of analysis.

Table 3. Average Delay and Total Hours of Delay

	108th & NE 8th	108th & NE 10th	108th & NE 12th	112th & NE 2nd	Bell Way & NE 4th	Bell Way & NE 8th	148th & Main
Delay - sec/veh							
AM - NO LPI	31.4	15.3	12.7	17.7	27.7	36.7	42.0
AM - WITH LPI	34.8	18.9	16.3	20.4	30.9	39.7	51.2
Change	**11%**	**24%**	**28%**	**15%**	**12%**	**8%**	**22%**
	3.4	**3.6**	**3.6**	**2.7**	**3.2**	**3.0**	**9.2**
PM - NO LPI	41.2	21.1	15.5	21.9	40.8	45.9	48.9
PM - WITH LPI	43.5	23.1	20.1	26.0	43.2	49.5	62.8
Change	**6%**	**9%**	**30%**	**19%**	**6%**	**8%**	**28%**
	2.3	**2.0**	**4.6**	**4.1**	**2.4**	**3.6**	**13.9**
Delay- total hours							
AM - NO LPI	22.1	5.7	5.5	7.6	15.2	25.3	40.1
AM - WITH LPI	24.9	6.8	8.0	8.7	16.7	27.3	53.8
Change	**13%**	**19%**	**45%**	**14%**	**10%**	**8%**	**34%**
	2.8	**1.1**	**2.5**	**1.1**	**1.5**	**2.0**	**13.7**
PM - NO LPI	40.3	10.5	9.7	14.8	31.6	47.0	56.9
PM - WITH LPI	42.7	12.0	12.0	18.0	33.2	51.0	71.9
Change	**6%**	**14%**	**24%**	**22%**	**5%**	**9%**	**26%**
	2.4	**1.5**	**2.3**	**3.3**	**1.6**	**4.0**	**15.0**

Table 4 compares the percent of cycles with a pedestrian phase to the change in the delay at an intersection when LPI was applied.

In order to model the leading pedestrian interval in Synchro, a min recall had to be placed on the ped/hold phase in order to create demand, otherwise the LPI interval would never serve. However, at some intersections the pedestrian phase does not serve every cycle. The normal pedestrian actuation for the scenario of No LPI would have served less frequently than the scenario with LPI. Therefore, another scenario was modeled to include a pedestrian recall for the scenario of No LPI so the number of cycle with pedestrian phases were equal across the two scenarios. However, the ped recall did not result in a significant change in delay.

Table 4. Comparison of Percent of Cycles with Pedestrian's impact on delay

	% cycle with peds (no recall)	Ped Volume	Delay with no Recall	Delay with Recall
108th & NE 8th - AM	96-100%	300-400	31.6	31.4
108th & NE 8th - PM	96-100%	400-500	41.3	41.2
108th & NE 10th - AM	59-85%	100-200	16	15.3
108th & NE 10th - PM	69-100%	200-300	20.3	21.1
108th & NE 12th - AM	10-48%	<100	11.3	12.7
108th & NE 12th - PM	43-65%	<100	16	15.5
112th & NE 2nd - PM	33-74%	<100	21.6	21.9
Bell Way & NE 4th - PM	100%	500+	40.9	40.8
Bell Way & NE 8th - PM	100%	500+	45.9	45.9
148th & Main - AM	48-79%	<100	38.3	42
148th & Main - PM	60-88%	100-200	49.1	48.9