Evaluation of a Passive-Activated In-Roadway Warning Lights (IRWL) Crosswalk System

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Introduction

The purpose of this report is to provide the city of Appleton with the findings of an evaluation of a passive-activated in-roadway warning light (IRWL) system at two crosswalks on a refuge median, divided four-lane roadway running through the Lawrence University campus. Initially, these crosswalks were marked with the standard crosswalk warning signs and continental crosswalk markings. In the summer of 2012, a new IRWL system was installed at these crosswalks that extended across all four lanes of College Avenue at both crossings. IRWL at crosswalks, generally known as "flashing" or illuminating crosswalks or "in-pavement lights," consist of amber lights embedded in the pavement along one side of a crosswalk. The lights are installed in the pavement adjacent to the outside of the crosswalk markings, with the flashing lights positioned so they can be seen by oncoming traffic. The lights are normally dark, but when activated provide amber-yellow light while the pedestrian is crossing. The IRWL system also included synchronously activated yellow flashing lights on pole-mounted crosswalk indicator signs.

It was initially proposed that these lights would be passively activated using a bollard gateway system which uses a built-in sensor module to project and receive infrared light beams between opposing bollards. When a pedestrian entered the crosswalk zone and passed between the bollards, they would automatically activate the IRWLs. Concurrent with the activation of the IRWLs, pole-mounted crosswalk indicators signs with flashing yellow lights would be activated. However, upon consultation with Eric Lom, the City Traffic Engineer, it was decided to use motion-sensor cameras located at the crosswalks to activate the IRWL system.

Study Design and Methodology

To evaluate the IRWL crosswalk system, a before-after design was used to establish baseline and post-IRWL installation driver behaviors. In order to collect of data on the behavior of drivers as they approached the crosswalks, measurements were taken on both sides of the median at each crosswalk. Small lines were painted on the street at 10 feet intervals beginning at the crosswalk and extending 200 feet before the crosswalk. Two small poles were placed at the 140 feet and 200 feet markers. This made for a 60 feet window where driver behavior could be recorded by a video camera that was placed at the middle of the window (170 feet) and 50 feet back from the street.

In order to determine driver behavior when someone crossed the street, a staged pedestrian (adult male casually dressed) positioned at the crosswalks was used. There was a spotter at the 200 feet marker who used a walky-talky to notify the staged pedestrian that a car had entered the 60 feet window. At that time, the staged pedestrian crossed the street and the video camera would then capture the driver's behavior throughout the 60 feet window. These videos were then analyzed using a video analysis and modeling tool.

This process was used at six different crosswalk locations (number of videos before lights; number of videos after lights):

1) East bound traffic at the Main Hall crosswalk (n=172; n=114)
2) East bound traffic at the Library crosswalk (n=69; n=68)
3) West bound traffic when there is a green light at Lawe Street (n=19; n=12)
4) West bound traffic when there is a red light at Lawe Street (n=22; n=7)
5) West bound traffic when car is turning onto College from Lawe Street (n=40; n=23)
6) West bound traffic at the Conservatory crosswalk (n=235; n=69)

The videos were shot during 3 time periods (number of videos before lights; number of videos after lights)

1) Between 9:00 am and 1:00 pm (n=242; n=184)
2) Between 1:00 pm and 5:00 pm (n=169; n=53)
3) Between 5:00 pm and 9:00 pm (n=146; n=56)

Findings

The first way to evaluate the effectiveness of the IRWL system was to examine whether there was a difference before and after the lights were installed as to when the driver's brake lights came on within the 60 feet window. Table 1 shows the average braking distance in feet for the separate crosswalks and when all the crosswalks are combined.

Table 1. Average Braking Distance by Crosswalk

	East Bound		West Bound				All
	Main Hall	Library	Green light at College and Lawe	Red light at College and Lawe	Car turning onto College from Lawe	Conservatory	All Crosswalks
Before Lights	44.6	33.8	37.0	42.2	43.3	44.8	42.8
After Lights	27.9	28.6	28.6	23.6	33.9	33..3	29.6

It is clear from these results that drivers started braking significantly sooner within the 60 feet window after the lights were installed compared to before the lights were installed. For instance, drivers who were east bound and approached the Main Hall crosswalk started braking on average 44.6 feet into the 60 feet window before the lights were installed. After the lights were installed, they started braking on average 27.9 feet into the 60 feet window, a difference of 16.7 ft. When all the crosswalks were combined, the difference in average braking distance was 13.2 feet (42.8 feet before lights – 29.6 feet after lights).

Table 2 shows the average braking distance in feet by the time of day the video was shot. Similar to the findings in Table 1, the average braking distances of drivers after the lights were installed were significantly lower than before the lights were installed. It is also interesting to note that the shortest distance into the 60 feet window that drivers started braking was during the 5:00 - 9:00 pm time slot after the lights were installed (21.3 feet).

Table 2. Average Braking Distance by Time of Day

	9:00 am – 1:00 pm	1:00 pm – 5:00 pm	5:00 pm – 9:00 pm
Before Lights	44.8	47.9	34.4
After Lights	33.0	27.4	21.3

The second way to evaluate the effectiveness of the IRWL system was to examine whether there was a difference before and after the lights were installed regarding the velocity of the vehicles when they entered the 60 feet window and the velocity when they exited the 60 feet window. Remember, once they exited the 60 feet window, drivers still had 140 feet to travel before reaching the crosswalk. Therefore, a slower speed exiting the 60 feet window compared to entering the 60 feet window makes for a safer situation for the pedestrian. This was measured by subtracting the velocity of the vehicle when it entered the 60 feet window from the velocity when it exited the window. A negative value means the vehicle exited the 60 feet window at a slower velocity than when it entered the window while a positive number means it exited the 60 feet window at a higher velocity than when it entered the window. Therefore, negative values make for a safer situation for the pedestrian because the vehicle would have a slower velocity. Table 3 shows the average difference in velocity by crosswalk and when all the crosswalks were combined. At each crosswalk and when all the data from the crosswalks were combined, the average difference in velocity was slower after the lights were installed compared to before the lights were installed. For instance, at the East Bound – Main Hall crosswalk before the lights were installed, vehicles on average exited the 60 feet window at 1.52 mph faster than they entered the window. After the lights were installed, vehicles on average exited the 60 feet window 1.96 mph slower than they entered the window. It is also important to note that all the average differences in velocity were negative in all crosswalk situations after the lights were installed.

Table 3. Average Difference in Velocity by Crosswalk

	East Bound		West Bound				
	Main Hall	Library	Green light at College and Lawe	Red light at College and Lawe	Car turning onto College from Lawe	Conservatory	All Crosswalks
Before Lights	1.52	-2.44	-3.72	-.89	1.42	-.65	-.17
After Lights	-1.96	-4.72	-5.65	-4.96	-.63	-4.11	-3:23

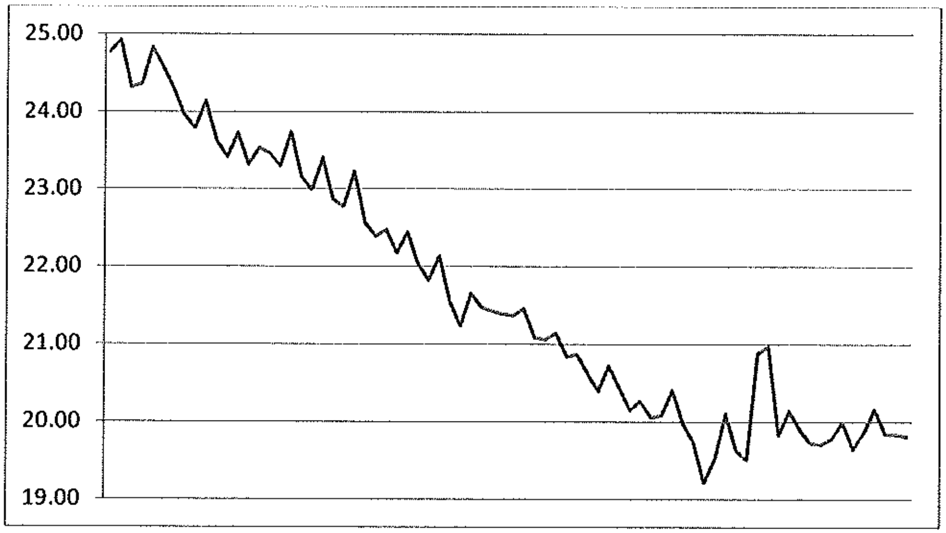
Table 4 contains the results for the average differences in velocity by time of day. As with the findings in the previous table, vehicles were exiting the 60 feet window at slower velocities than they entered across all times of day after the lights were installed. Before the lights were installed, there was very little change in the average difference in velocity from 9:00 am to 5:00 pm. Also, while the average difference before the lights were installed was negative for the 5:00 pm – 9:00 pm time slot (-1.27), it was still one mph less than the average difference in this same time slot after the lights were installed. So while the vehicles exited at a slower velocity than they entered the 60 feet window both before and after the lights, they exited on average two mph slower after the lights compared to one mph slower before the lights.

Table 4. Average Difference in Velocity by Time of Day

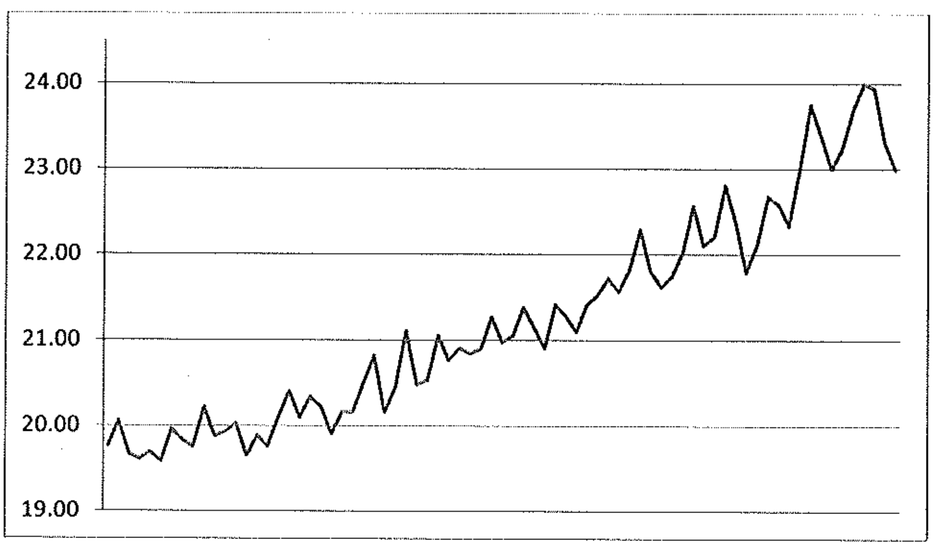
	9:00 am – 1:00 pm	1:00 pm – 5:00 pm	5:00 pm – 9:00 pm
Before Lights	.26	.18	-1.27
After Lights	-2.77	-5.78	-2.29

A third way to evaluate the effectiveness of the IRWL system is to examine the acceleration and deceleration patterns of vehicles as they passed through the 60 feet window. The video tracker software has the capability of graphing the velocity of vehicles as they progressed through the window. Although vehicle velocity varies from frame to frame and some velocity changes were small, it is possible to determine an overall pattern of whether the vehicle accelerates or decelerates. Graph 1 is an example of a vehicle that was classified as decelerating and Graph 2 is an example of a vehicle that was classified as accelerating. There are other patterns that are not as clear cut as those shown in Graph 1 and 2 but still suggest different velocity changes. These include when a vehicle decelerated then accelerated (Graph 3), accelerated then decelerated (Graph 4), had a constant velocity then decelerated (Graph 5) or accelerated (Graph 6).

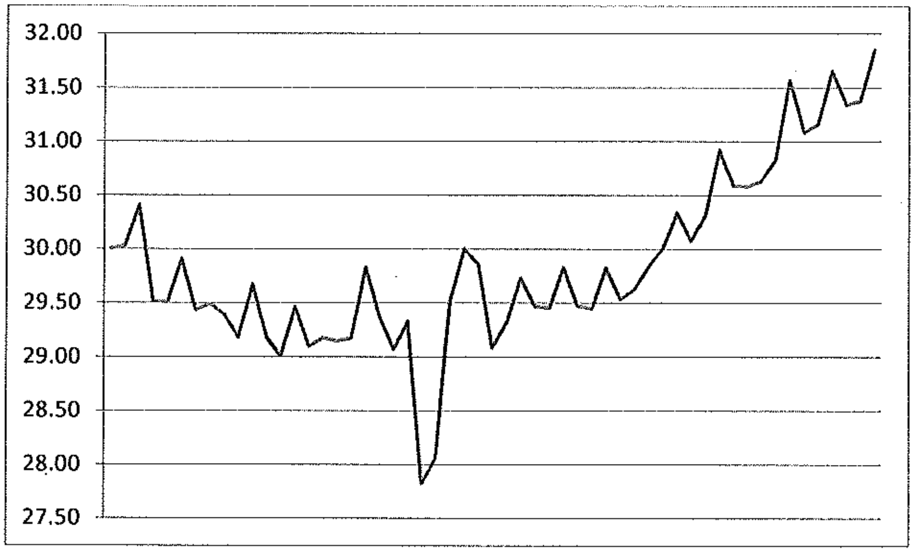
Graph 1. Example of a Vehicle that Decelerated



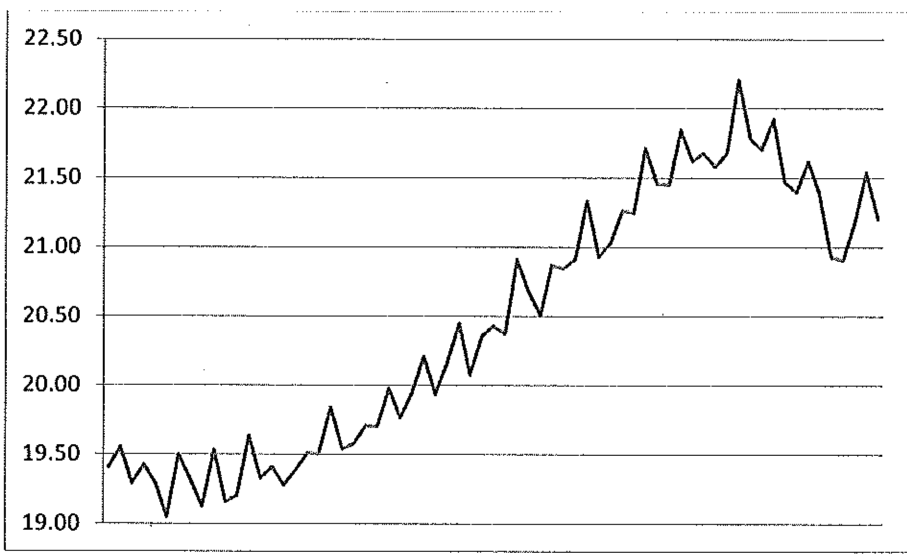
Graph 2. Example of a Vehicle Accelerating



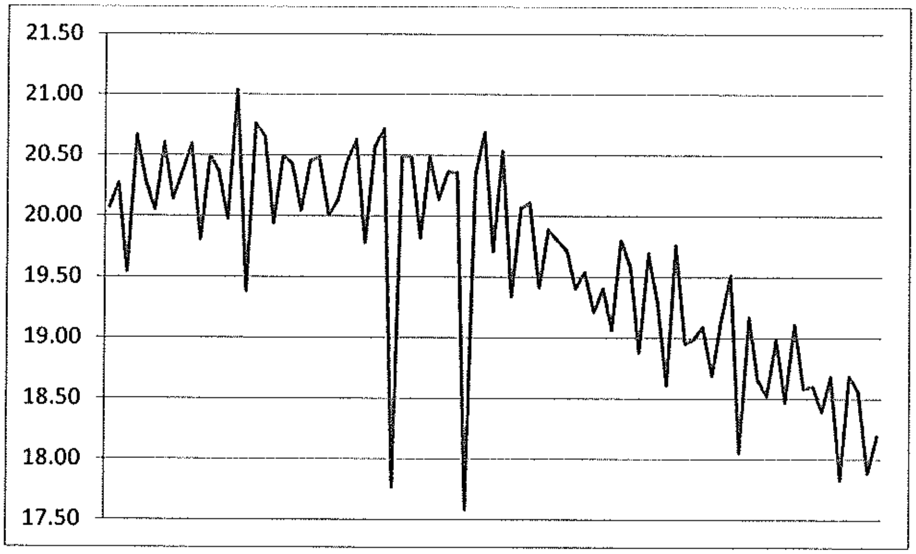
Graph 3. Example of a Vehicle that Decelerating then Accelerating



Graph 4. Example of a Vehicle Accelerating then Decelerating



Graph 5. Example of a Vehicle with Constant Velocity then Decelerating



Graph 6. Example of a Vehicle with Constant Velocity than Accelerating

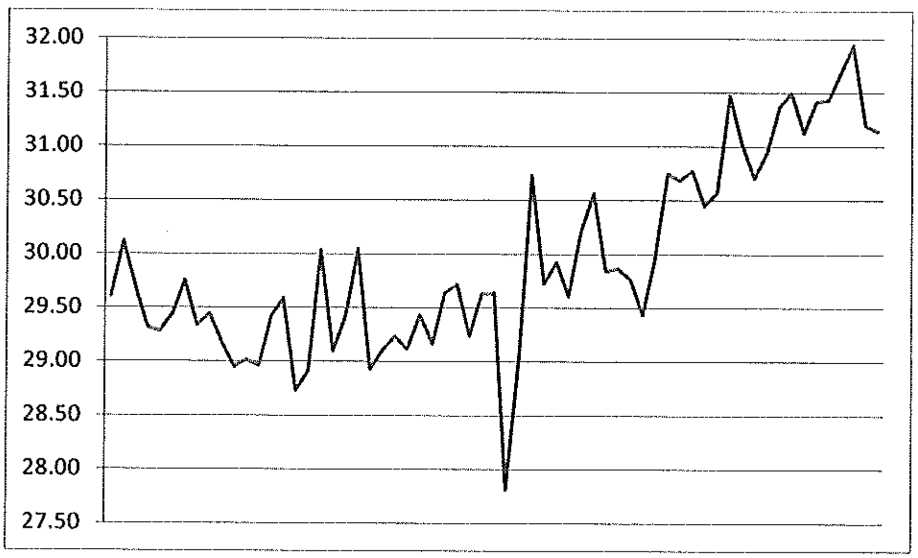


Table 5 shows the percentage of vehicles with these velocity patterns before and after the lights were installed. A higher percentage of vehicles decelerated only after the lights were installed then before (54.2% vs. 45.8%). On the other hand, a higher percentage of vehicles accelerated only before the lights were installed than after (83.3% vs. 16.7%). A lower percentage of vehicles decelerated after accelerating after the lights were installed than before (20.6% vs. 79.4%) while a higher percentage of vehicles accelerated after decelerating before the lights were installed (78.9% vs. 21.2%). Finally, deceleration occurred after maintaining a constant velocity for a larger percentage of vehicles after the lights were installed than before (53.8% vs. 46.2%) while a larger percentage of vehicles accelerated after maintaining a constant velocity before the lights were installed than after (63.6% vs. 36.4%). So all of the various velocity patterns after the lights were installed make for a safer pedestrian crossing compared to before the lights were installed.

Table 5. Percentage of Vehicles with Various Velocity Patterns

	Deceleration only	Acceleration Only	Decelerated then Accelerated	Accelerated then Decelerated	Constant Velocity then Decelerated	Constant Velocity then Accelerated
Before Lights	45.8%	83.3%	79.4%	78.9%	46.2%	63.6%
After Lights	54.2%	16.7%	20.6%	21.1%	53.8%	36.4%

The deceleration only and acceleration only velocity patterns were examined by location of crosswalk. Table 6 contains the results for the deceleration only pattern.

Table 6. Percentage of Vehicles that only Decelerated

	East Bound		West Bound			
	Main Hall	Library	Green light at College and Lawe	Red light at College and Lawe	Car turning onto College from Lawe	Conservatory
Before Lights	28.8%	44.0%	55.0%	50.0%	12.5%	61.5%
After Lights	71.2%	56.0%	45.0%	50.0%	87.5%	38.5%

In three of the crosswalk locations (east bound at Main Hall and the Library, west bound turning onto College from Lawe), a larger percentage of vehicles decelerated after the lights were installed compared to before the lights were installed. At the crosswalk locations where vehicles were either west bound with either a green light at College and Lawe or west bound at the Conservatory crosswalk, a greater percentage of vehicles decelerated before the lights were installed compared to after the lights were installed. At the crosswalk where vehicles were west bound with a red light at College and Lawe, the same percentage of vehicles decelerated both before and after the lights were installed.

Table 7 contains the results for the acceleration only pattern. In all of the crosswalk locations (except east bound at the Library and west bound with a green light at College and Lawe where there was only one vehicle) a larger percentage of vehicles accelerated before the lights were installed compared to after the lights were installed.

Table 7. Percentage of Vehicles that only Accelerated

	East Bound		West Bound			
	Main Hall	Library	Green light at College and Lawe	Red light at College and Lawe	Car turning onto College from Lawe	Conservatory
Before Lights	81.5%	0.0%	100.0%*	100.0%	77.3%	100%
After Lights	18.5%	100.0%*	0.0%	0.0%	22.7%	0.0%

*Only 1 vehicle

The deceleration only and acceleration only velocity patterns were also analyzed by time of day. Table 8 contains the results for the deceleration only pattern. A larger percentage of vehicles decelerated from 9:00 am to 5:00 pm after the lights were installed compared to before the lights were installed. However, for the 5:00 pm – 9:00 pm time slot, a larger percentage of vehicles decelerated before the lights were installed compared to after the lights were installed.

Table 8. Percentage of Vehicles that only Decelerated

	9:00 am – 1:00 pm	1:00 pm – 5:00 pm	5:00 pm – 9:00 pm
Before Lights	45.3%	37.5%	55.9%
After Lights	54.7%	62.5%	44.1%

Table 9 contains the results for the acceleration only pattern. For all time slots, a larger percentage of vehicles accelerated before the lights were installed compared to after the lights were installed.

Table 9. Percentage of Vehicles that only Accelerated

	9:00 am – 1:00 pm	1:00 pm – 5:00 pm	5:00 pm – 9:00 pm
Before Lights	76.6%	96.0%	89.5%
After Lights	23.4%	4.0%	10.5%

Summary

The results of the evaluation of the IRWL system at the crosswalks on the stretch of College Avenue that runs through the Lawrence University campus indicate the system is effective at improving both pedestrian and driver safety. Based on a before-after design, the analysis of videos that tracked vehicles with a 60 feet window which started 200 feet back from the crosswalks indicates that compared to when there was no IRWL system

- 1) drivers engaged their brakes sooner within the 60 feet window after the lights were installed,
- 2) there was a larger reduction in velocity from when vehicles entered the 60 feet window to when they exited after the lights were installed, and
- 3) a higher percentage of vehicles decelerated only and a lower percentage of vehicles accelerated only within the 60 feet window after the lights were installed.

The findings from 1) and 2) held across crosswalk locations and time of day. In most instances, the findings from 3) held across crosswalk locations and time of day. The most notable exception was that compared to after the lights were installed, a larger percentage of vehicles decelerated at the west bound Conservatory crosswalk and between 5:00 pm – 9:00 pm before the lights were installed. However, compared to after the lights were installed, a larger of percentage of vehicles accelerated at all crosswalk locations (except the east bound crosswalk at the Library and west bound with a green light at College and Lawe where there was only one vehicle) and at each time slot before the lights were installed.

The ultimate goal for Lawrence and the City of Appleton is to provide an environment where current students, potential students and their families, other visitors, faculty, and staff can safely walk about the entire campus and vehicle drivers can safely travel on College Avenue through the Lawrence campus knowing they will be promptly alerted to pedestrians using all crosswalks. The IRWL system that is currently in place goes a long way toward achieving that goal.

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Evaluation of a Passive-Activated In-Roadway Warning Lights (IRWL) Crosswalk System in a College Environment

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Study Purpose

The purpose of this study is to provide the city of Appleton with an evaluation of a passive-activated in-roadway warning light (IRWL) system at two crosswalks on a refuge median, divided four-lane road running through the Lawrence University campus. A before-after, staged pedestrian methodology will be used over a two-year period (2012-2014). The IRWL system will also include synchronously activated yellow flashing lights on pole-mounted crosswalk indicator signs and a pedestrian education program for Lawrence students, faculty, and staff. The objective of the IRWL study is to improve public safety according to the following criteria: 1) eliminate/minimize accidents and injuries to pedestrians, motorists, and property; 2) improve motorist and pedestrian yield compliance; and 3) lower incidence of risky pedestrian behavior.

Proposed IRWL Crosswalk System

The test sites for this study are two crosswalks on College Avenue between Lawe and Drew streets. These are referred to as the Park Crosswalk and Union Crosswalk. Currently, these crosswalks are marked with the standard crosswalk indicator signs. Lawrence University is proposing to install a new IRWL system at these crosswalks that would extend across all four lanes of College Avenue at both crossings. IRWL at crosswalks, generally known as "flashing" or illuminating crosswalks or "in-pavement lights," consist of amber lights embedded in the pavement along both sides of a crosswalk. The lights are installed in the pavement adjacent to the outside of the crosswalk markings, with the flashing lights positioned so they can be seen by oncoming traffic. The lights are normally dark, but when activated provide amber-yellow light while the pedestrian is crossing. Once activated, the lights flash at a constant rate for a set period of time, to be determined, to alert motorists that pedestrians are present in the crosswalk (Whitlock and Weinberger Transportation, 2010).

These lights will be passively activated using a bollard gateway system which uses a built-in sensor module to project and receive infrared light beams between opposing bollards. When a pedestrian enters the crosswalk zone and passes between the bollards, they automatically activate the IRWLs. The bollard system is directionally sensitive and only activates when entering the crosswalk zone and not when exiting. Concurrent with the activation of the IRWLs, pole-mounted crosswalk indicators signs with flashing yellow lights will be activated.

Testing Methodology

The testing methodology for this study is based on studies conducted by Whitlock and Weinberger (2010; 1998; 1997; 1995). To evaluate the IRWL crosswalk system, a before-after design will be used over a two-year period to establish baseline behaviors and post-IRWL installation behaviors. Over the two-year period we will sample motorist-pedestrian interactions under various seasonal, weather, time of day, and visibility conditions. The testing sessions for each condition and combination of conditions will consist of a minimum of 100 pedestrian crossings including 50 observations of traffic for each direction at each crosswalk. A trained crew of staged pedestrians and technicians will collect data on the samples of pedestrian crossings. A staged pedestrian (a male adult casually dressed) will test motorist yield compliance by first observing the traffic flow and then stepping into the crosswalk zone, thus activating the IRWL system and crosswalk indicators with flashing lights. Cameras focused on each crosswalk will be used to supplement the data collected by the staged pedestrians and technicians. In addition, a pedestrian education program will be administered to students, faculty, and staff about the current crosswalks and then again when the IRWL system is installed.

Metrics

During the staged pedestrian phase of the evaluation, data collected on motorist compliance will use the following metrics:

1) Drivers that yield or do not yield to pedestrians
2) The distance in advance of crosswalks at which drivers first apply their brakes
3) The distance at which drivers stopped to yield to pedestrians
4) The number of drivers that attempted to pass a stopped or yielding vehicle
5) The numbers of drivers that brake abruptly

1) A motorist will be recorded as yielding to the pedestrian if he/she slowed or stopped and allowed the pedestrian to cross. Non-yielding motorist will be recorded as non-yielding if he/she passes in front of the pedestrian, but would have been able to stop for the pedestrian based on the signal timing parameters published by the Institute of Transportation Engineers. In the study reported by Whitlock and Weinberger (2010), the dilemma zone for a 30-35 mph roadway is 185 feet. When the speed limit is 35-40, the dilemma zone is 235 feet. Measurement markings will be painted on the curb side of the street indicating these distances and 20 foot intervals up to the crosswalks.

2) and 3) Yielding distances will be measured by technicians recording the distance at which drivers react to the IRWL system by applying their brakes and the staged pedestrian noting the actual distance at which the motorist yielded in advance of the crosswalk.

4) A motorist will be recorded as attempting to pass a stopped or yielding vehicle if he/she changes lanes to pass the vehicle yielding to the pedestrian in the crosswalk.

5) A motorist will be recorded as braking suddenly if the front-end of the vehicle is observed by the technicians or staged pedestrian as dipping sharply toward the ground.

Outcomes

Reports on the performance of the IRWLs will be submitted to the City of Appleton on a schedule to be determined.

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