In-Pavement Pedestrian Flasher Evaluation: Cedar Rapids, Iowa

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Numerous strategies have been experimented with nationwide in an attempt to reduce the overall number of pedestrian-vehicle crashes, especially in instances where improper crossing or failure to yield was the proximate cause of the crash. Some of these measures include overhead signs, flashing warning beacons, advanced crossing signs, more visible pavement markings, in-street "Yield to Pedestrian" signs, and more recently, in-pavement flashing lights.

Pedestrian safety has been a key issue for the City of Cedar Rapids, Iowa, in particular at non-controlled intersections and mid-block crossings. In 2002, the city council gave preliminary approval to implement a pedestrian-actuated overhead flasher system in conjunction with an in-pavement flasher system at the intersection of 1st Avenue NE and 4th Street NE in the downtown central business district. This location is uncontrolled and has several elements that can create conflicts between pedestrians, vehicles, and trains that service local industry.

This report summarizes the results from a small-scale study completed by CTRE to evaluate the effectiveness of the in-pavement flasher system installed in downtown Cedar Rapids. The installation of in-pavement flashing warning lights at the pedestrian crosswalk at this site has had a net positive effect on the safety characteristics of the location. The results of this study show a marked improvement in motorist compliance with the state law requiring that motorists yield to pedestrians in the crosswalk. The pedestrian and motorist surveys show that both groups felt the in-pavement flashing lights have increased motorist awareness, especially at night. The data indicate the in-pavement flashing warning lights improved the motorists' response to pedestrians in the area, and that the system could be operational throughout summer and winter conditions.</td></tr>
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IN-PAVEMENT PEDESTRIAN FLASHER EVALUATION: CEDAR RAPIDS, IOWA

CTRE Project 03-145

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INTRODUCTION

Pedestrian safety is becoming a major priority on the nation's roadway network, particularly since the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 and the Transportation Equity Act for the 21st Century (TEA-21) in 1998. The National Highway Traffic Safety Administration (NHTSA) reported that during 2001, a total of 4,882 pedestrians and 728 bicyclists were killed on the nation's roadways; another 78,000 pedestrians and 45,000 bicyclists were injured (NHTSA 2002). Of those, 78.5 percent of pedestrian and 70.1 percent of bicyclist fatalities occurred at non-intersection locations. It is estimated that 28 percent of pedestrian fatalities occurred because the pedestrian improperly crossed a roadway or intersection, and another 26 percent occurred because a motorist failed to yield right-of-way to the pedestrian. In Iowa, a total of 19 pedestrians were killed during 2001, for a fatality rate of 0.65 fatalities per 100,000 population, well below the national average of 1.71 fatalities per 100,000 population (NHTSA 2002).

Numerous strategies have been experimented with nationwide in an attempt to reduce the overall number of pedestrian-vehicle crashes, especially in instances where improper crossing or failure to yield was the proximate cause of the crash. Some of these measures include overhead signs, flashing warning beacons, advanced crossing signs, more visible pavement markings, in-street "Yield to Pedestrian" signs, and more recently, in-pavement flashing lights. The current Manual on Uniform Traffic Control Devices (MUTCD) provides standards and guidance for the installation and operation of in-pavement flashing lights in Section 4-L. Although the manual uses the substitute term of "in-roadway" flashers, the systems will generally be referenced as in-pavement flashing systems to be consistent with early research.

Pedestrian safety has been a key issue for the City of Cedar Rapids, Iowa (2000 metropolitan statistical area population: 185,000), in particular at non-controlled intersections and mid-block crossings. In 2002, the city council gave preliminary approval to implement a pedestrian-actuated overhead flasher system in conjunction with an in-pavement flasher system at the intersection of 1st Avenue NE and 4th Street NE in the downtown central business district. This location is uncontrolled and has several elements that can create conflicts between pedestrians, vehicles, and trains that service local industry. Prior to the installation of the in-pavement flasher system, the use of in-street "Yield to Pedestrian" signs was evaluated for effectiveness by the City of Cedar Rapids and the Iowa Department of Transportation (Iowa DOT) via a study completed by the Center for Transportation Research and Education (CTRE) at Iowa State University.

This report summarizes the results from a small-scale study completed by CTRE to evaluate the effectiveness of the in-pavement flasher system installed in downtown Cedar Rapids.

LITERATURE REVIEW

Prior to MUTCD approval in 2000, several experimental applications of in-pavement flasher systems (see Figure 1) were completed and evaluated in other states, including Florida, New Jersey, Washington, and Hawaii. The use of in-pavement flashing lights has, to-date, been restricted to uncontrolled intersections and to mid-block locations to avoid becoming commonplace and to ensure that drivers are made aware of the special condition that exists at the specially-marked crossing. The in-pavement flashing units direct two or more flashing lights to the drivers when a pedestrian, or cyclist enters the cross walk. The lighting system is activated by a push-button or by a passive system that detects the breaking of a beam of energy by a cross walk user. Important design and operational details for the system include the method of activation, the number and placement of lights, the duration of the flashing period, and more. The following literature review will highlight portions of those issues, but the common feature in all of the systems is that the flashing units are placed to help drivers recognize the presence of crosswalk users and are the equivalent of a stop sign or a red traffic signal.

Figure 1. In-pavement flashing warning lights (walkinginfo.org)

Florida In-Pavement Flashing Lights Evaluation

Orlando, Florida, installed a flashing crosswalk in the spring of 1997 to connect a hotel on one side of the street with a theatre and arena on the other side of the street (Huang et al. 1999). Two conventional crosswalks were located in the vicinity of the new crosswalk and experienced similar pedestrian movements. A before-and-after study was completed to evaluate the pedestrian–motor vehicle conflicts and pedestrian activation of the flashing lights at the locations. Pedestrian interviews were also conducted to evaluate public response to the new crosswalk conditions.

The flashing crosswalk had small positive effects on most of the above criteria, although not all of them. The average speed of vehicles in the curb-lane dropped from 27.6 mph to 25.7 mph with pedestrians present and from 29.1 mph to 28.3 mph without pedestrians in the vicinity (the declines were not statistically significant). While only 13 percent of motorists stopped or slowed for pedestrians in the crosswalk before installation of the flashing lights, 34 percent stopped or slowed after installation (significant at the 0.001 level) if the system had been activated. Once the system had been installed, it was observed that about 28 percent of the pedestrians crossed the street in the crosswalk, although this figure jumped to 57 percent if law enforcement personnel were in the vicinity. Pedestrian interviews suggested that many pedestrians did not understand how the system worked, and several of them did not realize that the flashers operated during daylight hours.

Hawaii In-Pavement Flashing Lights Evaluation

The Hawaii Department of Transportation (Hawaii DOT) installed in-pavement flashing lights at an uncontrolled pedestrian crossing on the Pali Highway in response to pedestrian fatalities in 2000 (Prevedouros et al. 2000). The purpose of the project was to increase motorists' awareness of their responsibility to yield to pedestrians in the crosswalk. An evaluation was completed including before-and-after studies of traffic volume patterns, speeds, and delays, as well as pedestrian crossing patterns and delays and pedestrian–motor vehicle conflicts.

The study found that maximum spot speed was reduced approximately 17 percent, average spot speed was reduced approximately 26 percent, and 85th-percentile speed was reduced approximately 15 percent. In all cases, the reduction was larger in the southbound direction than in the northbound direction, although no hypothesis was given for this difference. The pedestrian waiting time was cut in half, from an average of 26.7 seconds to 13.2 seconds, and pedestrian crossing time was also reduced from an average of 33.6 seconds to 27.1 seconds, primarily due to the elimination of the need for pedestrians to wait in the median to cross the second direction of traffic. Approximately 31 percent of motorists disregarded pedestrians in the crossing before the project was completed, versus approximately 8 percent afterwards. The study also found that more pedestrians used the crosswalk properly after implementation of the project, and in the end, the Hawaii DOT was very pleased with the project outcome.

New Jersey In-Pavement Flashing Lights Evaluation

The New Jersey Department of Transportation identified a site in Denville, New Jersey, that involved several complexities for pedestrians attempting to negotiate the intersection (Van Derlofske et al. 2003). A before-and-after study was completed to evaluate traffic flow, vehicle approach speeds, and pedestrian–motor vehicle conflicts. Prior to installation of flashing warning lights, the crosswalk was striped with a more aggressive pattern.

In evaluating the approach speeds of vehicles, it was noted that the average approach speed was always lower with pedestrians present at the crosswalk than without pedestrians present at the crosswalk. With pedestrians present, the speed dropped from an initial average of 25 mph to 24.2 mph with the improved striping, and then to 21.6 mph when the flashing lights were installed. However, long-term studies showed that eight months after the initial installation of the flashing lights, average speeds with pedestrians present had risen to 23 mph and four months later to 27.5

mph. This implied that as motorists became accustomed to the new system, their driving behaviors reverted, and over time, speeds actually increased to higher levels than before.

Washington In-Pavement Flashing Lights Evaluation

In 1997, the City of Kirkland began installing in-pavement flashing lights to alert motorists to pedestrians in crosswalks (Godfrey 2002). A study completed in 2002 showed long-term benefits from the installation of these systems in Kirkland. The study found that more vehicles stopped for pedestrians at these locations, and that when they stopped, they tended to stop further in advance of the crosswalk. The study showed an 80 percent reduction in accidents at locations with the in-pavement flashers versus other similar locations without flashers. In the two instances when accidents occurred at these locations after installation of in-pavement flashing warning light systems, the system was either damaged by a previous collision with the controller box, or the pedestrian did not properly activate the system.

Maintenance has been the primary negative issue for the City of Kirkland, with early units being prone to damage from water infiltration or shearing from snowplows. Newer models of in-pavement flashing lights have lower profiles and are not as likely to be damaged, especially if rubber-edged blades are used on snowplows. The city continues to search for improved alternatives to test with the in-pavement lighting systems.

STUDY PLAN FOR CEDAR RAPIDS

In 2001, the City of Cedar Rapids identified three sites that were frequently identified as locations where pedestrian crossings were a special concern. At the three locations, the Traffic Engineering Department placed experimental signs (since approved for application within the MUTCD) in the street to remind motorists of their responsibility to Yield to Pedestrians in the Crosswalk, as specified by state law (Kannel and Souleyrette 2003). A part of the overall plan was to select one location, 1st Avenue NE and 4th Street NE, from the three sites previously examined to install an in-pavement flashing warning light system.

The original plan for data collection was to have both the before-and-after data collected during the summer of 2003. Construction delays and difficulty with installing and debugging the system resulted in the in-pavement flashers not being fully operational until September 2003. The after data were collected at the end of September. The researchers extended the completion time and used the opportunity to follow up with additional on-site observations including driver and pedestrian surveys in March 2004. The follow up and survey elements will be included in this report. However, it should be noted that it is possible that user characteristics, especially of the bicycle/pedestrian trail, may have changed somewhat during the two and a half months between the before-and-after data collection periods due to weather conditions and not totally due to system characteristics.

Study Site Information

The study site chosen for evaluation of in-pavement flashing lights is located at 1st Avenue NE and 4th Street NE in the downtown central business district of Cedar Rapids, Iowa (see Figure 2 and Figure 3). The major street at the location, 1st Avenue NE, is also designated as U.S. Highway Business 151 and is a major arterial with four lanes of traffic, a continuous two-way left turn lane (TWLTL), and a lane of parking in each direction, for a total of seven lanes. Several businesses are located in the immediate vicinity of the study site, the most notable of which are the U.S. Cellular Center and the Crowne Plaza Hotel. Surface parking lots are located across 1st Avenue NE from the U.S. Cellular Center, and a parking ramp is located across 4th Street NE from the Crowne Plaza Hotel, which it is connected to via a pedestrian skywalk.

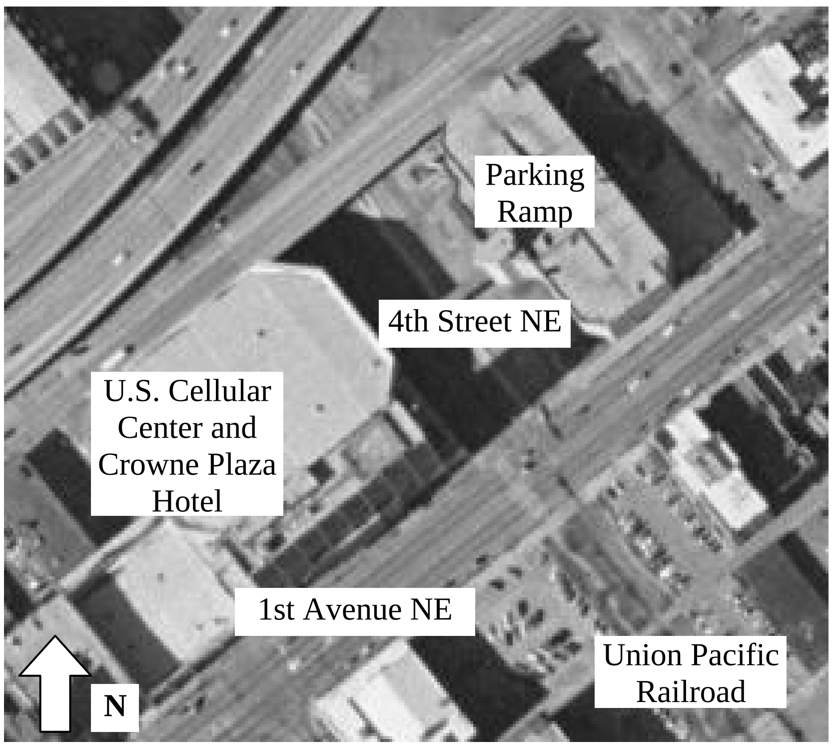

Figure 2. Study site location, downtown Cedar Rapids

Figure 3. Study site location, downtown Cedar Rapids, looking westbound

The location has many complexities that cause pedestrian crossings to become more difficult to execute safely. The Union Pacific Railroad, which services nearby industry, has a spur line that runs parallel to 4th Street NE; a bicycle/pedestrian trail runs adjacent to the rail line and crosses 1st Avenue NE at this crosswalk location. A 15-foot-wide service drive from the Crowne Plaza Hotel is located on the east side of the hotel and falls partially within the crosswalk where it meets the north curb line. Figure 4 is a northbound view showing the site after the in-pavement system was in place. In addition, the total distance to be crossed is rather large—approximately 80 feet from curb to curb across five lanes of traffic and two parking lanes. Traffic volumes on 1st Avenue NE are approaching 25,000 vehicles per day, with heavy peaking characteristics centered around the A.M. and P.M. peak periods. The posted speed limit through the corridor is 25 mph, but the 85th percentile speeds approach 30 mph. All of these issues make the crosswalk at this location difficult for pedestrians, bicyclists, and motorists to navigate while avoiding conflicts with each other and with the different physical features of the project location.

Figure 4. Crosswalk at ground level, looking northbound

The access drive posed a special design challenge to the contractors and the city. The city selected a passive detection system whereby the pedestrians were detected by passing between pairs of bollards located with one on each side of the crosswalk, as seen in Figure 4. Because the access entrance occurred in the crosswalk area on the far side of the street, vehicles entering the access drive would have activated the system if the detecting bollards on the north side were placed as widely as the bollards seen in Figure 4 on the south side of the street. As a result, pedestrians and cyclists approaching from the north had a smaller detection zone, as seen in Figure 5. Crosswalk users approaching from the right (west) had to make a greater effort to activate the flashers before they crossed.

Figure 5. Crosswalk at ground level, looking southbound

Data Collection Plan

The plan for collecting data was to conduct a before-and-after study of the site using several methods to document vehicle and pedestrian behavior. Approach speed data for each direction of travel were collected before and after the lighting system was installed using a radar gun. Video recordings of the intersection were also taken from the parking garage to determine the percentage of vehicles slowing or stopping for pedestrian movements at the crosswalk. The video data were also used to determine approximate pedestrian and bicycle volumes during the observed periods.

The data were collected during the P.M. peak period from 4:00 to 6:00 before the project was implemented and then during the A.M. (7:00 to 9:00), lunch hours (11:00 to 1:00), and P.M. (4:00 to 6:00) peak periods after the system was in place. The after period measurements were taken a minimum of two weeks after the installation when normal traffic conditions were in place. Data were also collected approximately six months after the installation of the flasher system for the P.M. peak period. This second 'after' data set was collected to help determine if driver behavior regressed back towards habits from before the system had been in place, or if they remained altered as a result of the project. Data before and after were collected under similar weather conditions and analyzed by the same person to ensure consistency in the before-and-after data. In addition, data from the "In-Street Yield to Pedestrian Sign" final report (Kannel and Souleyrette 2003) for the same location was included in the analysis.

Measures of Effectiveness

The measures of effectiveness used to help determine the net effect on the safety characteristics of the intersection include the following:

1. Vehicle speed changes from before implementation to after, evaluated both when pedestrians were present in the vicinity and when they were not
2. Percentage of first, second, and third vehicles to slow or stop for pedestrians in the crosswalk when they enter the adjacent lane
3. Surveys of pedestrians and motorists to determine the perceived safety benefit and level of compliance
4. Miscellaneous information such as law enforcement data and maintenance issues

DATA ANALYSIS

The crosswalk was videotaped for later analysis from the second level of the municipal parking garage located on the northeast corner of the intersection. Speed data were also collected with a radar gun from this location. The observation point provided an excellent overview of the crosswalk, making it ideal for capturing video data, and it was also not in the immediate field of view of motorists, making it ideal for gathering speed data while minimizing impacts on motorist and pedestrian behavior. The before data were collected during the P.M. peak on July 17, 2003, and the after data were collected during the A.M., lunch hour, and P.M. peaks on September 29, 2003, as well as during the P.M. peak on March 25, 2004. Also, included for comparison is the before-and-after data from the "In-Street Yield to Pedestrian Sign" study for the same location completed in May of 2003 by the Center for Transportation Research and Education at Iowa State University (Kannel and Souleyrette 2003).

Spot Speed Study Data

Speed data were collected at the study site on July 17, 2003 and September 29, 2003. Speed data were not collected on March 25, 2004 due to lack of availability of a suitable site for utilizing the radar gun to detect vehicle approach speeds. The data that were collected were split into four categories, eastbound and westbound lanes, both with and without pedestrians. A speed distribution is shown in Figure 6 for speeds recorded before and after the installation of the in-pavement pedestrian flashers at the project location. The distributions shown are for the P.M.

peak for the before-and-after data, as well as with and without pedestrians present in the vicinity of the crosswalk.

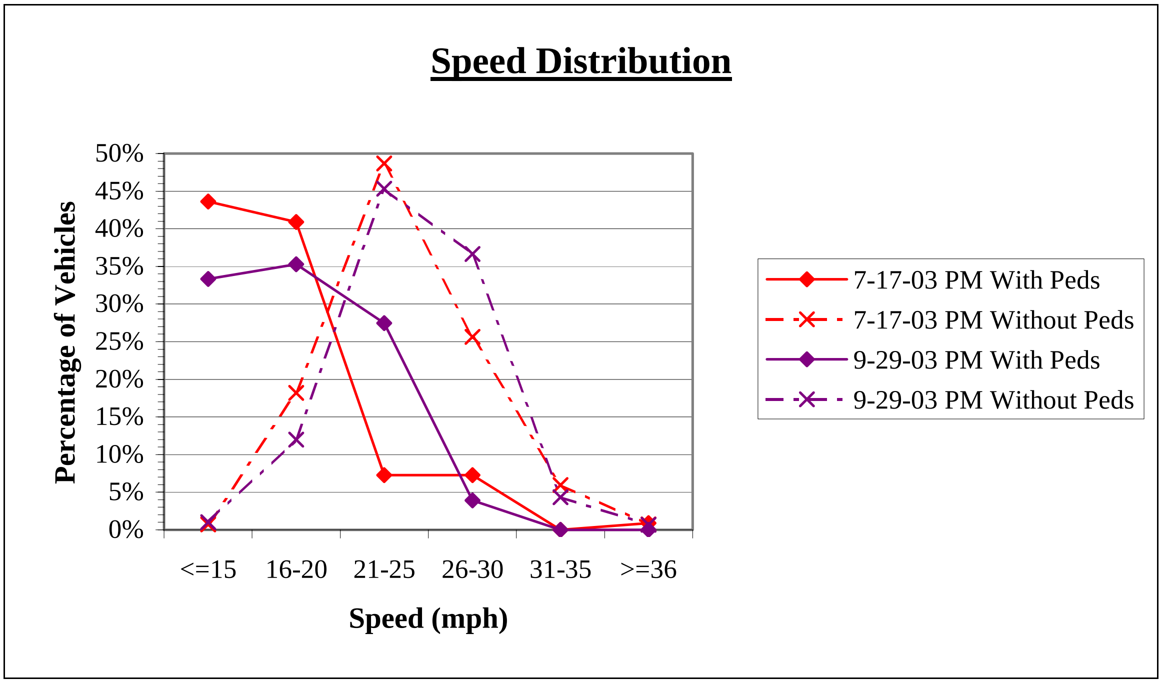

Figure 6. Spot speed distribution before and after project implementation

Figure 6 shows a slight shift to the right from before the improvement to after, indicating a slight increase in the average speed of vehicles through the project location. Additional analysis of the data, as shown in Table 1, indicates the changes in mean, 85 percentile, median, and speed range.

Table 1. Before and after spot speed summary data

Statistic	With Pedestrians		Without Pedestrians	
	Before	After	Before	After
Mean Speed	16.9 mph	18.3 mph	23.9 mph	24.7 mph
85th %-ile Speed	20.7 mph	22.0 mph	28.0 mph	28.0 mph
Median Speed	16 mph	18 mph	24 mph	25 mph
Minimum Speed	11 mph	13 mph	13 mph	14 mph
Maximum Speed	38 mph	29 mph	37 mph	44 mph
Sample Size	110	51	269	300

As shown in Table 1, the average spot speed of vehicles approaching the project location with pedestrians present increased from 16.9 mph to 18.3 mph. Without pedestrians present in the vicinity, the average spot speed of vehicles approaching the project location increased from 23.9 mph to 24.7 mph. The 85th percentile speed, or the speed at which 85 percent of the vehicles were below, was found to increase from 20.7 mph to 22.0 mph with pedestrians present, and remained constant at 28.0 mph without pedestrians present.

Under the assumption of a normal distribution for the speed data, a statistical t-test was utilized to determine the relative significance of the findings from the spot speed study. The average spot speeds before and after the project was implemented were compared to determine whether the project might have had an impact on the average vehicle approach speeds at the crosswalk. The basic, null hypothesis tested was as follows:

Mean speed before = mean speed after

The p-value gives the probability that the samples being compared to each other are not different. A p-value of 0.05 or less implies that there is less than a 5 percent chance of being wrong if the null hypothesis is rejected. Or, in lay terms, we could be 95% confident that mean speeds are different between the data sets under consideration. A p-value of 0.05 is a typically accepted maximum value to be considered statistically significant, while p-values between 0.05 and 0.10 are considered to be suggestive, but not statistically significant. The calculated probability incorporates information about the difference in the means as well as the amount of variation in the data set. If variance of the data is larger, the mean differences must be larger in order to detect statistical significance.

The calculated p values were as follows:

Condition	Speed after – speed before (mph)	p
Pedestrians present	1.4	0.063
Pedestrians not in crosswalk vicinity	0.8	0.014

In this case, using the standard 0.05 significance level, the speed change in the after condition would only be statistically significant when pedestrians were not in the crosswalk vicinity, but the change in speed from the before to the after condition when pedestrians were present was found to be statistically significant. In a practical sense, the small increase in average speed when potential crosswalk users are not present is not directly harmful. The greater concern is if drivers begin to rely on the flashing lights as an indicator of pedestrians or bicyclists in the area, rather than maintaining awareness of the activity at the curb. This is particularly important because several pedestrians and bicyclists do not cross the road where the pavement flashers are activated. Table 1 data are called to attention in this matter by observing that the maximum speed increased substantially when pedestrians were not present (from 37mph to 44 mph). However, the maximum speed represents a singe vehicle. The 85 percentile speed remained unchanged in the after state indicating that the majority of drivers are driving the same way, but a few faster vehicles have brought up the overall average.

Table 2 shows the approach speed analysis for vehicles by time of day. The time of day does not appear to have a significant effect on average approach speed with or without pedestrians in the vicinity. Statistical tests comparing the different means confirm this observation, as all but the comparisons involving the AM without pedestrians data were found to be statistically insignificant and those found significant had means varying by only one mile per hour.

Table 2. Time of day spot speed summary data

Statistic	With Pedestrians			Without Pedestrians		
	AM	NOON	PM	AM	NOON	PM
Mean Speed	19.0 mph	19.8 mph	18.3 mph	25.6 mph	24.6 mph	24.7 mph
85th %-ile Speed	24.0 mph	25.0 mph	22.0 mph	30.0 mph	28.0 mph	28.0 mph
Median Speed	18 mph	19 mph	18 mph	26 mph	25 mph	25 mph
Minimum Speed	13 mph	14 mph	13 mph	16 mph	15 mph	14 mph
Maximum Speed	30 mph	28 mph	29 mph	38 mph	34 mph	44 mph
Sample Size	58	56	51	300	300	300

A distribution of speeds, separated by time of day, is shown in Figure 7. The distribution in general supports the conclusion drawn from the data in Table 2. Time of day does not appear to have a significant impact on the average approach speed at the project location. The distribution shows the normal distribution pattern that is expected for standard statistical modeling. The times in which pedestrians were present had fewer observations and were not quite as evident to have the expected bell-shaped curve.

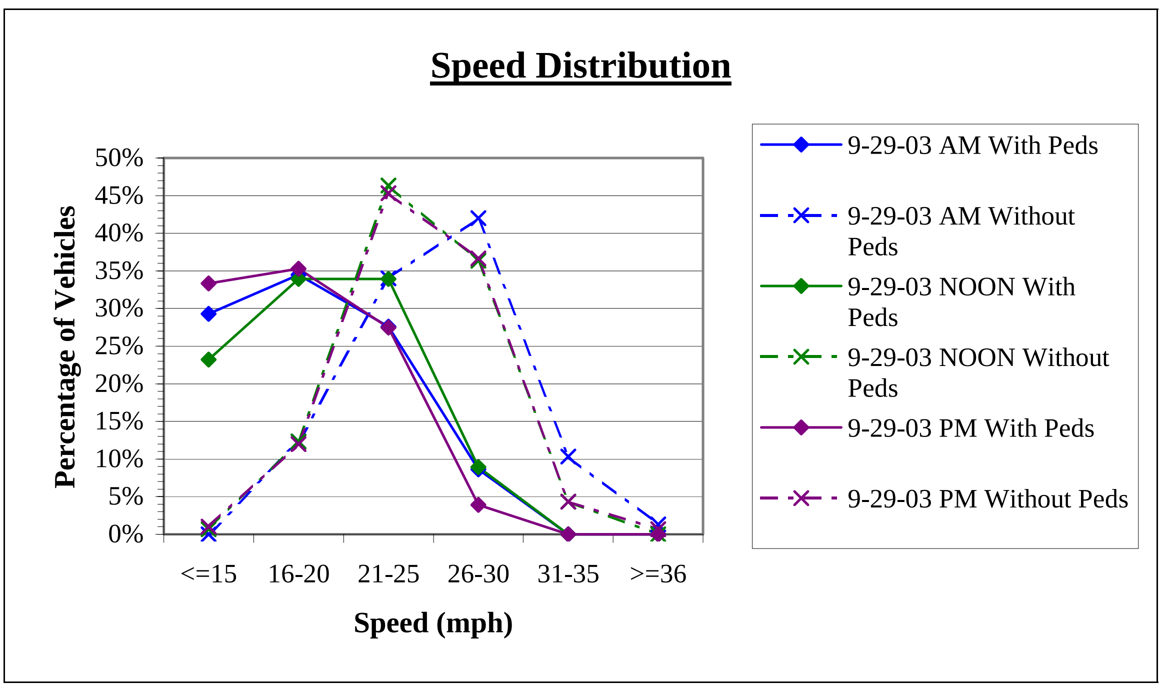

Figure 7. Spot speed distribution after project implementation by time of day

Several additional analyses were performed to look for speed variability but are not presented in the report. Spreadsheet summaries are available to the sponsor, but no additional highlights were identified.

Yielding to Pedestrians Data

Perhaps the best measure for estimating the safety impacts of the in-pavement flashing lights installed during this project is the change in motorist behavior in relation to yielding to pedestrians and bicyclists in the crosswalk. The measure of effectiveness utilized for this study was to calculate the percentage of occurrences in which the first, second, third, or fourth vehicle to approach the crosswalk yielded to or completely stopped for pedestrians in the crosswalk. The ideal situation would be for the first vehicle approaching the crosswalk to yield to pedestrians in the crosswalk 100 percent of the time. The cumulative percentages of vehicles yielding to pedestrians were tabulated and sorted by lane and direction of travel. A general representation of the system for labeling lanes for both directions of travel at the Cedar Rapids project location is shown in Figure 8. In general, the lane adjacent to the curb is utilized for on street parking through the corridor, lane 1 is always adjacent to the curb lane, lane 2 is adjacent to lane 1, and the center two-way left turn lane separates the eastbound lane 2 from westbound lane 2.

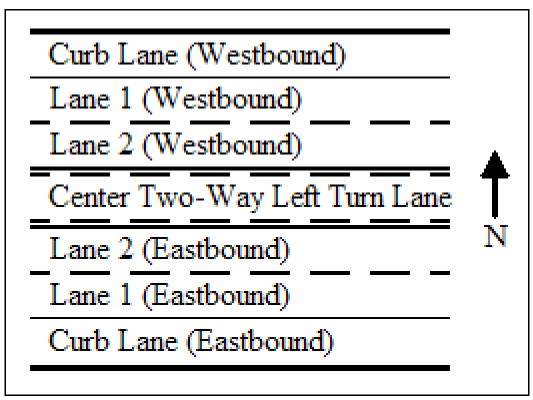

Figure 8. General representation of lane designations

The following guidelines were established by the research team to determine if approaching motorists were in compliance with the requirement to yield to pedestrians in the crosswalk:

1. Lane 1 – motorist had a responsibility to yield if a pedestrian had stepped from the curb into the curb (parking) lane or had entered the adjacent lane 2 from the center two-way left turn lane.
2. Lane 2 – motorist had a responsibility to yield if a pedestrian had entered either of the adjacent lanes (lane 1 or the center two-way left turn lane).
3. Center two-way left turn lane – motorist had a responsibility to yield if a pedestrian had entered either of the adjacent lanes (lane 2 for either side).

The same analyst completed the before-and-after assessments for the July 17, 2003, September 29, 2003, and March 25, 2004 data to maintain consistent judgment of driver behavior in relation to yielding to pedestrians in the crosswalk. A summary of the results for the before-and-after study for the in-pavement flashing lights study are shown in Table 3. The pedestrian /bicycle activity was generally low in March. The Center lane is shown in Table 3, but due to the combination of low vehicle and low crosswalk traffic, no meaningful comparisons are available.

Table 3. Cumulative percentage of motorists yielding before and after implementation (PM peak periods on 7/17/03, 9/29/03, and 3/25/04)

Vehicle Stopping	Eastbound						Center TWLTL			Westbound					
	Lane 1			Lane 2						Lane 2			Lane 1		
	7/17	9/29	3/25	7/17	9/29	3/25	7/17	9/29	3/25	7/17	9/29	3/25	7/17	9/29	3/25
1st	63.0	85.3	85.7	60.6	95.3	89.7	N/A	100.0	100.0	91.4	98.1	92.9	92.3	90.9	98.3
2nd	96.3	97.1	100.0	97.0	100.0	100.0	N/A	100.0	100.0	97.1	100.0	100.0	100.0	100.0	100.0
3rd	100.0	100.0	100.0	100.0	100.0	100.0	N/A	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4th+	100.0	100.0	100.0	100.0	100.0	100.0	N/A	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Sample Size	27	34	28	33	43	39	0	2	5	35	52	56	39	55	59

From Table 3 data, the most dramatic improvement was initially seen in the eastbound direction. Prior to installation of the in-pavement flashing lights, the first vehicle approaching the crosswalk yielded just over 60 percent of the time in either eastbound lane, versus 85 to 95 percent of the time immediately after project implementation. The eastbound Lane 2 values fell back approximately 5 percent for the first vehicles yielding six months later. Westbound lanes had high levels of compliance prior to installation of the in-pavement flasher system, and compliance improved slightly in westbound lane 2, while it decreased very slightly in westbound lane 1 immediately after implementation. Six months after implementation, westbound compliance ranged from approximately 93 to 98 percent of first vehicles yielding to pedestrians in the crosswalk. It is good to note that six months after installation of the in-pavement lights, motorist compliance had reached 100 percent by the time the second vehicle arrived.

The observation was also made that at six months, approximately half of the vehicles that failed to yield to pedestrians did so when a train was approaching the adjacent railroad crossing. The motorists that approached under these conditions were much more likely to try and squeeze through the intersection before the train arrived and blocked the street. Therefore, they were more likely to be judged to fail to yield to pedestrians who were in the crosswalk.

A comparison of motorist yielding behavior with respect to time of day for the immediately after implementation data (taken 9/29/03) is provided in Table 4. As is evidenced by Table 4, there does not appear to be any strong relationship between the yielding behavior of motorists and the time of day. The center two-way left turn lane had 100 percent compliance throughout the day, and the other lanes of traffic usually had reasonably compliant behavior, with more than 75 percent of the first vehicles to approach the crosswalk yielding to pedestrians and more than 95 percent of the second vehicles yielding.

Table 4. Cumulative percentage of motorists yielding by time of day after installation (September, 2003)

Vehicle Stopping	Eastbound Lanes			Center TWLTL			Westbound Lanes		
	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM
1st	93.3	83.7	90.9	100.0	100.0	100.0	76.3	79.0	94.4
2nd	100.0	97.7	98.7	100.0	100.0	100.0	98.3	98.4	100.0
3rd	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4th+	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Sample Size	60	43	77	5	3	2	59	62	107

Motorist yielding behavior was also evaluated over time by including data from the "In-Street Yield to Pedestrian Sign" final report (Kannel and Souleyrette 2003) for the same project location. The data from the yield to pedestrian sign study along with data from this study are summarized in Table 5.

Table 5. Cumulative percentage of motorists yielding over time

Vehicle Stopping	Eastbound Lanes					Westbound Lanes				
	YTP Signs		Flashers			YTP Signs		Flashers		
	6/02	10/02	7/03	9/03*	3/04	6/02	10/02	7/03	9/03*	3/04
1st	70.7	78.7	61.7	90.9	88.1	62.6	56.9	91.9	94.4	95.7
2nd	87.9	89.4	96.7	98.7	100.0	80.4	97.4	98.6	100.0	100.0
3rd	94.8	95.7	100.0	100.0	100.0	93.5	99.1	100.0	100.0	100.0
4th+	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Sample Size	174	47	60	77	67	107	116	74	107	115

*PM peak hour data

It is interesting to note that compliance increased when the intersection was equipped with the yield to pedestrian sign in phase 1 and with the in-pavement flashing system in phase two. Overall compliance appears to be increasing as well. The most notable exception is between the October 2002 and July 2003 eastbound first vehicles yielding, which regressed from nearly 79 percent back to below 62 percent. The other cases in which compliance dropped over time are much more minor in magnitude. Overall, the first vehicle compliance has leveled out at around 90 to 95 percent, while it appears that the second vehicle compliance has reached 100 percent. This is unlikely to improve much further as motorists approaching the intersection are likely to try and beat trains or pedestrians through the intersection, especially if they are in a hurry or have not been paying adequate attention.

The compliance data for yielding to pedestrians were statistically assessed using contingency table analysis. Due to sample size limitations, only two categories for vehicles stopping could be defined, so in all cases a two by two table was created. Table rows represented the number of times the first driver yielded to the crosswalk user, and group two combined all other cases. The columns represented before-and-after in-pavement marking installations. When comparing the before and after data, the changes between the July 17, 2003 and the September 29, 2003 data were found to be significant at the 99.99 percent level, implying a detectable increase in motorist compliance.

In comparing eastbound to westbound compliance, the March 25, 2004 data suggested the westbound direction to be more compliant than the eastbound, with a significance level of 94.5 percent. The September 29, 2003 data showed no significant difference between the eastbound and westbound directions.

When time of day was analyzed, it became evident that the P.M. data for the September 29, 2003 set were significantly more compliant than the A.M. or noon peak periods data. Comparing the noon peak to the P.M. peak gave a significance level of 99.75 percent, and comparing the A.M. peak to the P.M. peak gave a significance level of 97.95 percent. No significant difference was found between the A.M. and noon peaks.

Pedestrian and Motorist Survey Results

In order to gain perspective on how pedestrians and motorists perceive the safety benefit and level of compliance with the crosswalk, surveys were taken at the project location. The full survey sheets are shown in Appendix A. Both the pedestrian and the motorist surveys asked a total of five questions which could be answered on a scale of one to five, with one being total disagreement with the statement, and five being total agreement with the statement. Both surveys asked whether the installation of the pedestrian flasher system had increased motorist awareness of pedestrians in the crosswalk during the day and at night, as well as if motorists have been more likely to yield to pedestrians since installation of the system and if pedestrians have been more likely to cross in the crosswalk since the installation of the system. The pedestrian survey additionally asked if pedestrian safety had been increased as a result of the new system. The motorist survey additionally asked if motorists paid more attention to pedestrians in the vicinity of the crosswalk as a result of the new system. Each of the surveys additionally had room for comments.

A summary of the results of the pedestrian survey from March 25, 2004 is given in Table 6. A total of 40 pedestrian surveys were completed during the evaluation period.

Table 6. Pedestrian survey results

Question	Average	High	Low	Std. Dev.
Increased daytime motorist awareness	3.55	5	2	0.96
Increased nighttime motorist awareness	4.23	5	2	0.80
Motorists more likely to yield to pedestrians	3.23	4	1	0.70
Pedestrians more likely to cross in crosswalk	2.75	5	2	0.74
Increased pedestrian safety	3.33	5	1	0.83

The results of the pedestrian survey indicate that the responses were generally positive. Pedestrians felt that the in-pavement lights increased motorist awareness somewhat during the day, but significantly at night. Pedestrians were fairly neutral about whether motorists were more likely to yield to pedestrians, and disagreed slightly with the statement that more pedestrians utilized the crosswalk after the installation than before. The overall impression of the safety benefit was positive, although close to the neutral value of three. Standard deviations of the survey responses ranged from 0.70 to 0.96, which suggests that if similar studies were completed with a sample size of 40, the true means would be within approximately 0.2 of the values shown in the table 95 percent of the time if no changes in driver/pedestrian experience occurred.

The major concern that was commented on by pedestrians was the possibility of pedestrians who relied too much on the in-pavement lights to warn motorists and paid less attention to motorists as a result, which could potentially lead to conflicts. Other comments were made in relation to the bollard placement on the north end of the crosswalk, where pedestrians traveling to or from the U.S. Cellular Center would have to walk to the far side of the crosswalk to be able to activate the system. Most pedestrians interviewed felt that the time allotted for crossing in the crosswalk was adequate if motorists yielded immediately and let them cross. Comments were made about the possibility of some sort of passive detection system that could detect pedestrians in the crosswalk and then activate and deactivate the in-pavement lights accordingly, i.e., to shut the flashing off only after the pedestrian was detected on the other side.

A total of 40 motorists were also surveyed on March 25, 2004 during the same period, and the results of the survey are given in Table 7. In the interest of safety for the researcher, the sample of drivers was limited to persons who had passed through the intersection and entered the parking garage.

Table 7. Motorist survey results

Question	Average	High	Low	Std. Dev.
Increased daytime motorist awareness	3.70	5	2	0.82
Increased nighttime motorist awareness	4.48	5	3	0.60
Motorists more likely to yield to pedestrians	4.20	5	3	0.69
Pedestrians more likely to cross in crosswalk	2.43	4	1	0.90
Increased awareness of pedestrians in vicinity	3.93	5	3	0.69

The results of the motorist survey were also positive, in general more so than those of the pedestrian survey, with the exception of the likelihood of pedestrians to cross in the crosswalk. Motorists felt that the system increased their awareness fairly significantly during the day and even more so at night. They also felt that they were much more likely to yield to pedestrians in the crosswalk as a result of the in-pavement lights, and that they were in general more aware of pedestrians in the vicinity of the crosswalk.

The primary comment made by motorists was the general lack of pedestrian willingness to cross in the crosswalk. In many cases, pedestrians were observed crossing as little as ten feet outside of the crosswalk rather than traveling the additional distance to utilize the new system. Another comment concerned the visibility of the in-pavement lights when other vehicles were in front of them, and the suggestion was made to provide a visual overhead warning that would also be activated when the in-pavement lights were activated. Concern was also voiced over the complexity of the intersection that is involved, with the railroad crossing, service entrance to the convention center, and other miscellaneous distractions.

When comparing the results of the two surveys, the responses are in general as expected. Pedestrians responded less positively to motorist performance than motorists did, and vice versa. Both parties felt that motorist awareness of pedestrians in the crosswalk was increased by the in-pavement lights, with the most significant improvement being at night, when pedestrians may be more difficult to see. Both groups also felt that pedestrian compliance with crossing in the crosswalk was fairly limited.

Law Enforcement Observation Results

On October 23, 2003, the Cedar Rapids Police Department observed operations at the project location between 5:00 and 5:40 PM. As a result of the observation, four tickets and three warnings for failure to yield to pedestrians in the crosswalk were issued, one ticket for failure to have insurance was issued, and one ticket for violation of a restricted license was issued. No more specific enforcement projects have been completed at the project location by the Cedar Rapids Police other than occasional enforcement by individual officers who are patrolling the area.

Maintenance Issues

The City of Cedar Rapids has experienced no major maintenance issues as a result of the installation of the in-pavement lights at the project location. The only identified issue so far has been the tendency of the sensors and lights to “drift” out of alignment over time. The traffic department feels that this is most likely a result of the project’s proximity to the railroad crossing and the extreme vibrations the system is subjected to as a result. The department is working on a plan to install an external marking system which will allow signal technicians to see when the lights are properly aligned without completely removing the units from the pavement. A similar system could also be utilized on the sensors within the bollards to help with realignment.

The only other maintenance concern has been the accumulation of “dirty” snow and ice on the lenses of the in-pavement lights during the winter months. This problem essentially resolves itself within a few days after snowfall is ceased and when the heat created by vehicles traversing the project and the de-icing chemicals cause the slush to melt away from the lights. Snow removal itself has not been an issue, as all the snowplow drivers were made aware of the situation, and no physical damage has been identified in any of the in-pavement lights or the bollards. The system was active during the entire winter.

CONCLUSIONS

Measures to assess the effectiveness of the in-pavement flashers were restricted to observable features rather than changes in accident experience. The installation of in-pavement flashing warning lights at the pedestrian crosswalk at this site has had a net positive effect on the safety characteristics of the location. The results of the analysis for Cedar Rapids are consistent with the findings of other studies cited. Speed changes were found to be either insignificant or too small to be noticed by the average pedestrian utilizing the newly renovated crosswalk. The complexity of the site in question provides many issues for pedestrians, bicyclists, and motorists to identify and react to in order to safely negotiate the location, and the presence of the flashing in-pavement lights appears to help vehicle and pedestrian travelers, providing the system is properly utilized.

The most promising findings were in the percentage of vehicles yielding to pedestrians. The results of this portion of the study show a marked improvement in motorist compliance with the state law requiring that motorists yield to pedestrians in the crosswalk. By including data from the previous in-street sign study, it was noted that the overall compliance by motorists with regards to yielding to pedestrians has increased dramatically since the City of Cedar Rapids first began actively pursuing methods of improving pedestrian safety at this location.

Several issues with the crosswalk geometrics and maintenance make the location complex for pedestrians. The reduced detection area due to the service entrance to the U.S. Cellular Center and adjoining Crowne Plaza Hotel creates such a layout that the entire crosswalk width is not detected. Pedestrians and bicyclists approaching the north side curb are less likely to make the extra effort to activate the flasher system. However, failure to use the crosswalk can not solely be attributed to the difficult design condition at the north curb. Pedestrians and bicyclists had not given up old habits of mid-block crossings or crossings outside the marked area on the south approach.

Although maintenance was required to re-align units, the operational service level of the flashers offers an improvement over the in-street “Yield to Pedestrian” signs. Motorist compliance was improved with the flashing system overall, and although evening hours provided the highest driver conformance, the researchers’ observations and the motorists’ responses do not indicate the flashing lights were not observable during the day hours.

The pedestrian and motorist surveys show that both groups felt the in-pavement flashing lights have increased motorist awareness, especially at night. Pedestrians feel marginally safer as a result of the installation, and motorists feel that they are more likely to pay attention to pedestrians in the general area of the crosswalk. However, both groups feel that the new crosswalk has not encouraged more pedestrians to cross in the actual crosswalk.

The 1st Avenue NE and 4th Street NE site is a challenging area for pedestrian/vehicle control. While further observations are warranted to monitor the long-term response in terms of driving behavior, the crash experience should also be reviewed when sufficient time has elapsed. The data indicate the in-pavement flashing warning lights improved the motorists’ response to pedestrians in the area, and that the system could be operational throughout summer and winter conditions. The long-term availability is a major advantage for the in-street signs.

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APPENDIX A: PEDESTRIAN AND MOTORIST QUESTIONNAIRE

Pedestrian Survey

1. The installation of pedestrian-activated in-pavement flashing lights has increased motorist awareness of pedestrians in the crosswalk during the day.

DISAGREE -	-	NEUTRAL -	-	AGREE
1	2	3	4	5

2. The installation of pedestrian-activated in-pavement flashing lights has increased motorist awareness of pedestrians in the crosswalk at night.

DISAGREE -	-	NEUTRAL -	-	AGREE
1	2	3	4	5

3. The installation of pedestrian-activated in-pavement flashing lights has increased safety for pedestrians crossing in the crosswalk.

DISAGREE -	-	NEUTRAL -	-	AGREE
1	2	3	4	5

4. Motorists have been more likely to yield to pedestrians in the crosswalk since the installation of the pedestrian-activated in-pavement flashing lights.

DISAGREE -	-	NEUTRAL -	-	AGREE
1	2	3	4	5

5. Pedestrians, in general, have been more likely to cross the street in the crosswalk since the installation of the pedestrian-activated in-pavement flashing lights.

DISAGREE -	-	NEUTRAL -	-	AGREE
1	2	3	4	5

Comments: ____

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Motorist Survey Questions

1. The installation of pedestrian-activated in-pavement flashing lights has increased motorist awareness of pedestrians in the crosswalk during the day.

DISAGREE -	-	NEUTRAL -	-	AGREE
1	2	3	4	5

2. The installation of pedestrian-activated in-pavement flashing lights has increased motorist awareness of pedestrians in the crosswalk at night.

DISAGREE -	-	NEUTRAL -	-	AGREE
1	2	3	4	5

3. Motorists have been more likely to yield to pedestrians in the crosswalk since the installation of the pedestrian-activated in-pavement flashing lights.

DISAGREE -	-	NEUTRAL -	-	AGREE
1	2	3	4	5

4. Motorists pay more attention to pedestrians in the vicinity of the crosswalk since the installation of the pedestrian-activated in-pavement flashing lights.

DISAGREE -	-	NEUTRAL -	-	AGREE
1	2	3	4	5

5. Pedestrians, in general, have been more likely to cross the street in the crosswalk since the installation of the pedestrian-activated in-pavement flashing lights.

DISAGREE -	-	NEUTRAL -	-	AGREE
1	2	3	4	5

Comments: ____

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