The Effects on Safety of In-Roadway Warning Lights at Crosswalks: Novelty or Longevity?

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Abstract

In-roadway warning lights are being installed at crosswalks around the United States in an effort to improve pedestrian safety. Although prior evaluations have studied the effectiveness of in-roadway warning lights, results have been mixed. A field study was conducted in Rockville, Maryland to assess whether in-roadway warning lights increase safe crossing situations for pedestrians at uncontrolled locations. This study was a before and after study and investigated driver behavior (e.g., driver yielding) and pedestrian behavior (e.g., crossing location, wait times to cross). Findings from this study indicated that in-roadway warning lights do lead to shorter wait times to cross and to increased driver yielding. Pedestrians, however, are not more likely to use the crosswalk after the lights are installed and many still choose to cross at other locations. Based on observations of the crosswalk, we have several suggestions for improving the effectiveness of in-roadway warning lights. First, improved performance may result if systems are installed with both passive and active actuation. In addition it may be beneficial to place the detection bollards further apart than the width of the crosswalk. A number of pedestrians entered the crosswalk just outside the passive detection system, and did not trigger the lights. The present paper describes the results from the before and after phases of this research project. One year after installation, in Spring 2005, we will collect more data to examine the long-term effects of in-roadway lighting. Initial results, however, demonstrate the treatment's promise and opportunities to improve them even more.

INTRODUCTION

Statement of Problem

In-roadway warning lights[i] are being installed at crosswalks around the United States in an effort to improve pedestrian safety (see Whitlock and Weinberger, 1998; Prevedouros, 2001; and Boyce and Van Derlofske, 2002). Although empirical evaluations have been conducted to see if in-roadway warning lights improve pedestrian safety, results have been mixed. The present study assessed whether in-roadway warning lights increase safe crossing opportunities for pedestrians.

Research Goals

Past research has failed to definitively answer several main questions about the effects of in-roadway warning lights. This study examined some of these in order to provide further evidence about the potential benefits of in-roadway warning lights. The primary research questions are:

- What is the yielding behavior of drivers approaching a crosswalk with in-roadway warning lights?
- Where do pedestrians choose to cross? Are they more likely to use the crosswalk after the warning lights are installed?
- Are driver and pedestrian behavior changes due to in-roadway warning lights stable over time (e.g., a year later)?

Background

In 2001, 78,000 pedestrians were injured and 4,882 pedestrians were killed in the United States. Results from a recent Traffic Safety Facts report that analyzed pedestrian fatality statistics from 2001 indicate that: 1) 64% occurred on urban roadways; 2) 40% occurred in areas with a posted speed limit below 40 mph; and 3) 78% occurred at non-intersection locations. Statistics also indicate that pedestrians are unsafe in a variety of lighting conditions. Thirty-two percent of fatalities occurred in daylight, 30% occurred in the dark, and 33% occurred in "dark but lighted" conditions (Shanker, 2003[ii]). In-roadway warning lighting has emerged as a potential way to reduce these types of fatalities and injuries.

In-roadway lighting is a pedestrian crossing treatment that is used to alert drivers to the presence of pedestrians at uncontrolled crossings. A crosswalk is lined on each side with a series of amber lights embedded in the roadway facing oncoming traffic. In-roadway warning lights are typically actuated in one of two ways. In one type of system, the pedestrian actuates the lights by using a traditional push-button. In another system, the pedestrian is detected by a passive detection system that triggers the lights. The lights are visible to the approaching driver as a warning that someone is in or near the marked crosswalk. As early as 1978, researchers began investigating notions of illuminated crosswalks. Polus and Katz (1978) investigated a specialized crosswalk illumination system that used illuminated pedestrian warning signs and projection of light on the roadway that spanned the length of the crosswalk. Examining almost 200 sites in Israel over a one to two year period, the researchers found a reduction in nighttime pedestrian accidents compared to sites serving as controls. This finding suggests that modern in-roadway warning lights might have similar effects on pedestrian safety in the United States.

The Millennium Edition of the Manual on Uniform Traffic Control Devices (MUTCD) has approved the application of in-roadway warning lights at crosswalks. It states:

- "If used, In-Roadway Warning Lights at crosswalks shall be installed only at marked crosswalks with applicable warning signs. They shall not be used at crosswalks controlled by YIELD signs, STOP signs, or traffic control signals."
- "If used, In-Roadway Warning Lights at crosswalks shall be installed along both sides of the crosswalk and shall span its entire length."
- "If used, In-Roadway Warning Lights at crosswalks shall initiate operation based on pedestrian actuation and shall cease operation at a predetermined time after the pedestrian actuation or, with passive detection, after the pedestrian clears the crosswalk."
- "If used, In-Roadway Warning Lights at crosswalks shall display a flashing yellow signal indication when actuated. The flash rate for In-Roadway Warning Lights at crosswalks shall be at least 50, but not more than 60, flash periods per minute. The flash rate shall not be between 5 and 30 flashes per second to avoid frequencies that might cause seizures."
- "If used on one-lane, one-way roadways, a minimum of two In-Roadway Warning Lights shall be installed on the approach side of the crosswalk. If used on two-lane roadways, a minimum of three In-Roadway Warning Lights shall be installed along both sides of the crosswalk. If used on roadways with more than two lanes, a

minimum of one In-Roadway Warning Light per lane shall be installed along both sides of the crosswalk."

- "If used, In-Roadway Warning Lights shall be installed in the area between the outside edge of the crosswalk line and 3 m (10 ft) from the outside edge of the crosswalk. In-Roadway Warning Lights shall face away from the crosswalk if unidirectional, or shall face away from and across the crosswalk if bi-directional."

A small body of research has been conducted during the relatively brief history of in-roadway warning lights. The main advantage of in-roadway warning lights was expected to be enhanced noticeability of a crosswalk by drivers resulting in reduced vehicle speeds and increased yielding to pedestrians, reduction of vehicles in the crosswalk when pedestrians are present, and reduced pedestrian-vehicle conflicts. However, empirical results have varied greatly across situations and often little methodological information has been provided or research results have been vague. What follows is a description of the seminal studies of in-roadway warning lights and their primary findings as they relate to each research goal.

What is the yielding behavior of drivers approaching a crosswalk with in-roadway warning lights?

A review of the research indicates that installation of in-roadway warning lights has immediate effects on driver behavior. Whitlock and Weinberger, 1998, conducted the first major study of in-roadway warning lights evaluating its use at nine intersections in California. They concluded that the use of in-roadway warning lights improved drivers' awareness of crosswalks and modified drivers' behavior in a positive manner toward pedestrians (e.g., speed, advance braking distance, and yielding). Huang, Hughes, Zegeer, & Nitzburg, 1999, also observed that after the installation of lights, vehicle speeds declined both when pedestrians were present and when they were not, but these differences were not significant. However, motorists' yielding behavior increased significantly after the installation of the lights. More motorists stopped or slowed down when a staged pedestrian attempted to cross the road. Interestingly, this effect persisted for cases when the lights were deactivated (after installation). They also found that with in-roadway warning lights, there were fewer vehicle-pedestrian conflicts than elsewhere. In analyzing these conflicts, they found that if pedestrians crossed adjacent to the crosswalk, it was most likely that motorists would take actions (e.g., braking) to avoid a conflict. If pedestrians crossed elsewhere, it was most likely that the pedestrian would have to take action (e.g., increasing walking speed) to avoid being struck.

Prevedouros, 2001 also observed a speed decline when in-roadway warning lights were activated, as well as improvements for pedestrian wait time, curb-to-curb duration, and the number of vehicles disregarding pedestrians. At two of four sites following the installation of lights, Hakkert, Gitelman, & Ben-Shabat 2001 and 2002, observed a decline in vehicle speed and pedestrian-vehicle conflicts and an increase in giving way behavior to pedestrians who were beginning to cross. Boyce & Van Derlofske, 2002, and Van Derlofske, Boyce, & Gilson 2003 found that adding in-roadway warning lights to a well-delineated location further increased noticeability but had no effect at the actual site on the number of conflicts. However, installation of the lights led to a reduction in vehicle speed and a reduction in the number of vehicles that passed over the crosswalk while a pedestrian was waiting.

In summary, the research indicates that immediately following the installation of in-roadway warning lights, there are improved crossing situations for pedestrians. Frequently, vehicle speed is reduced and drivers are more likely to yield to pedestrians who are trying to cross. This often results in fewer conflicts between pedestrians and vehicles.

Where do pedestrians choose to cross and do they actuate the system using a pushbutton?

The aforementioned results indicated safer crossing opportunities when lights are installed. However, this is only meaningful if pedestrians actually take advantage of these opportunities afforded by the lights. Do pedestrians take advantage of in-roadway warning lights if they are present? This can be evaluated by looking at a) whether pedestrians choose to use crosswalks with lights or choose to cross elsewhere, and b) whether pedestrians actually activate the lights when a pushbutton actuation system is present (versus a pedestrian detection system).

Most of the studies reviewed evaluated sites that used automatic pedestrian detection systems to activate the in-roadway warning lights. Hakkert, et al., 2001 and 2002, simply reported for three sites that the number of people who crossed outside the crosswalk declined after the lights were installed. However, other researchers have reported more detailed effects. Huang, et al., 1999, found that only a small percentage (28%) of pedestrians they observed opted to crossed at a crosswalk with the in-roadway lighting, but that this percentage increased (57%) when police were present to direct traffic for events at a nearby theater. In their observations of pedestrian behavior, Boyce and Van Derlofske, 2002, and Van Derlofske et al., 2003, noted that some pedestrians did not use the crosswalk at all, but preferred to cross to a center island at a different location and use it as a halfway point. When pedestrians did use the crosswalk, they often did not wait for the in-roadway lights to come on, and instead crossed quickly if a sufficient gap in traffic existed. The researchers noted that it was very difficult for pedestrians to know whether the lights were on or not. Also, they found that a third of the observations were incorrect, being misses or false positives. Less than half of the observations were hits; the lights flashed when a pedestrian was crossing or waiting to cross. Observations indicated that drivers did not know what to do when the lights were flashing. Some drivers slowed as they crossed in front of a pedestrian, while others stopped and waited for the lights to stop flashing, even if no pedestrian was present.

Only two research studies evaluated sites that utilized pushbutton actuation. Whitlock and Weinberger, 1998, found at one site that only 33% of pedestrians used the pushbutton when crossing to activate the lights. Prevedouros, 2001, did not report a rate of use. However, he did find a reduction in the number of pedestrians crossing outside the crosswalk following the installation of the lights. After the lights were installed, more pedestrians crossed in the crosswalk.

In summary, it appears that it is possible to see improvements in the number of people using a crosswalk after lights are installed. However, it is also clear, that usage varies greatly in terms of factors other than the presence or absence of in-roadway warning lights, perhaps pedestrians' motivations (e.g., being late for a show), system reliability, gap availability, and others.

Are the effects of in-roadway warning lights stable over time (e.g., a year later)?

Most of the research investigating in-roadway warning lights has not investigated whether the positive effects persist over time or are novel. For the most part, studies that have examined long-term effects have lacked experimental control and the influence of other factors cannot be ruled out. That is, something other than the in-roadway lights could be responsible for changes in driver yielding behavior. Whitlock and Weinberger, 1998, did not do a broad study of the longevity of the effects of in-roadway warning lights. However, they note that at one site, two years after installation, drivers were observed making sweeping motions with their heads approaching a crosswalk with in-roadway warning lights, ostensibly scanning for pedestrians. Additionally, driver yielding and braking distances remained higher than the baseline observation, although they did decline from the point of lighting installation. Hakkert, et al., 2001 and 2003, also report some long-term effects, respectively several months after the first post-installation observation, concluding that the effects of lighting persist over time. At some sites, however, improvements became smaller during the subsequent observation, approaching the baseline rates for yielding and speed. Boyce and Van Derlofske, 2002, and Van Derlofske et al., 2003, found that adding in-roadway warning lights to a striped location led to a reduction in vehicle speed. However, this effect of lighting on speed tended to diminish over time. Thus, results are mixed regarding the longevity of the effects of in-roadway warning lights.

Summary

Previous researchers have attempted to address the major research questions of the current research study:

- Where do pedestrians choose to cross?
- What is the yielding behavior of drivers approaching a crosswalk with in-roadway warning lights?
- Are the effects of in-roadway warning lights stable over time (e.g., a year later)?

However, several methodological or presentation problems exist in previous research. For example, Whitlock and Weinberger, 1998 provided no information about the number of observations made, how long after installation data collection occurred, or how data were collected and analyzed. Further, it appears that no crosswalks served as controls to estimate changes due to variables aside from the lighting installation. Because of these study limitations, we do not know how well these findings generalize to other sites. Boyce and Van Derlofske, 2002, Van Derlofske et al., 2003, and Huang, et al., 1999, relied on staged pedestrians. Huang, et al. also did not report significance testing information or information about pedestrian volume, demographics, or exposure. For instance, it is possible that the site has a tremendous amount of visitors or tourists, given that the crosswalk runs between an arena and a hotel. Thus, the novelty effect may have been persistent because there was non-permanent population, and the effects may have been different in a less commercial neighborhood. In Hakkert, et al., 2001 and 2002, all significance test results referred to comparisons between each “after” observation and the initial observation; the two “after” observations were never compared to each other. Therefore, it is difficult to assess whether the effects were diminishing. Finally, Boyce and Van Derlofske, 2002, and Van Derlofske et al., 2003, reported data from genuine and staged pedestrians mixed together and no significance test results were reported, with the exception of analysis of survey interviews. In addition, the researchers did not consider two factors. First, the final evaluation occurred two days after the September 11th terrorist attacks 30 miles outside of New York City, which may have had a substantial effect of the number, type, and behavior of the pedestrian population. Second, the researchers mentioned that the light output from the lighting units declined greatly after one year. Both of these situations could have had an effect on the long-term evaluation of the lights.

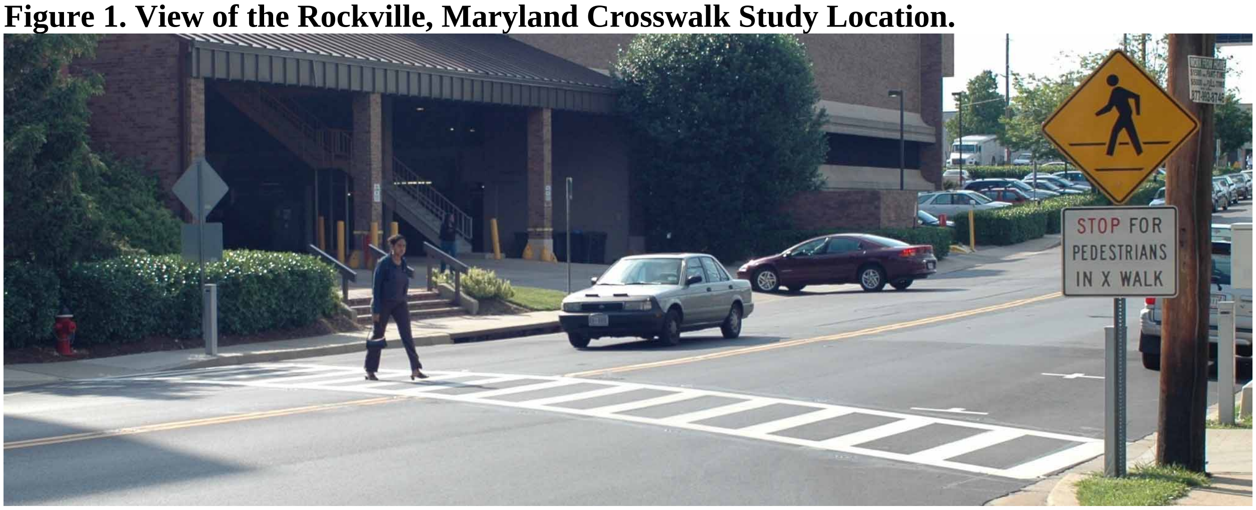
In the present study the behavior of pedestrians and drivers was observed before and after the installation of lighting at an uncontrolled crosswalk. Subsequent observations will be made at this site one-year after installation in order to assess the longevity of effects. The long-term data collection effort has not yet taken place and therefore will not be discussed in this report.

METHOD

Site Description

The test site used in this project was in Rockville, Maryland near a Metro Station entrance. The site is pictured below in Figure 1. The crosswalk traverses a two-lane road with street side parking allowed on each side. The crosswalk lacks stop control and the speed limit is 25 mph. On the Metro side of the road (i.e., the right side of the photograph in Figure 1), just before the crosswalk, there is an intersection for buses to turn onto the roadway. A hotel is on the opposite side of the crosswalk (i.e., the left side of Figure 1) from the Metro station. The in-roadway lighting system installation involved: two passive detection bollards on the edge of the curb at either end of the crosswalk, seven lights on each side of the crosswalk, and a series of four lights in the center line as a vehicle approaches to the crosswalk from either direction. The series of four lights are each spaced about 15 feet apart and light up in sequence to draw attention to the crosswalk. The lights along the crosswalk blink on and off at the same rate.

Figure 1. View of the Rockville, Maryland Crosswalk Study Location.



Measures

Observations were made of road and sidewalk users' behavior (i.e., drivers and pedestrians) at the Rockville, Maryland site. Recordings of the crossings were made using a pole-mounted camera. The camera captured an overview of the roads, sidewalks, and crosswalks and the people and drivers using them. The camera was positioned so that drivers and pedestrians would be unlikely to notice it and alter their behavior.

Data collection (for both the before and after periods) took place during morning rush hour, midday, and evening rush hour. About 13 hours of before data and 10 hours of after data were collected. The before data were collected in December 2004 and the after data were collected in March/April of 2004, beginning a little over a month after treatment installation. Data coding was performed on a standard desktop computer. The DVD video footage was displayed on the computer screen and for each pedestrian crossing, a data coder answered a series of on-screen questions about the crossing.

The following measures were of primary interest in this research project:
The percentage of vehicles that stopped or slowed to let a pedestrian cross.

- Pedestrian group size.
- The percentage of the crosswalk the pedestrian used (i.e., the percentage of the crossing spent within the confines of the crosswalk markings).
- The number of pedestrians who hurried to complete a crossing.
- The number of pedestrians who made assertive movements to get drivers to yield.
- Wait time before the pedestrian initiated a crossing (for both near side and far side portions of the crossing).

Most measures were computed separately for each direction of traffic. That is, for every pedestrian crossing event, we coded driver and pedestrian behavior for the near side lane (i.e., the first lane the pedestrian crossed) and we did the same for the far side lane (i.e., the second lane of traffic the pedestrian crossed) of traffic. By coding the data in this fashion, we were able to examine whether pedestrians had different crossing experiences on the near side compared to far side. For example, were drivers on the far side more likely to yield to pedestrians once a pedestrian had completed his or her near side crossing?

RESULTS

Overview

There were 744 total observed crossings, with 368 occurring before installation and 376 in the after period. We counted and coded all pedestrian crossings that occurred within our camera view of the crosswalk. Some of these crossings involved pedestrians in groups—thus, the total number of pedestrians observed was 931 with 453 before and 478 after the in-roadway lighting was installed.

During the after data collection period, there was a temporary system malfunction with the passive actuation system. When pedestrians crossed from the Metro side of the roadway, the lights failed to trigger. However, for crossings originating from the hotel side, the lights did turn on. This problem actually offered an ideal opportunity to compare driver yielding for crossings during the same data collection period: if the after data for crossings where the lights failed are similar to the before data, then we should have even greater confidence that any driver or pedestrian behavior differences between these data sets and the lighted crossings are due to the treatment. It should be noted that in-roadway lighting systems typically are installed to be minimally detectable to pedestrians in the crosswalk. This design technique could pose problems for situations when the system malfunctions if the pedestrians assume the lights are coming on.

Pedestrian crossing locations

The in-roadway lighting had no impact on whether pedestrians opted to use the marked crosswalk. For the before period 72.8% of the pedestrians used the crosswalk whereas 75.0% did so in the after period. Roughly one-quarter of the pedestrians opted to cross completely outside the marked crosswalk. As would be expected, most of these crossings were due to convenience and to reduce walking distance by taking a shorter path to a destination such as the Metro station. The lights do not encourage more pedestrians to use the marked crosswalk. The question becomes whether the lights improve crossings for those pedestrians who do use the crosswalk.

Pedestrian/Vehicle Interactions

In order to get a better understanding of how the lights affected pedestrian and driver behavior, we pared down the data to focus exclusively on those crossings in the before and after periods where at least one vehicle could have yielded for the pedestrian. Presumably the lights provide little benefit for crossing situations without vehicles; their greatest benefit should occur when vehicles are present. Therefore the remainder of the results section examines only crossings where there was a potential pedestrian/vehicle interaction. For these analyses there were 178 pedestrian crossing events (i.e., either single pedestrians or pedestrians crossing in a group) in the before period and 159 in the after period with 77 crossing with the lights on and 82 crossing without the lights being actuated. Table 1 presents the measurements for the before and after periods, with the after period separated by whether the lights came on for the pedestrian crossing.

Table 1. Pedestrian and Driver Measures for Crossings Involving At Least One Vehicle.

	Before	After (Lights)	After (No Lights)
Percentage of pedestrians that had a vehicle yield to them—Near Side	36.0%	70.7%	41.4%
Percentage of pedestrians that had a vehicle yield to them—Far Side	64.9%	98.1%	74.4%
Average number of vehicles passing through crosswalk before one yields—Near Side	1.5	1.0	1.5
Average number of vehicles passing through crosswalk before one yields—Far Side	0.6	0.7	0.6
Average pedestrian wait time—Near Side	5.0 sec	3.3 sec	4.8 sec
Average pedestrian wait time—Far Side	0.4 sec	0.5 sec	0.6 sec
Percent of pedestrians making hurried crossings—Near Side	6.2%	3.9%	2.4%
Percent of pedestrians making hurried crossings—Far Side	6.2%	3.9%	2.4%
Percent of pedestrians making assertive crossings—Near Side	9.0%	10.4%	3.7%
Percent of pedestrians making assertive crossings—Far Side	9.6%	7.8%	17.1%

Driver Yielding, Average Vehicles Passing a Pedestrian, and Pedestrian Wait Times

As can be seen in Table 1, there was a significant increase in driver yielding in the after period when the lights came on. In general, the before data and the after data with no lights look quite similar. Therefore, in-roadway lighting does increase the likelihood that drivers will yield. For both the near and far side lanes, there was roughly a 30 percent increase in driver yielding compared to the two control conditions. The most impressive aspect of these data is that driver yielding on the far side (i.e., once the pedestrian had already traversed one lane) was close to 100 percent. The benefits of the lights are also evident in the decline in the average number of cars that passed a pedestrian and in the reduced pedestrian wait times. All of the differences described were statistically significant. Figure 2 depicts a driver who has yielded to pedestrians crossing from the Metro station. (Note that although not visible in this photograph, the in-roadway lights were on and were visible to the driver).

Figure 2. A Driver Waits For Pedestrians To Cross After Treatment Installation.

Note: This is an example of pedestrians completing a near side crossing and a driver yielding to them on the far side.

Pedestrian Hurries and Assertive Crossings

There are several additional aspects of interest from Table 1. First, the treatment did not alter pedestrian behavior for hurried or assertive crossings in any clear way. The rate of hurried crossings, interestingly, was identical for both the near and far side data. This is because most hurried pedestrians continued to speed their crossing across the entire roadway rather than hurrying across one lane only. Regarding the assertive crossings, the lights probably did not affect pedestrian assertiveness. This is important because it suggests that the treatment did not create a false sense of security for pedestrians. The assertiveness results for the after period without lights are more difficult to interpret—given the small sample, it is hard to determine whether this is simply noise in the data set or a meaningful difference.

DISCUSSION

As the findings from this report suggest, in-roadway lighting can improve the quality of pedestrian crossings at crossing locations without stop control. The study site witnessed a significant increase in yielding drivers after the lights were installed. Support for this effect was bolstered by our ability to compare how drivers behaved in the same data collection sessions when the lights failed to operate for some pedestrians. As Table 1 shows, the data for pedestrians in the after period where the lights failed to actuate look more like the before data than the data for pedestrian crossings where the lights came on.

Findings from the present study indicate that it is important to provide both passive and active actuation options. In the present study, the passive actuation experienced some technical problems and pedestrians could not get the lights to trigger. If pushbuttons were installed at these locations, then pedestrians would have had a backup option. Future research may also be needed to determine whether pedestrians should be able to see lights from the crosswalk. It is unclear from the present study whether pedestrians crossing from the Metro side in the after period even knew that the lights failed to come on.

Not all actuation problems were due to the system, however. A number of pedestrians did not trigger the lighting because they veered into the crosswalk just outside the range of the passive actuators. It may be beneficial to install the passive detectors further apart to capture more pedestrians who enter the crosswalk from just outside the markings. Other alternatives include marking the passive detectors so that pedestrians notice them and recognize the need to step between them them. A final possibility would be to install placards to educate pedestrians about the in-roadway lighting system and how it works. Clearly this is a last resort because placards may not benefit all pedestrians (e.g., visually impaired or non-native English speaking pedestrians).

Acknowledgements

The authors would like to acknowledge the technical assistance of Dana Duke, Jason Kennedy, and Patrick Robinson in collecting and analyzing the data. We would also like to thank Sandra Marks a civil engineer in Rockville who alerted us of this installation.

REFERENCES

Boyce, P., & Van Derlofske, J. (2002). *Pedestrian crosswalk safety: Evaluating in-pavement, flashing warning lights*. Final report, March, 2002. Troy, New York: Lighting Research Center, Rensselaer Polytechnic Institute.

Hakkert, A. S., Gitelman, V., & Ben-Shabat, E. (2001). An evaluation of crosswalk warning systems. In the *Proceedings of the 80th annual meeting of Transportation Research Board (TRB)* Washington, DC, January 7-11, 2001, Paper 01-0135.

Hakkert, A. S., Gitelman, V., & Ben-Shabat, E. (2002). An evaluation of crosswalk warning systems: Effects on pedestrian and vehicle behavior. *Transportation Research Part F 5*, 233-250.

Huang, H., Hughes, R., Zegeer, C., Nitzburg, M. (1999). *An evaluation of the LightGuard™ pedestrian crosswalk warning system*. Report for the Florida Department of Transportation Safety Office, June, 1999.

Katz, Okitsu, & Associates. (2000). *Illuminated crosswalks: An evaluation study and policy recommendations.* Report to City of Fountain Valley, California, October 2000.

Manual on Uniform Traffic Control Devices, Millennium Edition. (2001). Washington, DC: Federal Highway Administration.

Polus, A., & Katz, A. (1978). An analysis of nighttime pedestrian accidents at specially illuminated crosswalks. *Accident Analysis and Prevention, 10*, 223-228.

Prevedouros, P. D. (2001). Evaluation of in-pavement flashing lights on a six-lane arterial pedestrian crossing. In the *Proceedings of the 71st Annual Meeting of the Institute of Transportation Engineers (ITE)*, Chicago, Illinois, August, 2001.

Prevedouros, P. D. (2001). *Evaluation of Lightguard™ flashing lights at a pedestrian crossing along Pali Highway*. Mānoa, Hawaii: University of Hawai'i, final report, Honolulu, Hawaii, December 15, 2001.

Shanker, U. (2003). *Pedestrian roadway fatalities.* Washington, DC: National Center for Statistics and Analysis, technical report # DOT HS 809 456.

Traffic Safety Facts 2001: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System. (2001). Washington, DC: National Highway Traffic Safety Administration.

Van Derlofske, J., Boyce, P. R., & Gilson, C. H. (2003). Evaluation of in-pavement, flashing warning lights on pedestrian crosswalk safety. In the *Proceedings of the 82nd Annual Meeting of the Transportation Research Board (TRB)*, Washington, DC, January 12-16, 2003, Paper 03-2639.

Whitlock & Weinberger Transportation, Inc. (1998). *An evaluation of a crosswalk warning system utilizing in-pavement flashing lights*. Report for the State of California Office of Traffic Safety, April, 1998.

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[i] Various terms, such as “in-pavement crosswalk lighting,” “illuminated crosswalks,” and “flashing crosswalks,” have been used to describe in-roadway warning lights at crosswalks.
[ii] Shanker only investigated single vehicle pedestrian fatalities, which make up 91.4% of all pedestrian fatalities. The remaining fatalities were classified as multi-vehicle pedestrian fatalities.