An Evaluation of a Crosswalk Warning System Utilizing In-Pavement Flashing Lights

Primary Funding Provided By
State of California Office of Traffic Safety

Additional Funding Provided By
Federal Highway Administration through the University of North Carolina
Highway Safety Research Center

April 10, 1998

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EXECUTIVE SUMMARY

Introduction

In response to an unusually high incidence of pedestrian/vehicle collisions, the City of Santa Rosa, California initiated a new concept in proactive pedestrian warning systems for uncontrolled crosswalks in 1993 after experiencing a significant number of pedestrian fatalities and injuries. A private citizen came forth to the City with an idea for a flashing device to be installed on the pavement surface along the crosswalk lines facing traffic. The In-Pavement Flashing Lights Crosswalk Warning System's purpose was to warn the driving public of the presence of pedestrians in the crosswalk at uncontrolled intersections. The citizen is a pilot and the idea came to him when he thought that airport runway strobe lights used in landing his plane might be useful at crosswalks. The experimental system consists of a series of flashing light units which are embedded in the pavement adjacent to a marked crosswalk. The lights reflect toward the oncoming traffic to warn drivers of a pedestrian's presence.

The California Traffic Control Devices Committee allowed the City if Santa Rosa to test the experimental device at selected locations. The California Office of Traffic Safety also granted funds to the City to study the effectiveness of the device. The private citizen developed the In-Pavement Flashing Lights Crosswalk Warning System, while the City was responsible for the construction and installation requirements of the devices and the analysis of the device through a consultant. The system was eventually installed at three locations in the City of Santa Rosa, two in 1994 and one in 1995. Those sites were evaluated and the findings presented in a report, *Analysis of an Experimental Pedestrian Crosswalk Device, W-Trans/TJKM, July 17, 1995.*

In 1996, the California Traffic Control Devices Committee (CTCDC) endorsed the testing of the system in additional California cities in order to determine if the device should be sent on to the California State Department of Transportation for standardization. *Evaluation of an Experimental Crosswalk Warning System, July 1, 1997*, presented an evaluation on the In-Pavement Flashing Lights Crosswalk Warning System based on the operation and experience in the Cities of Fort Bragg, Lafayette, Petaluma, and Willits. Additional evaluation was conducted at one of the original Santa Rosa test sites two years following the initial installation of the device.

Primary funding for that study was provided primarily by the California Office of Traffic Safety (OTS) through the Cities of Fort Bragg, Lafayette, West Hollywood and Willits.

This report presents an update to the *Evaluation of an Experimental Crosswalk Warning System* based on additional experience in the Cities of Orinda, California and Kirkland, Washington. Funding for this update was provided through the Federal Highway Administration's Pedestrian Facilities Program, which is being conducted by the University of North Carolina Highway Research Center.

Findings

The concept of flashing amber lights embedded in the pavement at uncontrolled crosswalks clearly has a positive effect in enhancing a driver's awareness of crosswalks and modifying driver habits to be more favorable to pedestrians.

The In-Pavement Flashing Lights Crosswalk Warning System has a much more significant effect in enhancing a driver's awareness of crosswalks during adverse weather conditions such as darkness, fog and rain.

Over the long term, the affect of the crosswalk warning system will degrade slightly during daytime condition from initial implementation of the system. However, the resulting conditions will represent improved vehicle reaction characteristics compared with conditions before installations.

The In-Pavement Flashing Lights Crosswalk Warning System has the potential to be an effective traffic control device since it fulfills a need, commands attention, conveys a clear meaning, commands respect of road users, and gives adequate time for proper response.

An automatic detection system is more appropriate than a push button system and can result in less confusion for the pedestrian.

A recently demonstrated "bollard gateway system" which utilizes two parallel modulated visible red beams seems to be the most promising automatic activation technology.

The warning system seems to be partially effective at locations where there is at least a moderate flow of pedestrians (100 pedestrian crossing per day).

At speeds less than 35 mph, drivers seem to be able to respond properly if at least 400 feet of sight distance is provided to the warning system.

The presence of a lighting device at the outer edge of the travel lane may be a hazard to some bicyclists.

Each successive prototype of the lighting devices which has been tested has been superior in terms of their physical durability. Further improvements to its durability are still warranted. However, the desires of the market will dictate further physical evolution of the device.

Recommendations

Since the concept of flashing amber light embedded in the pavement at uncontrolled crosswalks clearly has merit in modifying driving habits to be more favorable to pedestrians, further use of this concept should be perused at appropriate locations.

The current installation pattern should be maintained as a standard. However, the outermost device should be placed to avoid the path of bicyclists the extent possible.

The device should be no higher than ¾ -inch, which is the maximum height of a standard lane delineator button.

Amber flashing lights seem to be the most appropriate color based on vehicle laws and considering a person's visual capabilities.

In the long run, an automatic pedestrian activation system seems to be more appropriate than a pedestrian push button. This allows the pedestrian to cross with caution and at their own discretion. The most promising technology to date has been the bollard gateway system.

Appropriate street lighting should be considered at crosswalks where the system is applied. Street lighting will allow the pedestrian to be more visible at night and wash out the glow of the lighting devices so they do not distract the pedestrian.

Federal standardization through the Manual on Uniform Traffic Control Devices (MUTCD) and consistency with crosswalk laws in states other than California should be investigated. An organization such as the Institute of Transportation Engineers would be an appropriate organization to peruse this course of action.

Based on the experience of the initial test sites, it is recommended that the following guidelines be met for installation of the In-Pavement Flashing Lights Crosswalk Warning System. The development of guidelines will be important in focusing use of the device where it will be most effective and maintaining its effectiveness through limiting the number of locations where it is present.

The Crosswalk Warning System should be used at uncontrolled crosswalks.

Main street average vehicular approach speeds should be 45 mph or less.

Main street traffic volumes should be between 5,000 and 30,000 vehicles per day. (It should be noted that the City of West Hollywood will be testing the device on Sunset Boulevard which has 55,000 vehicles per day.)

At speeds less than 35 mph, the approaching motorist should have visibility of the lighting devices at least 400 feet in advance of the crosswalk (measured from 3.5-foot eye height of the driver to 1 inch at the edge of the crosswalk line). At speeds greater than 35 mph, appropriate additional sight distance to the warning lights should be provided.

There should be no other crosswalks or traffic control devices at least 250 feet in advance or following the crosswalk location.

A minimum pedestrian volume of 100 pedestrian per day is suggested for application of the system.

Agencies, which install the system, should ensure that the public is educated on the proper use of the device by both driver and the pedestrian.

Effectiveness

Based on these survey results, the In-pavement Flashing Lights Crosswalk Warning System has clearly had a positive effect in enhancing a driver's awareness of the crosswalks and modifying driving habits to be more favorable to pedestrians. The extent of the effectiveness of the device depends on the specific site and seems to be impacted by the following geometric and operational characteristics:

- weather and lighting conditions
- width of the street and associated number of light installations

- grade change and curvature of the street
- level of traffic enforcement
- community's attitude toward the pedestrian
- speed of the traffic
- amount of pedestrian activity

Based on observations of the device's operation during adverse lighting conditions, it should be noted that the In-Pavement Flashing Lights Crosswalk Warning System has a much more dramatic effect in increasing a driver's awareness of crosswalks during adverse weather conditions such as darkness, fog and rain.

To be effective, as defined by the *Manual on Uniform Traffic Control Devices*, a traffic control device should meet five basic requirements, as follows:

1. Fulfill a need
2. Command Attention
3. Convey a clear, simple meaning
4. Command respect of road users
5. Give adequate time for proper response

The In-Pavement Flashing Lights Crosswalk Warning System has met these requirements in the following ways:

Fulfill a Need
This warning system was developed due to a specific need in the City of Santa Rosa. The interest by other jurisdictions to be a part of this second phase of testing, indicates that the concern and associate need were not isolated. The exposure of this concept through the media and professional journals has helped it gain national attention and interest because communities do have need for a cost effective means of addressing pedestrian safety issues at unprotected crosswalks.

Command Attention
The results of the data analysis has clearly shown that the use of lights in the pavement activated only when pedestrians are present gains the attention of the driver. The percentage of drivers which yield to the pedestrians has increased significantly at all of the study locations with the addition of the warning system.

Convey a Clear Simple Meaning
A flashing amber/yellow light used under various applications is intended to warn drivers to act with caution. With the experimental system, the intention is the same. The flashing amber lights placed on the roadway conveys the clear message of caution.

Command Respect of Road Users
Previous studies have shown that continuously flashing beacons at urban crosswalks do not increase driver awareness since these passive applications eventually become part of the background scenery. The experimental warning system commands respect of the road users since it is only activated when a pedestrian is crossing the street.

Give Adequate Time for Proper Response
Depending on the roadway alignment, the lights can be viewed from 1,000 to 1,500 feet away from the crosswalk. As long as the devices are being placed so that at least 300 to 400 feet of sight distance is available to the lead vehicle in a platoon, adequate time for driver response is available.

Driver Understanding of the Device
Based upon some of the comments received from drivers, most drivers seem to understand that they should react with some caution by either reducing their speed, or applying their brakes. Observations of drivers' reaction two years later at the original Santa Rosa installation revealed a consistent "sweeping" of the drivers head back and forth looking for pedestrians when lights were activated. There is some confusion by a small percentage of drivers who are unaware of whether they are required to stop when lights flash. Some other confusion has been caused by malfunctions on the automatic detection system.

Pedestrians Understanding of the Device
The automatic detection system has seemed to result in less confusion for the pedestrian than the push button activation because it does not require them to act in any way other than crossing the street as they would at any other uncontrolled crossing. Based on field observations at the Petaluma test site, which has the automatic activation, the pedestrians seem to be continuing to cross the street with the same level of caution as before.

Give Adequate Time for Proper Response
Depending on the roadway alignment, the lights can be viewed from 1,000 to 1,500 feet away from the crosswalk. As long as the devices are being placed so that at least 300 to 400 feet of sight distance is available to the lead vehicle in a platoon, adequate time for driver response is available.

Activation System
The activation system for this type of warning system is one of the most important features contributing to its effectiveness. Considering the experience at all of the test sites which have included both manual activation (push button) and automatic activation (overhead ultrasonic and overhead video imaging), an automatic detection system seems to be more appropriate than a manual push button activation. This recommendation is based on the following considerations:

- Historically, the pedestrian push button has been used almost exclusively as part of a standard traffic signal installation, which includes pedestrian signal heads. Pedestrians who encounter a pedestrian push button with out the associated traffic signal equipment are unlikely to expect it and may not understand what it is for. Worse, they may interpret a push button as giving them the right of way.
- Since this application is considered a warning system to the driver, no visual indication should be given to the pedestrian.
- The public may perceive the act of pushing a button as a way to cause approaching vehicles to stop.
- Based on field observations of several push button operated crosswalks warning systems in Santa Rosa, California, the frequency with which pedestrians used the push buttons varied with the volume of traffic. During off-peak periods when traffic volumes were lower, approximately one-third of the pedestrians activated the system. During peak periods when traffic volumes required the crossing pedestrian to wait for a gap, the use of the push button increased up to approximately two-thirds of the time.
- An automatic detection system should be less confusing to pedestrians because it does not require them to act in any way other than crossing the street with caution and at their own discretion. It also makes the pedestrian more responsible for their actions and causes less confusion.

It should be noted that the ultrasonic detection system which has been used to date has not performed satisfactorily. In general, the lights have activated 60 to 70 percent of the time when a pedestrian uses the crosswalk. Periodically, a turning vehicle or swaying trees have activated the lights with no pedestrians present. The video imaging detection system which was installed by the City of Petaluma seems to be a superior system but still has occurrences of false and non-

activations. A recent demonstrated "bolland gateway system" which utilizes two parallel modulated visible red beams seems to be the most promising technology. When pedestrians break the two beams in succession while walking into the street, the system activates 100 percent of the time. The system does not activate when a pedestrian breaks the beam in the reverse order leaving the street.

Physical Durability
The devices used in the In-Pavement Flashing Lights Crosswalk Warning Systems for the current test site, which are a third generation prototype, have been superior to the original prototype in terms of durability. There have been several instances of devices being damaged due to a street sweeper in Petaluma and logging trucks in Willits. They were replaced. The newest button type design, which has been tested in the field for less than a year. Has performed better in terms of durability than the previous design and is more resistant to damage by snowplows and street sweepers, however, there have been instances of damage which required replacement.

Comparisons with Standard Devices
An overhead flashing beacon is a standard device which can be used in the application of warning the driver of a pedestrian crosswalk. As indicated above previous studies have shown that continuously flashing beacons at urban crosswalks do not increase driver awareness since these passive applications eventually become part of the background scenery. Currently, there are other studies underway in the East Coast, which are evaluating the effectiveness of pedestrian activated, overhead flashing pedestrian signs.

The only way to directly compare the effectiveness of the In-pavement Flashing Lights Crosswalk Warning System versus an overhead flashing beacon would be to install each at the same location in succession to determine how each impacts driver attention. None of the participating agencies was willing to go to the expense of this endeavor. Therefore, this report focussed directly on the potential effectiveness of the experimental system and its merit.

Based on the experience of the test sites in Fort Bragg, Lafayette, Petaluma, Santa Rosa, Willits, Orinda and Kirkland, the following findings and recommendations are presented. These findings and recommendations may be modified based on future experiences of the system.

Findings

1. The concept of flashing amber light embedded in the pavement at uncontrolled crosswalks clearly has a positive effect in enhancing a driver’s awareness of crosswalks and modifying driving habits to be more favorable to pedestrians.
2. The In-Pavement Flashing Lights Crosswalk Warning Systems has a much more significant effect in enhancing a driver’s awareness of crosswalks during adverse weather conditions such as darkness, fog, and rain.
3. Over the long term, the affects of the crosswalk warning system will degrade slightly during daytime conditions from initial implementation of the system. However, the resulting long-term conditions still represent improved vehicle reaction characteristics compared with conditions before installations.
4. The warning system is expected to be extremely effective over the long term in enhancing driver awareness of the presence of a pedestrian during the hours of darkness.
5. The In-Pavement Flashing Lights Crosswalk Warning System has the potential to be effective traffic control device since it fulfills a need, commands attention, conveys a clear meaning, commands respect of road users, and gives adequate time for proper response.
6. An automatic detection systems is more appropriate than push a button system and can result in less confusion for the pedestrian because it does not require them to act in any way other than crossing the street as they would at any other uncontrolled crossing.

7. The ultrasonic automatic pedestrian detection technology tested in this evaluation was not found to be completely reliable in activating the system. The video imaging technology was superior was superior to the ultrasonic detection, but still had many instances of false and non-activities. A recently demonstrated "bollard gateway system" which will utilizes two parallel modulated visible red beams seems to be the most promising technology.
8. It is estimated that pedestrians use a push button in the 30 to 60 percentage range for this type of application depending on the volume of traffic. The absence of a pedestrian crossing indication does not generally prompt pedestrians to seek out the push buttons.
9. The warning system seems to be particularly effective at locations where there is at least moderate flow of pedestrians (100 pedestrians crossing per day). These locations tend to have sites characteristics, which lead the driver to expecting pedestrian crossings.
10. At speeds less than 35 mph, drivers seem to be able to respond properly if at least 400 feet of sight distance is provided to the warning system.
11. At speeds greater than 40 mph, drivers seem to have difficulty stopping safely if less than 600 feet of sight distances is available prior to the warning lights.
12. The presence of a lighting device at the outer edge of the travel lane may be a hazard to some bicyclists.
13. Each successive prototype of the lighting devices that have been tested has been superior in terms of their physical durability. Further improvements to its durability are still warranted. However, the desires of the market will dictate further physical evolution of the device.

Recommendations

1. Since the concept of flashing amber lights embedded in the pavement at uncontrolled crosswalks clearly has merit in modifying driving habits to be more favorable to pedestrians, further use of this concept should be persued at appropriate locations.
2. There have been suggestions to have the devices only on the lane lines. This may not be desirable since the device in the center of the lane is the light most visible to drivers in that lane. The current installation pattern should be maintained as a standard. However, the outermost device should be placed to avoid the path of bicyclists to the extent possible.
3. The devise should be no higher than ¾-inch which is the maximum height of a standard lane delineator button.
4. Amber flashing lights seem to be the most appropriate color based on vehicle laws and considering a person’s visual capabilities. Therefore the amber lights and size of the lens should be maintained as a standard.
5. In the long run, an automatic pedestrian activation system seems to be more appropriate than a pedestrian push button. This allows the pedestrian to cross with caution and at their own discretion. It also makes the pedestrian more responsible for their actions and causes less confusion. The most promising technology to date has been a "bollard gateway system" which utilizes two parallel-modulated visible red beams.
6. If a pedestrian push button is used, the sign which accompanies the button should be yellow and read, "Push Button for Warning Flasher/Cross with Caution" or similar wording. The use of a standard walking man symbol such as is used in the pedestrian head at a traffic signal and which indicates a protected pedestrian crossing should be avoided.
7. If a pedestrian push button is used with appropriate signage, in order to address ADA (American with Disabilities Act) issues, the installation could be supplemental with a voice box which says, ""he warning flashers have been activated – cross with caution," or similar wording.
8. Appropriate street lighting should be considered at crosswalks where the system is applied. Street lighting will allow the pedestrian to be more visible at night and wash out the glow of lighting devices so they do not distract the pedestrian.

9. Federal standardization through the Manual on Uniform Traffic Control Devices (MUTCD) and consistency with crosswalk laws in states other than California should be investigated. An organization such as the Institute of Transportation Engineers would be an appropriate organizations to persue this course of action.
10. Based on the experience of the initial test sites, it is recommended that the following guidelines be met for installation of the In-Pavement Flashing Lights Crosswalk Warning System. These guidelines may be modified based on future experiences of the system. The development of guidelines will be important in focusing use of the device where it will be most effective and maintaining its effectiveness through limiting the number of location where it is present.
11. Main street average vehicular approach speeds should be 45 mph or less.
12. Main street traffic volumes should be between 5,000 and 30,000 vehicles per day. (It should be noted that the City of West Hollywood will be testing the device on Sunset Blvd. Which has 55,000 vehicles per day
13. The Crosswalk Warning System should be used at uncontrolled crosswalks.
14. At speeds less than 35 mph, the approaching motorists should have visibility of the lighting devices at least 400 feet in advance of the crosswalk (measured from 3.5-foot eye height of the driver to 1-inch height at the edge of the crosswalk line). At speeds greater than 35 mph, appropriate additional sight distance to the warning lights should be provided.
15. There should be no other crosswalks or traffic control devices at least 250 feet in advance or following the crosswalk locations.
16. A minimum pedestrian volume of 100 pedestrians per day is suggested for application of the system.
17. Agencies that install the system should ensure that the public is educated on the proper use of the device by both drivers and the pedestrian.