Evaluation of Automated Pedestrian Detection at Signalized Intersections

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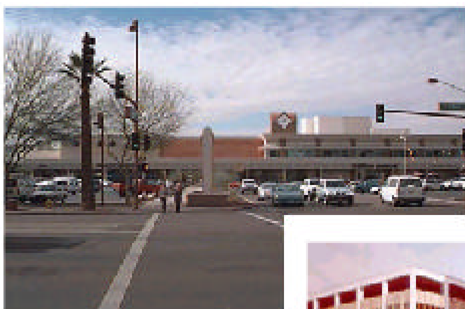

U.S. Department of Transportation
Federal Highway Administration
Research, Development, and Technology
Turner-Fairbank Highway Research Center
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McLean, VA 22101-2296

Pedestrian & Bicycle Safety

FOREWORD

The FHWA's Pedestrian and Bicycle Safety Research Program's overall goal is to increase pedestrian and bicycle safety and mobility. From better crosswalks, sidewalks and pedestrian technologies to growing educational and safety programs, the FHWA's Pedestrian and Bicycle Safety Research Program strives to pave the way for a more walkable future.

At many signalized intersections, pedestrian detection is accomplished by the pedestrians pushing buttons to activate the Walk phase. Pedestrians often do not activate the Walk signal because they believe the button already has been pressed, do not think it is working, or cannot access the button. Automated pedestrian detection systems can detect the presence of pedestrians and call the Walk signal without any require action by the pedestrian. This study evaluated the safety effects of microwave and infrared detectors used in conjunction with standard pedestrian push buttons. This study was part of a larger Federal Highway Administration research study investigating the effectiveness of innovative engineering treatments on pedestrian safety. It is hoped that readers also will review the reports documenting the results of the related pedestrian safety studies.

The results of this research will be useful to transportation engineers, planners, and safety professionals who are involved in improving pedestrian safety and mobility.

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and Development

NOTICE

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16. Abstract

Automated pedestrian detection systems provide the means to detect the presence of pedestrians as they approach the curb prior to crossing the street, and then "call" the Walk signal without any action required on the part of the pedestrian. The objective of the present study was to evaluate whether automated pedestrian detectors, when used in conjunction with standard pedestrian push buttons, would result in fewer overall pedestrian-vehicle conflicts and fewer inappropriate crossings (i.e., beginning to cross during the Don't Walk signal). "Before" and "after" video data were collected at intersection locations in Los Angeles, CA (infrared and microwave), Phoenix, AZ (microwave), and Rochester, NY (microwave). The results indicated a significant reduction in vehicle-pedestrian conflicts as well as a reduction in the number of pedestrians beginning to cross during the Don't Walk signal. The differences between microwave and infrared detectors were not significant. Detailed field testing of the microwave equipment in Phoenix revealed that fine tuning of the detection zone is still needed to reduce the number of false calls and missed calls.

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INTRODUCTION

Statement of the Problem

Pedestrian Walk / Don't Walk signals are special types of traffic control devices intended for controlling pedestrian traffic (MUTCD, 1988). The conventional Walk / Don't Walk messages provide pedestrians with reliable information about (a) when it is appropriate to begin crossing the street (steady Walk signal), (b) when pedestrians should not start crossing (flashing Don't Walk), and (c) when pedestrians should not be in the street at all (steady Don't Walk). To optimize the efficiency of traffic signals, many are designed to be vehicle-actuated. At actuated traffic signals, pedestrians may have to press a push button in order to receive the Walk signal and to ensure that they will have enough time to cross the street.

A problem with this arrangement is that not all individuals wanting to cross will press the push button. A previous study suggested that only about half of all pedestrians use the push button (Zegeer et al., 1985). There are a number of possible reasons why pedestrians do not use the push button. They may not be aware that pressing the button is necessary to obtain the Walk signal, because many signals do not have a push button and automatically allocate a Walk interval on every cycle. Even when pedestrians are aware of the requirement, the delay between the time that the push button is pressed and the Walk signal appears can be long enough that some pedestrians think that the system is malfunctioning. Visually impaired pedestrians may not realize that the push button exists or may not be able to find it (Bentzen and Tabor, 1998). Pedestrians with severe mobility impairments may be unable to press a conventional push button. In any case, the result is that pedestrians may attempt to cross against the signal.

A number of different automated pedestrian detection technologies have been proposed as a means of detecting the presence of the pedestrian, so that he / she does not have to press the button. These include the use of infrared, microwave, and video image processing (for example, Zegeer et al., 1994; UK Department of Transport, 1993; Ekman and Draskocsky, 1992; King, 1994).

Microwave and Infrared Technologies

A microwave detector generates a beam of energy at a particular frequency. The basis for detection is the device's ability to detect a difference in the frequencies of the outgoing beam and the beam that is reflected back (the Doppler effect). The beam has to be targeted accurately, especially when the size of the object to be detected (e.g., a pedestrian) is significantly less that of other moving objects (e.g, passing vehicles).

Infrared technologies are already well established for both vehicle and off-road pedestrian detection. Examples of locations in which infrared is used to detect pedestrian presence include grocery stores, shops, banks, and entrances to other public buildings. The efficiency of infrared detection methods can be degraded if the object remains still. Infrared devices cannot discriminate the direction of pedestrian movement, nor can they determine the number of objects detected.

Both microwave and infrared detectors work by calling the Walk signal when a person enters the detection zone on the curb. The size and shape of the detection zone varies depending on the type of detector used and how it is positioned. A delay can be built in so that persons are detected only if they stay within the detection zone for more than a minimum amount of time. Such a delay will help to

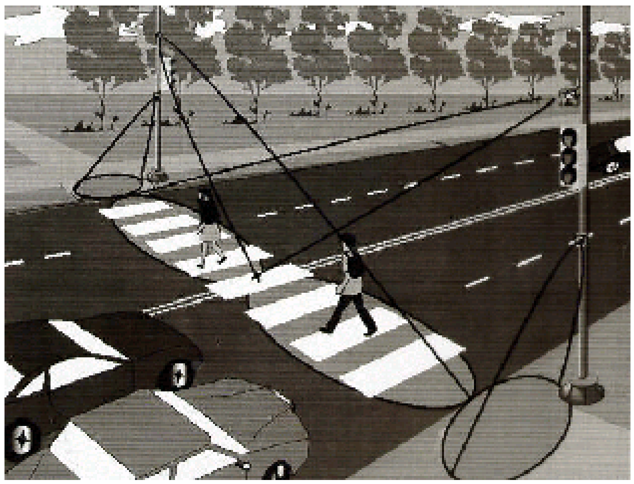

Figure 1. An automated pedestrian detection system.

prevent false actuations resulting from persons who are merely passing through the detection zone and do not intend to cross the street. A more detailed discussion of alternative detection technologies is given elsewhere (Sherborne, 1992).

Experience With Automated Pedestrian Detection

In the United Kingdom, Puffin (Pedestrian User-Friendly INtelligent) crossings respond to pedestrian demand and do not delay traffic unnecessarily when no pedestrians are present (UK Department of Transport, 1993). Pedestrian presence is sensed either by use of a pressure- sensitive mat or by an infrared detector mounted above the crossing location. Pressure on the mat is used both for initial detection as well as to confirm that the pedestrian has not departed the crossing zone before the Walk signal appears. If the pedestrian departs the crossing zone prior to the appearance of the Walk signal, the call will be canceled.

Puffin crossings may also utilize an additional sensor to detect the continued presence of pedestrians in the crosswalk, thereby allowing the signal phase to be extended for those requiring additional time to cross. The conversion of a standard signal to a Puffin crossing in Victoria, Australia, reduced by 10 percent the number of pedestrians who started to cross before the pedestrian Walk signal was presented (Catchpole, 1996). Similar results were reported in Växjö, Sweden (Ekman and

Draskoczy, 1992). The Swedish results also showed that the number of vehicle-pedestrian conflicts decreased after the microwave detectors were in place.

The Dutch PUSSYCATS (Pedestrian Urban Safety System and Comfort At Traffic Signals) system consists of a pressure-sensitive mat to detect pedestrians waiting to cross, infrared sensors to detect pedestrians within the crossing, and a near-side pedestrian display (Tan and Zegeer, 1995). Although pedestrians perceived PUSSYCATS to be at least as safe as the old system, many pedestrians reported that they did not understand the function of the mat. As many as half of all pedestrians refused to use the system. Similar applications are being used in the United Kingdom and France (Levelt, 1992).

Objective of the Present Study

Although automatic detection systems for pedestrians have been used successfully in Europe and Australia for several years, such applications are in the early stages of testing and use in the United States. Differences in signal hardware plus cost and other considerations have prevented direct and immediate application of these technologies in the United States.

The present study evaluated automated pedestrian detection systems installed at sites in Los Angeles, CA (infrared and microwave); Phoenix, AZ (microwave); and Rochester, NY (microwave). At the Los Angeles site, a second set of sensors was used to detect pedestrians who were crossing in the crosswalk. This additional detector monitored pedestrians in the crosswalk. It extended the clearance interval (steady Don't Walk before opposing traffic had the green) until pedestrians were safely on the other side of the street. All other locations were equipped with only one sensor that detected pedestrians who arrived in the queuing area at the curb.

The goals of the analysis were to determine if automated pedestrian detectors, when used in conjunction with standard pedestrian push buttons (a) decreased the likelihood of pedestrians beginning to cross during the Don't Walk signal and (b) decreased vehicle-pedestrian conflicts. This study also included a detailed analysis of the microwave detection zone and detection accuracy in Phoenix.

METHOD

Data collection consisted of videotaping motorist and pedestrian behavior before and after automated detectors were installed in Los Angeles, Rochester, and Phoenix. At each location, pedestrian push buttons already existed and remained operational after the automated detectors were added. In Los Angeles, data were collected under three conditions, no automated detector in operation, infrared detector in operation, and microwave detector in operation.

Data were collected during daylight hours, under dry conditions (no snow or ice was on the ground in Rochester). A video camera was set up on the sidewalk, approximately 23 m (75 ft) upstream from the intersection, in Rochester and Phoenix. In Los Angeles, the camera was set up on the top level of a parking deck. The camera was positioned so that the crosswalk of interest was visible, and pedestrians in the crosswalk were walking either toward or away from the camera. The pedestrian queuing areas, the pedestrian signals and push buttons, and traffic signals for parallel traffic were also recorded by the camera. Table 1 shows the number of hours of data collection and the number of pedestrians that were videotaped at each study site.

Table 1. Number of Pedestrians and Hours of Data Collection at Each Study Site.

STUDY SITE	NUMBER OF PEDESTRIANS (HOURS OF DATA COLLECTION IN PARENTHESES)	
	BEFORE	AFTER
Los Angeles: San Pedro and Temple	573 (2 hr)	533 (4 hr - with infrared) 590 (1 hr 50 min - with microwave)
Rochester: Crittenden and Lattimore	767 (4 hr)	555 (2 hr)
Rochester: State and Corinthian	277 (7 hr 20 min)	208 (3 hr 30 min)
Phoenix: Central and Earll	500 (2 hr)	671 (4 hr)

Los Angeles, Temple and San Pedro (east side crosswalk)

The Temple and San Pedro site is a “T” intersection (Figure 2). Temple Street is an east-west street and San Pedro Street comes from the south to form the “T.” There are marked crosswalks and push buttons across the east and south legs only. A sign directs pedestrians wishing to cross the west leg to the east leg. The signal controlling the south side crossing is on pedestrian recall. Automated pedestrian detectors were added to the east side crosswalk. On both the northeast and southeast corners, one detector picked up pedestrians who entered into the detection zone on the sidewalk (waiting to cross the street) and a second detector picked up pedestrians who were still in the crosswalk.

If a pedestrian was detected as still being in the crosswalk, the crossing time was extended by 0.2-s increments to a maximum of 6 additional seconds. The extended crossing time corresponded to a walking speed of 0.9 m/s (3.0 ft/s), compared with the customary 1.2 m/s (4.0 ft/s). During the extended crossing interval, the steady Don’t Walk signal was displayed and the onset of the green signal for opposing motorists (traveling on Temple) was delayed.

Figure 2. Temple and San Pedro (Los Angeles).

Rochester, Crittenden and Lattimore (north side crosswalk)

Lattimore Road is a north-south road, and Crittenden Boulevard is an east-west road (Figure 3). The west leg of this intersection is an entrance to a large parking lot. Both the north side and the south side crosswalks were controlled by push buttons. Each push button controlled both the north side and south side crosswalks. The signal controlling the east side crosswalk was on pedestrian recall. Unlike the other three crosswalks, the west side crosswalk was a ladder design, and was not controlled by a pedestrian signal. The north side crosswalk was the treatment site. It connected the parking lot to the University of Rochester medical complex. The south side crosswalk connects two parking lots.

Rochester, State and Corinthian (north side crosswalk)

This intersection is in downtown Rochester. State Street is a north-south arterial, and Corinthian Street is a very short east-west street that forms a T-intersection to the west (Figure 4). The east end of Corinthian is a municipal parking garage. The north side crosswalk is controlled by a push button. There was no pedestrian signal controlling the east side crosswalk. The south leg did not have a marked crosswalk. Traffic on State always had the green light unless there was a vehicle on Corinthian or unless a pedestrian pushed the button.

Figure 3. Crittenden and Lattimore (Rochester).

Figure 4. State and Corinthian (Rochester).

Phoenix, Central at Earll (south side crosswalk)

Central Avenue is a major arterial with seven lanes and an ADT of more than 38,000 (Figure 5). Earll Drive is a main driveway to Park Central Mall (west leg) and aligns with a local street on the east side of the intersection. The vehicle traffic on Earll is intermittent and the number of pedestrians crossing Central varies throughout the day. Since traffic volumes on Central are high for most of the day, fixed-time operation (which would provide a pedestrian Walk interval on every cycle, including times when pedestrians are not present) could cause substantial congestion.

Figure 5. Central and Earll (Phoenix).

RESULTS

The videotapes were watched, and the relevant pedestrian and motorist behaviors were recorded.

Pedestrians Who Began to Cross During the Steady Don't Walk

Because automated pedestrian detectors will call the Walk signal for pedestrians who do not push the button, most pedestrians will have the opportunity to start crossing on the Walk signal. Thus, it was thought that fewer pedestrians would begin to cross during the steady Don't Walk after automated pedestrian detectors were installed. Figure 6 shows the percentage of pedestrians who began to cross during the Don't Walk signal under three conditions: (1) push button only, (2) push button and microwave detector, and (3) push button and infrared detector.

At the Temple and San Pedro site in Los Angeles, both infrared and microwave detectors were

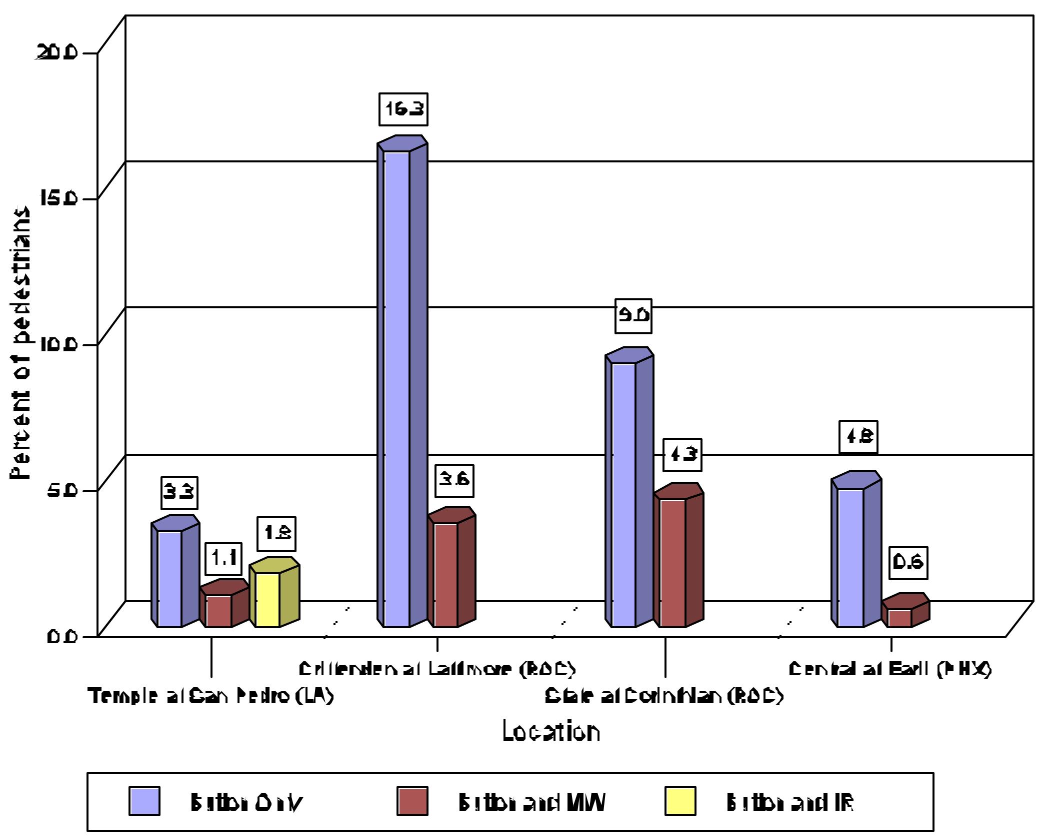

Figure 6. Pedestrians who started crossing when the pedestrian signal was steady Don't Walk and parallel traffic had the green.

evaluated. Both types of detectors, when used in conjunction with the push button, resulted in a significant reduction in the percentage of pedestrians beginning to cross during the Don't Walk signal (χ^2 = 6.019, df = 1, p = 0.014). Infrared and microwave detectors each produced results that were significantly different from the push button only condition (χ^2 = 6.586, df = 2, p = 0.037). The effectiveness of the infrared and microwave detectors did not differ from each other (χ^2 = 0.867, df = 1, p = 0.352).

In Rochester, at the Crittenden and Lattimore site, the use of the microwave detector together with the push button significantly reduced the number of pedestrians beginning to cross during the Don't Walk signal (χ^2 = 43.935, df = 1, p = 0.001). The same results were seen at the Central and Earll site in Phoenix (χ^2 = 11.317, df = 1, p = 0.001). A significant change was not, however, achieved with the microwave detector installed in Rochester at State and Corinthian (χ^2 = 0.036, df = 1, p = 0.849). The key point is that the automated detectors ensure that the Walk display will appear. Failure to use the push button means that the pedestrian crosses on a steady Don't Walk display, often without being assured of sufficient time to get across.

Thus, significant improvements in pedestrian compliance were achieved at three of the four study sites. The magnitude of these effects, while not large, is consistent with that obtained elsewhere (Catchpole, 1996).

With respect to the extended crossing time for pedestrians still in the crosswalk, the data show the following:

(1) Without automatic pedestrian detection or extension, 47 percent of pedestrians at Temple and San Pedro finished crossing during the steady Don't Walk signal while parallel traffic still had a green. With the extension capability operational, there was a significant increase (from 47 to 53 percent) in pedestrians who finished during the steady Don't Walk while parallel traffic still had a green (χ^2 = 5.496, df = 1, p = 0.0l9), even though fewer pedestrians *began* to cross during the same steady Don't Walk signal.

(2) The addition of the extension capability significantly reduced the percentage of pedestrians (from 16 percent to 7 percent) who *finished* crossing during a steady Don't Walk display after the signal for oncoming traffic had turned to green (χ^2 = 42.0l7, df = l, p = 0.00l).

Taken together, these data indicate that the extension capability was serving to increase protected time for pedestrians. More pedestrians were able to complete crossing during the (still protected) steady Don't Walk (parallel traffic green). Fewer pedestrians were still in the street during the unprotected Don't Walk (oncoming traffic green).

The Effects of Automated Detection on Pedestrian-Vehicle Conflicts

In this study, a conflict was defined as any pedestrian-motorist interaction in which either the pedestrian or the motorist stops or slows down so that the other can proceed. For example, all of the following situations were considered to be conflicts:

1. A motorist stops or swerves to avoid hitting a pedestrian.
2. A right-turning motorist slows or stops to let a pedestrian cross.
3. A pedestrian crossing against the signal stops halfway across the road to wait for a gap in opposing traffic.
4. Opposing traffic stops and waits for a pedestrian who is crossing against the signal.

Conflict data were collected at Temple and San Pedro in Los Angeles and at the two Rochester sites. The results of the conflict studies are shown in Figure 7.

For the Los Angeles site, the use of automatic pedestrian detectors in conjunction with the conventional push button significantly reduced vehicle-pedestrian conflicts (χ^2 = 33.533, df = 1, p = 0.001). There were no significant differences based on whether the infrared or microwave detector was

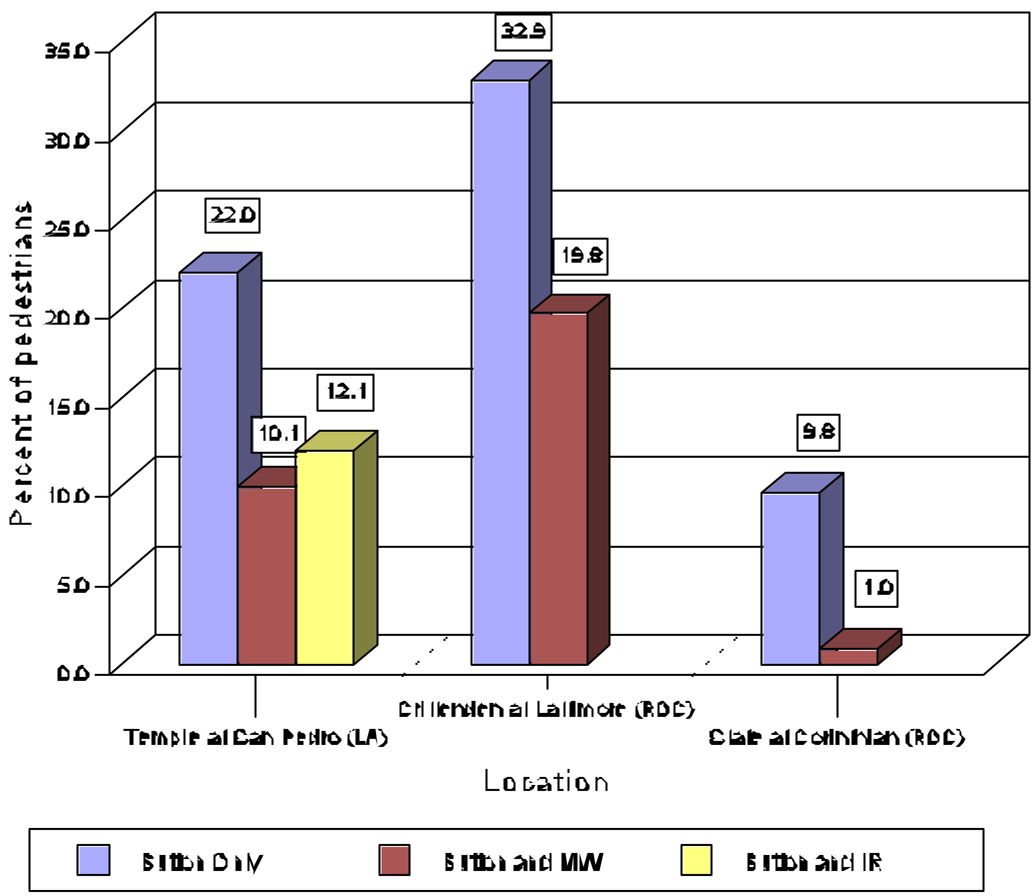

Figure 7. Pedestrians who experienced conflicts with motor vehicles.

used (χ^2 = 0.918, df = 1, p = 0.338). Similar effects were obtained with use of microwave detection at Crittenden and Lattimore in Rochester (χ^2 = 17.653, df = 1, p = 0.001) and at State and Corinthian (χ^2 = 16.311, df = 1, p = 0.001) in Rochester. Conflict data from the Phoenix site could not be analyzed because of visual limitations associated with the site.

Figure 8 shows the relationship between conflicts and the likelihood of pedestrians crossing during the Don't Walk phase. A linear relationship accounts for only about 20 percent of the variance (R^2 = 0.20). Note that the y-intercept of the function would lead one to predict that about 10 percent of all pedestrians would still encounter some form of conflict even if the percentage of pedestrians beginning to cross during the Don't Walk signal was reduced to zero.

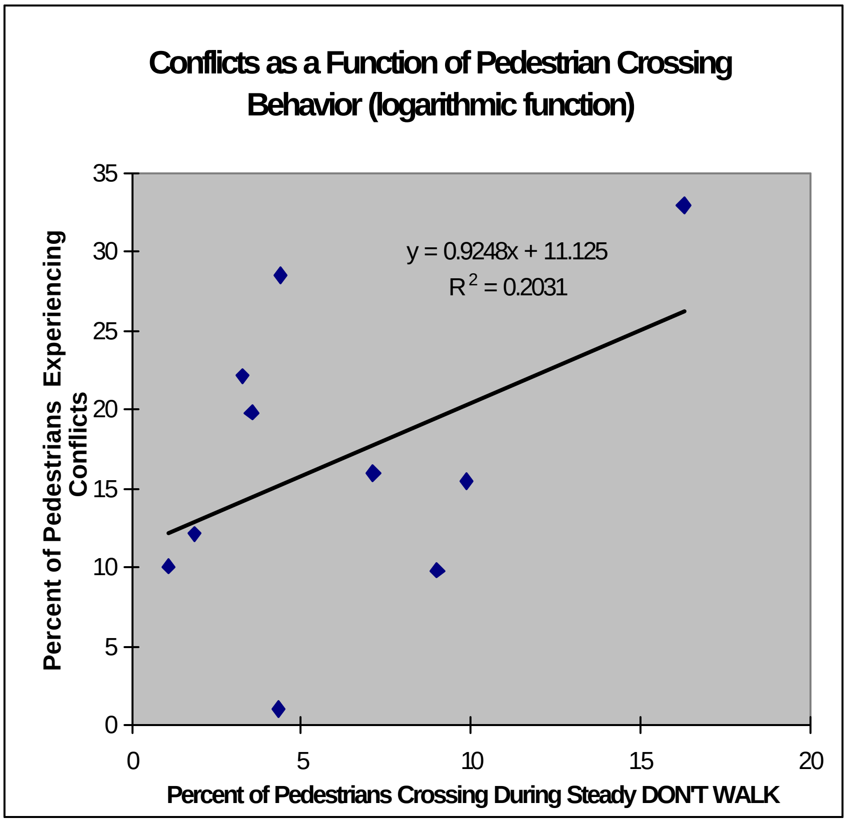

Figure 8. Pedestrian-vehicle conflicts as a function of the percentage of pedestrians crossing during the steady Don't Walk phase.

Logarithmic and exponential "fits" were found to offer no improvement over the simple linear function. While it was possible, for example, to account for almost twice the variance with a fourth-order polynomial, the process that might be responsible for producing such a complex relationship is not at all clear. More precise clarification of these relationships lies beyond the limited data provided by observations of these three sites. It is sufficient to say that as more pedestrians begin to cross during the

Don't Walk signal, more people will still be in the street when opposing traffic begins to move, and therefore more conflicts will occur. While conflicts from opposing traffic could be minimized by delaying the green for opposing traffic, conflicts from turning vehicles would still be present.

The most commonly observed pedestrian action was *running*, which occurred roughly 10 to 15 percent of the time at all sites. This occurred regardless of whether or not the push button was augmented with automatic detectors. Running can be a response to seeing the flashing or steady Don't Walk signal or to seeing the light for parallel traffic change to yellow. Pedestrians may run when they see traffic approaching from the left or right, or to get out of the path of a turning vehicle.

Accuracy of Microwave Sensors

The discussion above dealt with the effects of the automated detectors on pedestrian behavior and conflicts. This section discusses detector accuracy in Phoenix; Portland, Oregon; and Los Angeles.

The Phoenix Traffic Engineering Department tested the accuracy of the microwave sensors at Central and Earll. In this test, a red indicator light unobstrusively located on the signal pole illuminated when the sensor detected a pedestrian waiting to cross. This test was used to determine the number of false actuations and missed pedestrian calls. False actuations increase the delay to traffic on the main street by creating more stoppages and longer stoppages when there may be no vehicles on the side street nor any pedestrians waiting to cross the main street. Pedestrians who were missed by the automated detectors could, of course, still call the Walk signal by pressing the button.

The initial testing revealed that the sensors on occasion falsely detected slow-moving, right-turning vehicles next to the pedestrian detection zone. Some of the false actuations could not be explained by any actions within or near the detection zone. As recommended by the manufacturer, the system's antenna was rotated, and fewer false calls occurred afterwards. Heavy rain during the test period resulted in the sensor giving false calls on each cycle.

There were also a few missed calls during the testing period, but these were much fewer in number than the number of false actuations. The missed calls involved persons who were standing outside the detection zone. There were no instances of pedestrians standing within the detection zone for at least 4 s and not being detected.

After various adjustments were made to the sensors, they were activated with the pedestrian signal equipment for full evaluation. In general, while the sensors did not perform correctly in all cases, they had a positive effect upon pedestrian behavior. Experience, however, indicates that further fine-tuning of the equipment could result in additional benefits to pedestrians while minimizing adverse effects on motor vehicle flow.

Both microwave and infrared detectors were tested in Portland. The results showed that microwave detectors performed better than infrared detectors in terms of fewer false calls (1 percent vs. 4 percent). Microwave detectors were more likely to miss calls (7 percent vs. 1.5 percent for infrared). The detection zone was larger for the microwave [15 m (49 ft) in length and up to 6 m (20 ft) in width] than it was for the infrared [14 m (45 ft) in length and up to 1 m (3 ft) in width] (Beckwith and Hunter-Zaworski, 1998).

The City of Los Angeles tested microwave detectors at two locations, in rainy weather. The false call rate was 3.5 percent. Through traffic in the curb lane and right-turning vehicles triggered the false calls. The missed call rate was 1.5 percent. Pedestrians who crossed very close to the sensor pole accounted for the missed calls (Brian Gallagher, Los Angeles Department of Transportation, unpublished data).

More evaluations of this type are recommended to better understand the operational constraints of new technologies being applied for the first time in the pedestrian environment. A more extensive description of the testing in Phoenix is given in the Appendix.

DISCUSSION

The data provide evidence that the use of devices to automatically detect the presence of pedestrians at signalized crossings can improve the performance at conventional pedestrian push button locations. The data show that improvements can be expected in terms of:

❑ **A decrease in the likelihood that pedestrians will begin crossing during the steady Don’t Walk signal, which decreases the likelihood of encountering opposing traffic.**

The addition of automated pedestrian detectors to sites with existing pedestrian push buttons resulted in an overall 24 percent increase in the number of pedestrians who began to cross during the Walk signal (Figure 9). This was accompanied by an 81 percent decrease overall in the number of pedestrians who began to cross during the steady Don’t Walk signal. The number of sites upon which these results are based is small and, as the data have shown, pedestrian performance can vary widely across sites. The reader should therefore be cautious in extrapolating these results to other sites.

Automatic pedestrian detectors seem to derive their effectiveness *not* from their relationship to the pedestrian information that is displayed, since the information is identical to that provided when the push button is pressed. Instead, the improvement is in increasing the likelihood that a pedestrian will receive the Walk signal. Pedestrian detection (either by the push button being pressed or by automatic detection) is important in that it ensures that at least a minimum interval will be provided for the pedestrian to cross. A person who crosses without using the push button to “call” the Walk signal has no way of knowing the duration of the green time for parallel traffic, and therefore is at risk of having insufficient time to cross the street.

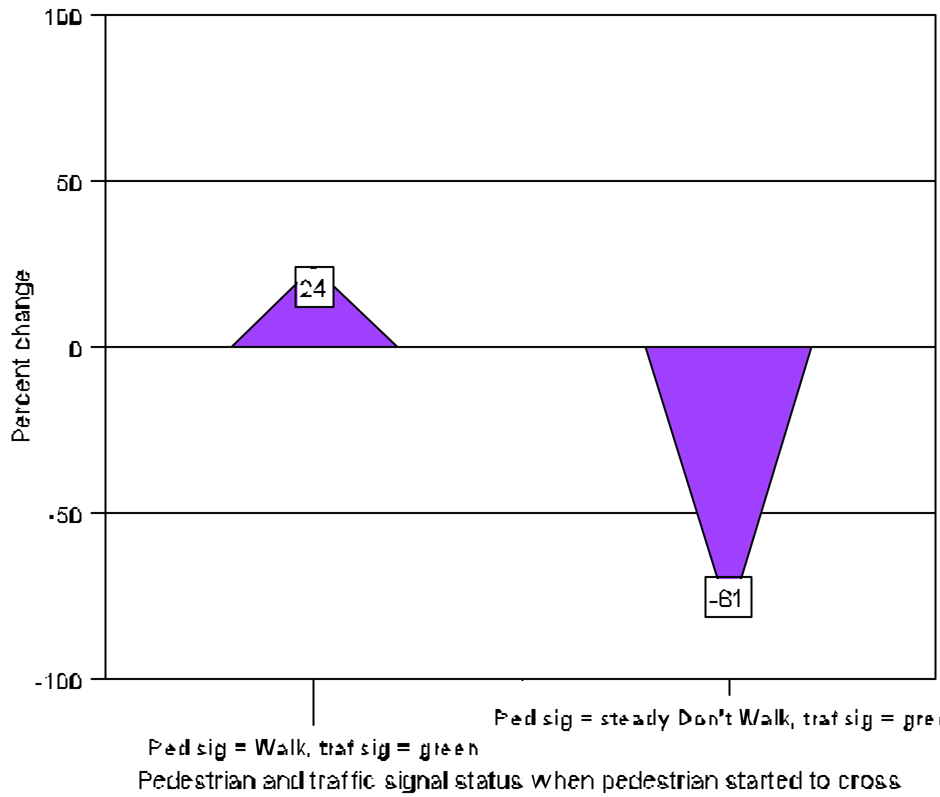

Figure 9. Change in when pedestrians started to cross after automated pedestrian detectors were added.

❑ **A decrease in the number of conflicts experienced by pedestrians while crossing**.

The addition of automatic detectors to sites using conventional pedestrian push buttons reduced vehicle-pedestrian conflicts (Figure 10). Conflicts encountered by pedestrians during the first half of their crossing were reduced by 89 percent, and conflicts during the second half by 42 percent. Conflicts associated with right-turning vehicles were reduced by 40 percent. “Other” types of conflicts were reduced by 76 percent.

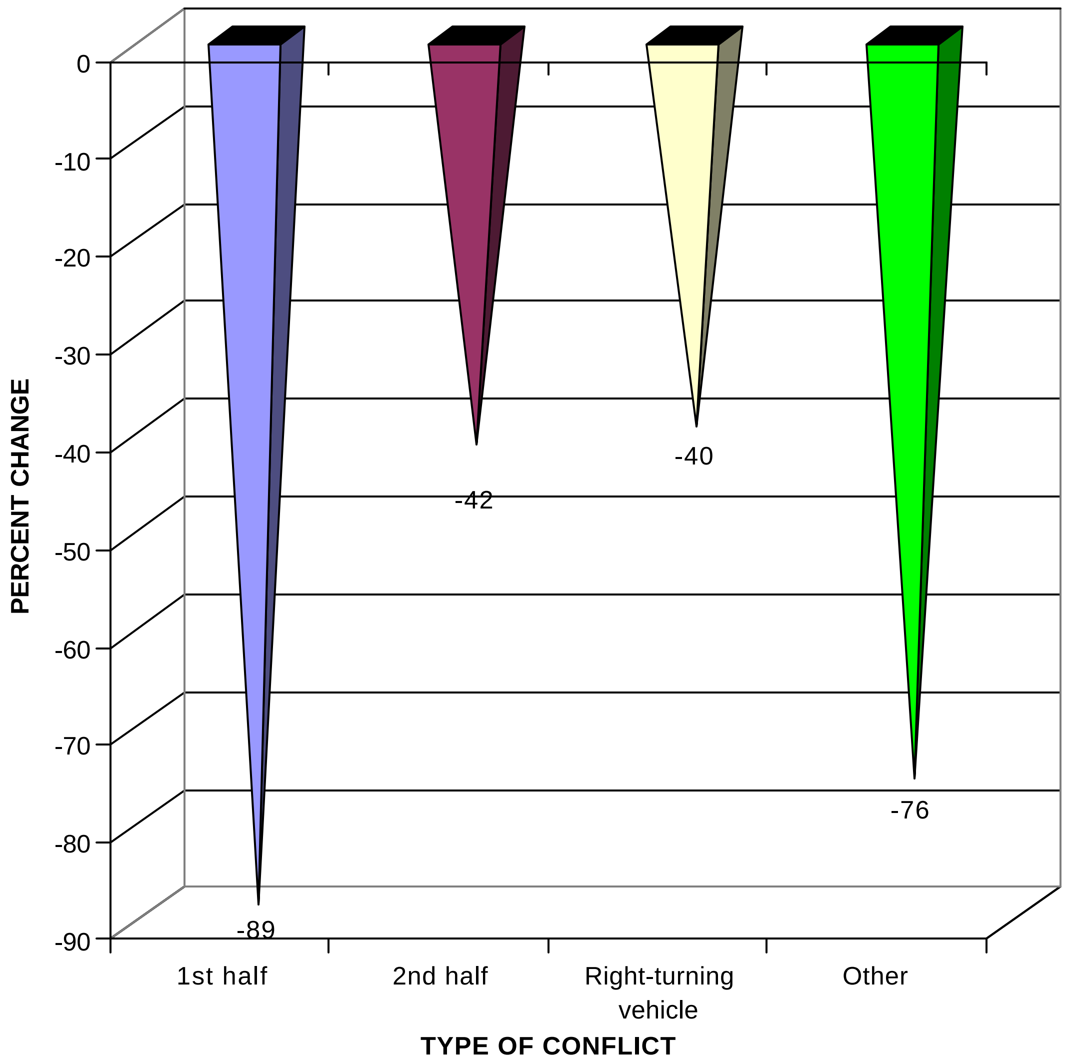

Figure 10. Change in pedestrian-motor vehicle conflicts by type after automated pedestrian detectors were added.

CONCLUSIONS

The present data suggest that automated pedestrian detectors can provide significant operational and safety benefits when installed in conjunction with conventional pedestrian push buttons at actuated traffic signals. The likelihood of fewer inappropriate crossings (during the steady Don't Walk signal) and fewer vehicle-pedestrian conflicts are expected to be correlated with improved pedestrian safety. It remains to be shown whether the benefits of automatic detection outweigh its cost. A task that remains is to correlate the reduction in inappropriate crossings and the reduction in conflicts with a reduction in pedestrian crashes and/or travel delays for both the pedestrian and the motorist. This additional information is needed to develop warrants for the most effective use of these new technologies.

It is expected that development and refinement of automatic pedestrian detectors will continue in the United States because of their potential benefits. Improvements are needed in detection accuracy to reduce the number of false alarms and missed calls at intersections. In the meantime, the sensors appear to be best suited for actuated signals at mid-block crossings where there is not a problem with right-turning vehicles producing false calls. It also appears best to have a buffer area separating the sidewalk and the street to reduce the number of false actuations from pedestrians walking along the sidewalk who do not intend to cross the street. Further research is also needed to test the effectiveness of automated detection systems without any push button calls.

None of the study sites were characterized by a complete absence of pedestrians crossing on a flashing or steady Don't Walk signal. This goes to show that neither the use of a push button nor the use of a push button in conjunction with automatic detection can ensure complete control over pedestrian crossing behavior. However, this study showed that the use of automatic detection can result in positive changes in pedestrian behavior during critical portions of the crossing sequence, and in so doing, will likely decrease the chance of a pedestrian-motor vehicle conflict.

As noted above, this study evaluated automated detectors at four intersections in three cities. The reader is advised that conditions specific to the study sites and / or the dates that videotaping was conducted could have affected the results. It is recommended that data be collected at a larger number of locations in the future as more of these devices are installed in U.S. cities. This will assist traffic engineers in better understanding the types of locations where automated detectors are best suited.

ACKNOWLEDGMENTS

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APPENDIX

Evaluation of the SMARTWALK 1400 Microwave Pedestrian Sensor in Phoenix, Arizona

The City of Phoenix tested a Smartwalk 1400 Pedestrian Sensor made by Microwave Sensors, Inc., in order to determine if it could be used to supplement or replace the traditional pedestrian push button to call the Walk signal.

Slightly more than half of the 850 traffic signals in Phoenix are equipped with pedestrian push buttons. Most of these are at intersections of arterial and collector or local streets outside of the downtown core. Intersections with pedestrian push buttons all have prominent signing at the intersection stating Push Button for Walk (with an arrow pointing in the direction of travel), and many have supplemental signs explaining the meaning of the Walk, flashing Don't Walk, and steady Don't Walk signal indications. All intersections have been checked to ensure that the pedestrian push buttons are conveniently located at the intersection and are accessible. Still, a relatively high proportion of pedestrians fail to use the push button before crossing.

Field testing was conducted at the intersection of Central and Earll Drive in central Phoenix. All pedestrians are required to cross Central Avenue on the south leg crosswalk. Pedestrians must use the push buttons on the southwest or southeast corners of the intersection to obtain a Walk signal and enough time to cross Central Avenue. Without pedestrian actuation, pedestrians will usually not have enough time to cross Central Avenue. The pedestrian detector was installed at the southwest corner of Central Avenue and Earll Drive to detect eastbound pedestrians waiting to cross Central Avenue. The detector was set up to supplement the pedestrian push button at the corner.

Instead of hooking up the sensor directly to the traffic signal, it was connected to a red indicator light that revealed when it was "activated" by a pedestrian waiting to cross Central Avenue. Dots were lightly painted on the sidewalk to outline the edges of the detection zone. This allowed an observer to determine if a pedestrian entered the detection zone. Signal engineers decided to use a 4-s delay to detect a pedestrian waiting to cross. It was thought that a 4-s delay was optimal since people walking across the detection zone have enough time to clear the zone without actuating the sensor.

The first problem encountered with the microwave sensor was that it would "detect" slow-moving cars making a right turn outside the pedestrian detection zone and cause an activation. This was a "false call." To limit the number of false calls, the edge of the detection zone was moved back to about 76 cm (30 in) behind the curb. Despite moving the detection zone back from the street, some slow-moving, right-turn vehicles (usually Right Turn on Red vehicles) were still creating some false activations. Furthermore, with a 76-cm (30-in) setback between the curb and detection zone, an eastbound pedestrian waiting to cross Central Avenue can walk through the detection zone and then stand at the curb without causing the microwave sensor to be activated.

Another hurdle was that some pedestrians would intentionally stand in the shade near the traffic signal while waiting to cross, and would be outside the pedestrian detection zone. This is especially true during the hot summer months when pedestrians are looking for any possible relief from the direct sunlight. Because these "shade areas" vary by the time of day, it would be difficult to target any specific area to include in the detection zone. Because of this problem, it was felt that the microwave sensor may not be a complete replacement for the pedestrian push button, but there is still considerable potential for its use as a supplement to the push button.

During preliminary observation, yet another limitation was observed: the microwave motion sensor cannot detect which direction a pedestrian is traveling. The goal is to only detect eastbound pedestrians waiting to cross, and not westbound pedestrians who had already crossed, nor northbound/southbound pedestrians who were walking along the sidewalk through the detection zone. Thus, it is important that the delay be long enough to exclude these other pedestrians walking at the corner and target the population of eastbound pedestrians. Yet, long delay times may cause the sensor to not detect some pedestrians wanting to cross.

The microwave sensor worked very well if a single pedestrian or small group of pedestrians were walking north, south, or westbound through the detection zone. They generally would not activate the sensor. However, if two or more pedestrians occupied any portion of the zone for the 4-s delay interval in any direction, a call would be sent to the signal, indicating another source of false calls.

The sensor was installed in August 1998. Manual observations of the microwave sensor activation were conducted in September and October 1998. An observer would discreetly stand near the southwest corner in a position where they could observe if the red indicator light activated, and if a pedestrian was standing in the detection zone. Eight hours and 25 minutes of manual observations were gathered. A proper detection was recorded if one or more pedestrians waiting to cross Central Avenue (eastbound) stood withing the detection zone for at least 4 s, and the indicator light revealed an activation. A false call was recorded if the indicator light appeared, which was caused by one or more other or incorrect types of activations (right-turning vehicles, westbound pedestrians, north/south pedestrians, and other problems). Missed calls were counted when one or more eastbound pedestrians were waiting to cross (for at least 4 s) but no activations occurred. A summary of the results is shown below:

- Proper pedestrian detection and activation = 194
- False calls = 182
- Missed calls = 27

A proper pedestrian detection may result from a single pedestrian or a group of pedestrians waiting to cross. More than one activation could be recorded during a given cycle. If a pedestrian crossed eastbound against the signal or during the Walk signal and did not wait at least 4 s before crossing, that observation was discounted.

Most of the missed calls involved eastbound pedestrians standing between the curb and the detection zone who had walked through the detection zone in less than 4 s. Thus it is important that the detection be as close to the edge of the street as possible. A few missed calls involved pedestrians standing outside the detection zone in other areas. There were no instances of pedestrians standing within the detection zone for at least 4 s and not being detected.

The number of false calls was also a concern. On some occasions, it was difficult for the observer to explain exactly what action may have caused a false call, and a few of the false calls could not be explained by any action occurring within or near the detection zone. About 25 of the false calls occurred because of right turns or the presence of buses/large trucks in the curb lane. When city officials contacted the manufacturer's technical expert, they were asked to send a photograph of the installation to see if he could determine a reason why these problems were occurring. He noted that the microwave sensor was not properly mounted with the respect to the position of the antenna and recommended rotating the sensor so that the antenna was on the side of the sensor, and not on the top of the microwave sensor.

The rotation of the antenna reduced the number of false calls for right-turning cars and allowed the placement of the detection zone closer to the intersection. The detection zone was moved to about 46 cm (18 in) from the back of the curb, which would also reduce the number of missed calls. A sufficient number of manual observations was not obtained with the revised sensor installation because the test period ended and the sensor equipment had to be returned. However, during 30 minutes of observation, there were 15 proper detections observed, 13 false calls, and 3 missed calls from pedestrians waiting on the curb. Three of the false calls were caused by right-turning vehicles.

The sensor's performance was also observed during a steady downpour—the sensor produced continuous calls for actuation despite there being no pedestrians present. The manufacturer's technical expert claimed that this should not occur during a light rain, but the manufacturer has not been able to eliminate the problem of continuous calls during a heavy rain.

The manufacturer reported that the sensor installation and antenna are being modified to further reduce the number of false calls resulting from right-turning vehicles at the corner. Further testing also needs to be conducted on the optimal delay time before a detection can occur. This optimal delay time may vary based on the cycle length and the number of pedestrians who are crossing.

At the present time, the sensor appears to be better suited for actuated signals at mid-block crossings where there is not a problem of right-turning vehicles that may produce a false call. It is also best to have a buffer area (separation) between the sidewalk and the street so that pedestrians walking along the sidewalk do not produce false calls.

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