The Effects of Innovative Pedestrian Signs at Unsignalized Locations: A Tale of Three Treatments

REPORT NO. FHWA-RD-00-098

August 2000

U.S. Department of Transportation
Federal Highway Administration
Research and Development
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

Pedestrian & Bicycle Safety

FOREWORD

The vision of the 1988 Federal Highway Administration National Strategic Plan is to create the best transportation system in the world; a transportation system that is safe, efficient, and intermodal, allowing all Americans to have access within and beyond their communities. Among other things, this transportation system will significantly reduce crashes, delays, and congestion; protect ecosystems and air quality; and accommodate pedestrians and bicyclists.

Reducing pedestrian and bicycle crashes requires knowledge of the activities leading to such events. Computerized State crash files often do not contain the level of detail necessary to determine the contributing factors for which countermeasures could then be selected. The Pedestrian and Bicycle Crash Analysis Tool (**PBCAT**) is a software product intended to assist practitioners with improving walking and bicycling safety through the development and analysis of a database containing details associated with crashes between motor vehicles and pedestrians or bicyclists, including the *crash type* which describes the pre-crash actions of the parties involved.

This product should be of interest to State and local bicycle coordinators, planners, transportation engineers, highway safety researchers, health and safety officials, and others involved in enhancing pedestrian and bicyclist safety.

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Michael F. Trentacoste, Director
Office of Safety Research and Development

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-00-098		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
THE EFFECTS OF INNOVATIVE PEDESTRIAN SIGNS AT UNSIGNALIZED LOCATIONS: A TALE OF THREE TREATMENTS	5. Report Date: August 2000 6. Performing Organization Code:
7. Author(s) Herman Huang, Charles Zegeer, Richard Nassi, and Barry Fairfax	**8. Performing Organization Report No.**
9. Performing Organization Name and Address Highway Safety Research Center, University of North Carolina, 730 Airport Rd, Bolin Creek Ctr., Chapel Hill, NC 27599-3430 City of Tucson, Department of Transport., P.O. Box 27210, Tucson, AZ 85726	**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-92-C-00138
12. Sponsoring Agency Name and Address Federal Highway Administration Turner-Fairbank Highway Research Center 6300 Georgetown Pike McLean, VA 22101-2296	**13. Type of Report and Period Covered** Research Report July 1, 1996 - October 31, 1999 **14. Sponsoring Agency Code**

15. Supplementary Notes

Contracting Officer's Technical Representative (COTR): Carol Tan Esse, HSR-20

16. Abstract

A variety of advisory and regulatory signs are used in conjunction with marked crosswalks to improve their visibility and increase the likelihood that motorists will yield to pedestrians. This paper evaluates three such devices: (1) an overhead CROSSWALK sign in Seattle, Washington; (2) pedestrian safety cones (with the message, "STATE LAW - YIELD TO PEDESTRIANS IN CROSSWALK IN YOUR HALF OF ROAD") in New York State and Portland, Oregon; and (3) pedestrian-activated "STOP FOR PEDESTRIAN IN CROSSWALK" overhead signs in Tucson, Arizona. The signs were used under different traffic and roadway conditions.

The New York cones and Seattle signs were effective in increasing the number of pedestrians who had the benefit of motorists stopping for them. At one location in Tucson, the overhead sign resulted in increased motorists yielding to pedestrians. The signs in Seattle and Tucson were effective in reducing the number of pedestrians who had to run, hesitate, or abort their crossing. None of the treatments had a clear effect on whether people crossed in the crosswalk.

These devices by themselves cannot ensure that motorists will slow down and yield to pedestrians. It is essential to use these devices together with education and enforcement. Traffic engineers can use other measures as well, including designing "friendlier" pedestrian environments at the outset.

17. Key Words	18. Distribution Statement
crosswalks, pedestrians, motorists, behavior, signs	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	31	

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

INTRODUCTION

Crossing streets at uncontrolled (i.e., no traffic signal or STOP sign) locations can pose a serious risk to pedestrians. Pedestrians who cross at midblock account for as much as 26 percent of all motor vehicle-pedestrian crashes, according to a 1996 review of 5,000 pedestrian crash reports from six different states. That study found that another 32 percent of motor vehicle-pedestrian crashes were intersection-related. Ninety-three percent of the midblock crashes and 40 percent of the intersection crashes occurred at uncontrolled locations (Hunter et al., 1996).

Local agencies may or may not paint crosswalks at uncontrolled locations on the basis of average daily traffic, pedestrian volumes, and other warrants. However, even if a crosswalk has been painted across the roadway, the driver may not notice the crosswalk markings, even if the markings are in good condition and crosswalk signing is in place. Adequate gaps may be relatively infrequent on wide streets where vehicle volumes and speeds are high. In addition, the driver may not physically see the pedestrian because the pedestrian is obscured by parked vehicles along the curb, by a vehicle in another lane that has stopped to allow the pedestrian to cross, or perhaps by other visual obstructions. At night, crosswalks and pedestrians can be extremely difficult for motorists to see in time to stop.

Moreover, many drivers do not stop or slow down for pedestrians in crosswalks, even when they are legally required to do so. For example, Section 11-502a of the *Uniform Vehicle Code* states that "when traffic-control signals are not in place or not in operation the driver of a vehicle shall yield the right of way, slowing down or stopping if need be to so yield, to a pedestrian crossing the roadway within a crosswalk when the pedestrian is upon the half of the roadway upon which the vehicle is traveling, or when the pedestrian is approaching so closely from the opposite half of the roadway as to be in danger." (Uniform Vehicle Code, 1992)

To make crosswalks more visible and/or to increase motorist yielding, some local agencies use high-visibility crosswalks and various types of signs to supplement the crosswalk marking. Some cities are experimenting with innovative signs and markings. For example, in Seattle and Tucson, the city traffic engineer has the authority to test innovative traffic control devices.

The first section of this paper summarizes past research for special pedestrian-related signs and devices at uncontrolled crossing locations. The report then provides findings on the effects of an overhead crosswalk sign in Seattle, Washington; seven sites with pedestrian safety cones in New York State and Portland, Oregon; and three pedestrian-activated overhead signs in Tucson, Arizona. The research reported in this paper is part of a national-level research effort to evaluate the operational and safety effects of various pedestrian treatments: crosswalks, sidewalks, traffic calming, automated pedestrian detection, countdown pedestrian signals, and illuminated pedestrian push buttons.

PAST RESEARCH AND PRACTICE

Many different types of signs and crosswalk markings have been used by State and local agencies at uncontrolled crossing locations. Variations of crosswalk markings include parallel lines, ladder, continental style, zebra, and crosswalks painted completely in white.

Zebra crossings in Sweden consist of high-visibility crosswalk markings on the roadway (Figure 1). These are accompanied by zebra crossing signs (Figure 2) to alert motorists, much the same way that the pedestrian crossing sign (W11A-2 in the MUTCD, 1988) is used in the United States. Only 27 percent of drivers approaching a nonsignalized zebra crossing in Lund, Sweden, slowed down to avoid hitting a pedestrian, whereas 57 percent of drivers kept the same speed. Another 16 percent accelerated (Várhelyi, 1996).

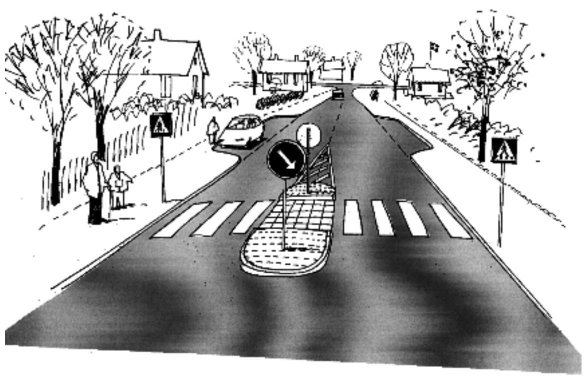

Figure 1. A zebra crossing used in Sweden.

Figure 2. Sign accompanying zebra crossings in Sweden.

The pedestrian-motor vehicle accident rate at zebra crossings (all unsignalized) in five Swedish cities was twice as high as the rate at unsignalized, unmarked crossings. These results were attributed to pedestrians' experiencing a false sense of safety at zebra crossings (Ekman, 1988). The pedestrian conflict rate was also about twice as high at zebra crossings compared to unmarked crossings (Ekman, 1996). Drawing upon past experience as a guide, the Swedish National Road Administration is now developing new guidelines for zebra crossings.

Cities in the United States use a variety of overhead and side-mounted signs to draw motorists' attention to crosswalks (Figure 3). The signs may be, for example, the W11A-2 pedestrian crossing sign as described in the *Manual on Uniform Traffic Control Devices* (1988), or they may be internally illuminated overhead signs. Moreover, the signs may be accompanied by flashing beacons.

Figure 3. Cities in the United States and Canada use a variety of signs to draw motorists' attention to crosswalks.

Several nonsignalized intersections in Clearwater, Florida, have internally illuminated overhead crosswalk signs coupled with high-visibility crosswalk markings (Figure 3, middle). Daytime drivers were 30 to 40 percent more likely to yield to pedestrians at the locations with the devices, compared with locations without the devices. Nighttime drivers at the experimental locations were 8 percent more likely to yield. Pedestrians crossing at the experimental locations were more likely to use the crosswalk than those crossing at the control locations. The devices did not have an effect on the following: (1) whether pedestrians looked before crossing; (2) incidence of pedestrians forcing the right of way; (3) the number of pedestrians who ran across the road; and (4) occurrence of pedestrian/vehicle conflicts (Nitzburg and Knoblauch, 1999).

Toronto, Ontario, Canada has hundreds of “pedestrian crossovers” at midblock crossings. These consist of internally illuminated overhead signs (with an “X” symbol) and beacons that flash when activated by a push button (Figure 3, bottom).

A similar device, consisting of an overhead flashing beacon used in conjunction with either a STOP WHEN FLASHING sign, an overhead sign with the pedestrian symbol, or with both signs, was evaluated (Van Houten et al., 1998). Only the STOP WHEN FLASHING sign reduced motor vehicle-pedestrian conflicts. The sign and the pedestrian symbol were both effective in increasing driver yielding when the beacons had been activated, and the combination of the sign and the symbol was even more effective (Van Houten et al., 1998).

Illuminated crosswalk signs at 20 locations in Tokyo, Japan, did not seem to be effective in reducing crashes. In fact, crossing-related crashes within 200 m (656 ft) of where the signs were installed increased by 4.8 percent after the signs were installed (Accident Prevention Effects, 1969).

On multilane roads, advance stop lines can be used to encourage motorists to stop farther back from a crosswalk. When motorists stop too close to a crosswalk, their vehicles block the view of pedestrians to drivers in adjacent lanes, and a multiple-threat pedestrian crash could result. When motorists stop farther back, sight distances improve between pedestrians and drivers in adjacent lanes, allowing them a better opportunity to avoid a crash. Van Houten and Malenfant (1992) found that the use of a sign reading “STOP HERE FOR PEDESTRIANS” in conjunction with an advance stop line reduced motor vehicle-pedestrian conflicts by 90 percent.

Advance pavement markings are used at some multilane zebra crossings in Stockholm, Sweden, with the intent of improving sight distances by encouraging motorists to stop farther upstream for pedestrians. However, these markings did not have a significant effect on increasing the percentage of motorists who stopped 4 meters upstream from the crosswalk, and there was no change in the number of serious conflicts (Towliat and Ekman, 1997).

As mentioned above, crosswalks and pedestrians can be difficult for motorists to see at night. Crosswalk lighting and flashing crosswalks can help enhance motorists’ nighttime visibility of pedestrians. With improved lighting at seven sites in Philadelphia, drivers appeared to be more aware that they were approaching a crosswalk and the researchers perceived pedestrians’ clothing to be more visible (Freedman et al., 1975). An Australian study found that floodlighting of pedestrian crossings, using sodium lamps, resulted in a significant decrease in nighttime pedestrian accidents (Pegrum, 1972). A combined illumination and signing system was tested at crosswalks in Israel (Polus and Katz, 1978). The results showed that nighttime

Figure 4. Flashing crosswalk in Orlando, Florida.

pedestrian accidents decreased by 43 percent at illuminated sites and increased by 60 percent at nonilluminated control sites.

Flashing crosswalks can alert motorists to pedestrians in a crosswalk, especially at night. Orlando, Florida, Santa Rosa, California, and Kirkland, Washington are among the cities that are currently using in-pavement types of flashing crosswalk displays. These consist of lights ("flashers") embedded in the roadway on both sides of the crosswalk (Figure 4). When activated, the lights flash at oncoming motorists, thereby alerting them to one or more pedestrians in the crosswalk. Both push-button and automated detection systems have been used to activate the flashers.

These flashing crosswalks have been found to increase the percentage of motorists who yield to pedestrians. Conflicts between motor vehicles and pedestrians were less likely when pedestrians crossed in the flashing crosswalk than when they crossed somewhere else. The effectiveness of the flashing crosswalk was also found to depend upon the amount of parking activity in the area, the amount of pedestrian activity on the sidewalks near the crosswalk, traffic volume, and the length of time that the lights flash (Whitlock & Weinberger Transportation, 1995 and 1998; Huang et al., 1999).

In summary, a wide variety of treatments have been used in the United States and other countries, with the intent of enhancing pedestrian safety at unsignalized crossing locations. Some devices were found to be beneficial. Other devices had little effect or were potentially harmful. The reader is advised that pedestrian volumes, motor vehicle volumes and speeds, roadway widths, adjacent land uses, and local driving culture can all influence the effects of treatments on pedestrian safety.

DEVICES EVALUATED IN THIS STUDY

As summarized in the preceding section, several treatments have been used in the United States and other countries with the intent of enhancing pedestrian safety at unsignalized crossing locations. This report describes the evaluation of innovative signs that direct approaching motorists to stop for pedestrians (New York and Tucson signs), or to be alert for pedestrians in a crosswalk (Seattle CROSSWALK sign). These devices are described below.

New York Pedestrian Safety Cones

In 1996, the New York State Department of Transportation developed a pedestrian safety cone that could be placed in the middle of the crosswalk (Figure 5). This device consists of a traffic cone, fitted with a safety orange, retroreflective “jacket” bearing the sign, “STATE LAW -- YIELD TO PEDESTRIANS IN YOUR HALF OF ROAD. The YIELD sign itself is 46 cm high by 30 cm wide (18 in by 12 in). The cone is about 0.9 m (3 ft) high. The intent of the pedestrian safety cone is to remind motorists to yield or stop for pedestrians.

Previously, some communities had installed signs on metal posts. These devices could potentially cause damage or personal injury if struck. Furthermore, the text on these signs was often misleading and unenforceable, because New York State law requires motorists to yield only to pedestrians who are in the same lane as the motorist (Olson, 1998). The pedestrian safety cone does not have the drawbacks of the older devices.

Figure 5. New York State pedestrian safety cone.

The cones are considered supplementary devices and should be installed in addition to any other necessary signs and pavement markings. The cones are to be used at marked, and signed (with YIELD TO PEDESTRIANS or pedestrian crossing sign) unsignalized intersection and midblock locations. They are not to be used at signalized intersections, nor where they will adversely affect motor vehicle turning radii. The cones should not be placed where speed limits exceed 48 km/h (30 mi/h) (Olson, 1998).

Pedestrian safety cones are a low-cost (about $150 each), easily implemented, and effective treatment. These devices are made of flexible material that makes them “forgiving” if struck by a vehicle, so that they do not damage the vehicle or become dangerous projectiles to pedestrians. They can be removed for snow removal or other maintenance purposes (Olson, 1998).

In this study, pedestrian safety cones were evaluated in Albany, Ballston Spa, Port Jefferson, Schenectady, Troy, all in New York State. One installation in Portland, Oregon, was also evaluated. The cones are also in use in other parts of New York, as well as New Jersey and Pennsylvania.

Tucson Overhead Pedestrian Regulatory Signs

The City of Tucson uses an extensive number of zebra crossings with advance warning signs and supplemental crosswalk signs. At locations where few drivers stop for pedestrians, pedestrian-activated flashing amber beacons are installed, similar in concept to the pedestrian crossovers used in Toronto. These do not always result in adequate safety for crossing pedestrians. However, Tucson’s flashing yellow beacon does not give a clear message to motorists that they should stop for pedestrians who are waiting to cross the street. The flashing beacons have not been found by city officials to have any clear beneficial impact on approaching drivers. In fact, at one of the school crossing locations, seven student pedestrians had been struck by motor vehicles in the previous five-year period.

Several locations were identified in the city of Tucson as needing added protection for pedestrians but they did not meet the MUTCD’s signal warrant. Installing full traffic signalization was not thought to be desirable for pedestrian protection, and was also thought to potentially increase total vehicle crashes. Moreover, some drivers do not always stop at traffic signals on a red phase, so even full signals do not properly protect pedestrians from drivers running red lights. Some drivers who do not stop at such sites may be unaware of the presence of pedestrians and/or may have a fear of being rear-ended by the high-speed traffic if they stop for pedestrians.

The city traffic engineer developed the concept of an overhead regulatory sign with the message “STOP FOR PEDESTRIAN IN CROSSWALK.” (Figure 6) This sign is considered to be an additional tool to supplement crosswalk laws when signalization is not an option. The device consists of overhead and side-mounted 1.2-m by 1.2-m (4-ft by 4-ft) fiber optic signs that are activated by a pedestrian push button. The message "STOP FOR PEDESTRIAN IN CROSSWALK" starts to flash immediately after the button is pushed. The flashing time at most sites was set based on the crossing distance divided by 1.2 m (4 ft) per second, plus 5 seconds. A slower walking speed was used at sites where elderly or impaired pedestrians regularly use the crossing. Each time the button is pushed, the flashers immediately begin to flash for another crossing interval.

Figure 6. Pedestrian regulatory sign, Tucson, Arizona.

The Tucson signs are installed on multilane highways with speed limits of 64 km/h (40 mi/h) or less, where there is pedestrian activity crossing the street, where motorists are not yielding to pedestrians, and where pedestrians are having difficulty in crossing. Most of the overhead regulatory signs are currently at high school crossing locations, which are not covered in the state code for 25-km/h (15-mi/h) school zone crossings.

Seattle Crosswalk Sign

The sign evaluated in Seattle consists of the word "CROSSWALK" in black letters on a yellow background (Figure 7). As of April 1999, the City of Seattle had installed a total of 182 overhead crosswalk signs. About four new ones are added each year. Some are accompanied by overhead flashing beacons and some are internally illuminated. Overhead crosswalk signs are used at midblock marked crosswalks where street width, parked vehicles, street trees, curves, or hills restrict motorists' view of the crossing. The signs are intended to alert motorists that there is a crosswalk. They do not direct motorists to stop for pedestrians (as do the signs in New York, Portland, and Tucson).

The signs have been well received by the community and will continue to be installed by the City at appropriate locations. The overhead CROSSWALK signs are always "there," instead

Figure 7. Overhead CROSSWALK sign in Seattle.

of being pedestrian-activated as are Tucson's signs. Hence, there is the possibility that the CROSSWALK signs will blend into the background and lose their effectiveness. Additionally, their benefit is recognized as being limited unless they are combined with other traffic controls and/or geometric enhancements.

DATA COLLECTION

Table 1 lists the treatments, study locations, number of travel lanes, and on-street parking status. All streets are two-way unless otherwise noted. The sites were all in urban locations. In general, traffic appeared to move more slowly at the New York and Seattle sites than at the Tucson sites. Ballston Spa, Port Jefferson, and Saratoga Springs all attract many summer vacationers, so many of the observed pedestrians and motorists were tourists.

Data were collected “before” and “after” the installation of the device at each location. All data were collected during daylight hours, when it was not raining or snowing. The data collection schedule depended heavily on the availability of personnel. For the pedestrian safety cones, the after data were usually collected within a month after installation. In Tucson and Seattle, the after data were collected about 2 to 4 months following installation.

A video camera was used to collect data at all locations. The video camera was set up on the sidewalk, approximately 61 m (200 ft) upstream from each crossing location. The camera faced in the same direction as traffic on that half of the roadway. This position allowed the camera to record, on videotape, pedestrians in the crosswalk and in the queuing areas on either side of the roadway. The camera also recorded whether approaching motorists stopped or slowed down for pedestrians. The videotapes were subsequently watched, and pedestrian and motorist behaviors were coded for use in analysis. Table 2 shows the number of hours of data collection and the total number of pedestrians recorded at each location.

Table 1. Characteristics of Study Locations.

TREATMENT	CITY AND LOCATION M = MIDBLOCK I = INTERSECTION	NUMBER OF LANES	SPEED LIMIT	ADT	ON-STREET PARKING
Overhead crosswalk sign	SEATTLE Western Ave at Bell St (I)	One-way street 2 lanes (Figure 8)	48 km/h (30 mi/h)	6,800	2 sides
Pedestrian safety cone	ALBANY Pearl St at Steuben St (I)	2 + two-way left-turn lane	48 km/h (30 mi/h)	9,000	2 sides
Pedestrian safety cone	BALLSTON SPA Milton Ave at Van Buren St (I)	2	48 km/h (30 mi/h)	15,500	2 sides
Pedestrian safety cone	PORT JEFFERSON Main St at Arden Pl (I)	2			2 sides
Pedestrian safety cone	SARATOGA SPRINGS Route 9 at Caroline St (I)	4	48 km/h (30 mi/h)	13,500	2 sides
Pedestrian safety cone	SCHENECTADY State St between Furman St and Division St (M)	2	48 km/h (30 mi/h)	14,000	2 sides
Pedestrian safety cone	TROY 15th St at RPI Union (M)	2	48 km/h (30 mi/h)	7,200	2 sides
Pedestrian safety cone	PORTLAND SE Division St at SE 30th Ave (I)	2	40 km/h (25 mi/h)	13,700	2 sides
Pedestrian regulatory sign	TUCSON Euclid Ave at 7th St (I)	4 + refuge island	48 km/h (30 mi/h)	22,000	No
Pedestrian regulatory sign	TUCSON St. Mary's Rd at Melrose Ave (I)	4 + two-way left-turn lane	56 km/h (35 mi/h)	32,100	No
Pedestrian regulatory sign	TUCSON Speedway Blvd at Plumer Ave (I)	6 + refuge island	64 km/h (40 mi/h)	61,700	No

Table 2. Sample Sizes and Hours of Data Collection at Each Study Location.

TREATMENT	CITY AND LOCATION M = MIDBLOCK I = INTERSECTION	TOTAL SAMPLE SIZE		HOURS OF DATA COLLECTION	
		BEFORE	AFTER	BEFORE	AFTER
Overhead crosswalk sign	SEATTLE, WA Western Ave at Bell St (I)	665	646	5 h 50 m	6 h 00 m
Pedestrian safety cone	ALBANY, NY Pearl St at Steuben St (I)	624	528	4 h 00 m	4 h 00 m
Pedestrian safety cone	BALLSTON SPA, NY Milton Ave at Van Buren St (I)	184	217	6 h 00 m	4 h 00 m
Pedestrian safety cone	PORT JEFFERSON, NY Main St at Arden Pl (I)	794	307	2 h 00 m	2 h 00 m
Pedestrian safety cone	SARATOGA SPRINGS, NY Route 9 at Caroline St (I)	514	146	2 h 00 m	2 h 00 m
Pedestrian safety cone	SCHENECTADY, NY State St between Furman St and Division St (M)	90	48	6 h 00 m	2 h 00 m
Pedestrian safety cone	TROY, NY 15th St at RPI Union (M)	549	548	2 h 00 m	2 h 00 m
Pedestrian safety cone	PORTLAND, OR SE Division St at SE 30th Ave (I)	66	323	2 h 00 m	6 h 00 m
Pedestrian regulatory sign	TUCSON, AZ Euclid Ave at 7th St (I)	311	293	3 h 05 m	3 h 30 m
Pedestrian regulatory sign	TUCSON, AZ St. Mary’s Rd at Melrose Ave (I)	58	80	4 h 50 m	5 h 45 m
Pedestrian regulatory sign	TUCSON, AZ Speedway Blvd at Plumer Ave (I)	59	67	5 h 20 m	8 h 00 m

RESULTS

Each treatment was evaluated according to four measures of effectiveness (MOEs).

1. Pedestrians for whom motorists yielded
2. Motorists who yielded to pedestrians
3. Pedestrians who ran, aborted, or hesitated
4. Pedestrians who crossed in the crosswalk

These MOEs were selected because they were thought to be the most closely correlated with the potential for reducing pedestrian crash risk. The results for the four MOEs are described in more detail in the following sections. The reader is advised that sample sizes vary even at the same location, because of daily fluctuations in pedestrian activity and because of the way that the MOEs were defined. For some observations, individual data items were not recorded, and these observations were not included in the analysis.

Pedestrians for Whom Motorists Yielded

Crosswalk signs are intended to alert motorists to the presence of pedestrians, especially at locations where motorists may not expect to see pedestrians. Therefore, it was hypothesized that each of the treatments would increase the likelihood that a pedestrian would have the benefit of a motorist yielding to him or her.

The chi-square statistic was used to compare the percentages of pedestrians for whom motorists yielded in the before and after periods (Table 3). This analysis included only pedestrians who crossed when motorists were approaching. The reader is reminded that the pedestrian was the unit of analysis. For example, if a total of 100 pedestrians crossed when vehicles were approaching, and motorists yielded to 50 pedestrians, then the percentage of pedestrians for whom motorists yielded is equal to 50 percent. It does not matter whether the 50 pedestrians crossed as one large group (with one motorist yielding), several smaller groups (with several motorists yielding), or one by one (with 50 motorists yielding).

Of the treatments that were evaluated, pedestrian safety cones most consistently allowed pedestrians to cross with the benefit of a motorist yielding to him or her (Table 3). Combining all seven safety cone sites in New York State and Portland, motorists yielded to 81.2 percent of pedestrians (Figure 8). This compares with 69.8 percent in the before period. The increase was significant at the 0.001 level and is consistent with the hypothesis.

Table 3. Percentage of Pedestrians for Whom Motorists Yielded.

TREATMENT	LOCATION	BEFORE	AFTER	SIGNIFICANCE
Overhead crosswalk sign	Seattle	45.5% (411)*	52.1% (438)	✓ (0.056)
Ped. safety cone	Albany	79.1% (43)	68.3% (63)	N
Ped. safety cone	Ballston Spa	25.4% (59)	46.8% (79)	✓ (0.010)
Ped. safety cone	Port Jefferson	74.3% (179)	91.3% (104)	✓ (0.001)
Ped. safety cone	Saratoga Springs	79.2% (303)	96.9% (32)	✓ (0.016)
Ped. safety cone	Schenectady	10.5% (19)	61.5% (13)	S
Ped. safety cone	Troy	87.1% (147)	93.4% (212)	✓ (0.041)
Ped. safety cone	Portland, OR	44.2 % (113)	28.6% (7)	N
Pedestrian regulatory sign	Tucson Euclid at 7th	83.9% (174)	67.7% (195)	X
Pedestrian regulatory sign	Tucson St. Mary's at Melrose	23.8% (42)	25.0% (48)	N
Pedestrian regulatory sign	Tucson Speedway at Plumer	0.0% (32)	12.8% (47)	✓ (0.036)

* Sample sizes in parentheses.
✓ Significant at the 0.10 level or better (p-values in parentheses).
X Significant but in the undesired direction.
N Not significant.
S Small sample size.

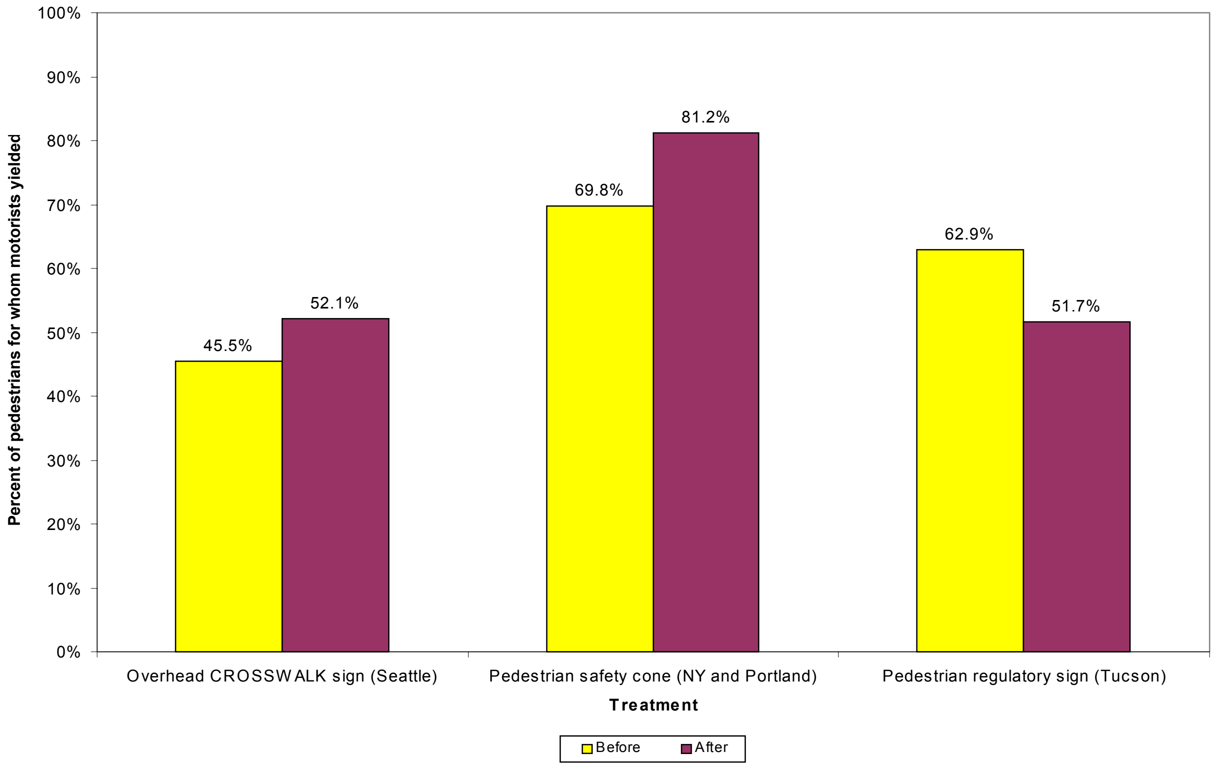

Figure 8. The effects of treatments on the number of pedestrians who benefitted from motorists yielding to them.

Most of the pedestrian safety cones were installed on low-speed, two-lane roads in urban areas, with parking on both sides, so vehicles were traveling at a relatively slow speed anyway and could stop more easily. The message "STATE LAW - YIELD TO [pedestrian symbol] IN YOUR HALF OF ROAD" served to remind motorists of their legal obligation to stop. It is possible that their placement along the centerline was perceived by motorists as an obstruction for which they needed to slow down and proceed carefully around.

Despite it only being a warning sign, the overhead CROSSWALK sign in Seattle had better results than some of the regulatory signs in Tucson and New York State. Motorists yielded to 45.5 percent of pedestrians in the before period and 52.1 percent in the after period. The increase in the number of pedestrians who benefitted was significant at the 0.06 level and is also consistent with the hypothesis.

In Tucson, motorists yielded for 62.9 percent of pedestrians before the STOP FOR PEDESTRIANS IN CROSSWALK signs were installed. This percentage decreased to 51.7 percent after the signs were installed (significant at the 0.01 level). These results do not support the hypothesis that more pedestrians would have the benefit of motorists yielding to them.

Motorists Who Yielded to Pedestrians

In a second analysis, the videotapes for Euclid at 7th were reviewed to determine the percentage of motorists who yielded to pedestrians in the before and after periods. Because the overhead sign is intended to instruct motorists to stop for pedestrians, it was thought that more motorists would yield to pedestrians after the sign was installed.

The unit of analysis here was motorists who approached while pedestrians were crossing or waiting to cross. The sample sizes of motorists and pedestrians are shown in Table 4. In the before period, 16.0 percent of motorists did not yield to pedestrians, compared with only 6.0 percent in the after period, when the sign was activated (Figure 9). This decrease was significant, with a χ^2 of 3.36 and a p-value of 0.0668. These results support the hypothesis that the overhead sign at Euclid and 7th had a positive effect on motorist yielding.

Table 4. Number of Pedestrians and Motorists, Euclid at 7th, Tucson.

BEFORE/AFTER	NUMBER OF PEDESTRIANS	NUMBER OF APPROACHING VEHICLES	NUMBER OF VEHICLES THAT DIDN'T YIELD
Before	296	212	34 (16.0%)
After, sign activated	58	50	3 (6.0%)
After, sign not activated	49	37	5 (13.5%)

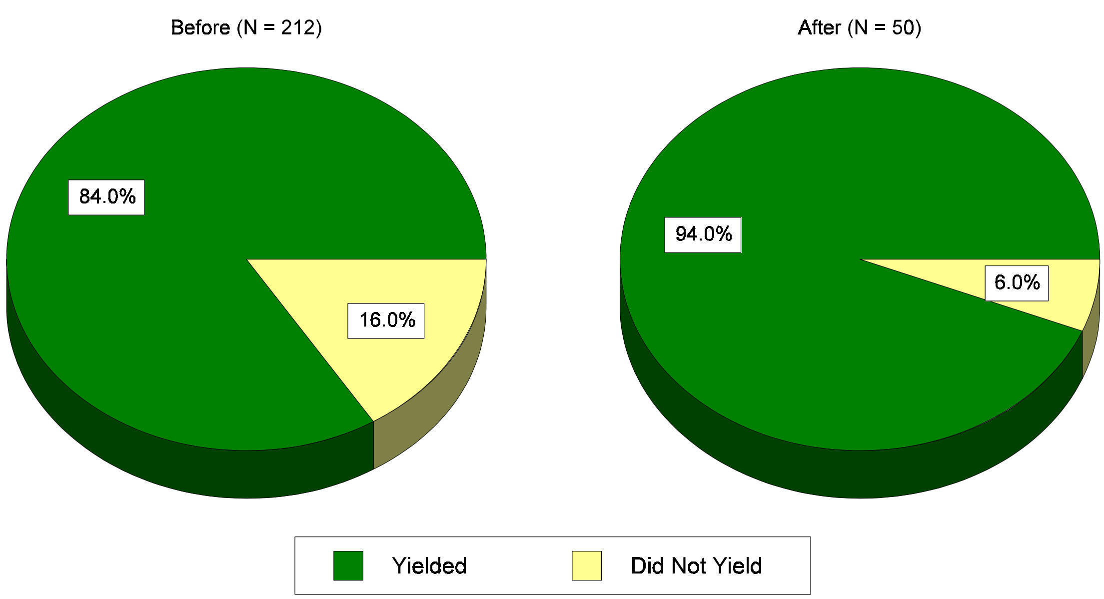

Figure 9. Percentage of motorists who yielded to pedestrians, Euclid at 7th, Tucson.

Pedestrians Who Ran, Aborted, or Hesitated

For the purposes of this study, it was presumed that pedestrians exhibited "normal" behavior if they walked across the roadway at a steady walking pace. Pedestrians were considered as not exhibiting normal behavior if they ran at any time during the crossing, if they aborted the crossing, or if they hesitated while crossing. A pedestrian aborted a crossing if he or she stepped into the roadway, and then retreated back onto the curb because of opposing traffic. A pedestrian hesitated if he or she stepped into the roadway and then waited for a gap before starting to cross, or if he or she crossed part of the way and then waited for a gap before completing the crossing.

The more that motorists yield, the less likely that pedestrians will feel a need to run, abort, or hesitate while crossing the street. As the study treatments are all intended to increase the probability that a motorist will yield, it was hypothesized that each treatment would reduce the number of pedestrians who ran, aborted, or hesitated.

The chi-square statistic was used to evaluate the change in the percentage of pedestrians who ran, aborted, or hesitated, from the before to the after period (Table 5). In Seattle, fewer pedestrians ran, aborted, or hesitated after the overhead crosswalk sign was installed (43.1 percent after vs. 58.2 percent before) (Figure 10). This reduction was significant at the 0.001 level and supported the hypothesis. The pedestrian safety cones in New York and Portland resulted in a slight decrease (but not statistically significant) in the percentage of pedestrians who ran, aborted, or hesitated, from 35.4 percent before to 33.3 percent after. Tucson's STOP FOR PEDESTRIAN IN CROSSWALK signs reduced pedestrian running/aborted crossings/hesitation from 16.7 percent before to 10.4 percent after. The reduction was significant at the 0.01 level and was consistent with the hypothesis.

The changes in pedestrian behavior (running, aborting, or hesitating) sometimes correlated with changes in the likelihood of motorists' stopping. Running was observed to be the predominant "abnormal" pedestrian behavior. Some pedestrians will run regardless of whether motorists are approaching or yielding. Thus, the effects of increased motorist stopping on reducing abnormal behavior may have been less than what might have been expected.

Table 5. Percentage of Pedestrians Who Ran, Aborted, or Hesitated.

TREATMENT	LOCATION	BEFORE		AFTER		SIGNIFICANCE
Overhead crosswalk sign	Seattle	58.2%	(644)*	43.1%	(615)	✓ (0.001)
Ped. safety cone	Albany	46.8%	(624)	41.8%	(550)	✓ (0.087)
Ped. safety cone	Ballston Spa	40.8%	(184)	40.8%	(196)	N
Ped. safety cone	Port Jefferson	31.2%	(775)	21.4%	(308)	✓ (0.001)
Ped. safety cone	Saratoga Springs	27.1%	(484)	35.6%	(146)	X
Ped. safety cone	Schenectady	31.3%	(83)	29.2%	(48)	N
Ped. safety cone	Troy	34.6%	(564)	30.8%	(548)	N
Ped. safety cone	Portland, OR	34.8%	(66)	29.1%	(323)	N
Pedestrian regulatory sign	Tucson Euclid at 7th	12.2%	(303)	5.3%	(282)	✓ (0.003)
Pedestrian regulatory sign	Tucson St. Mary's at Melrose	36.2%	(58)	19.1%	(63)	✓ (0.034)
Pedestrian regulatory sign	Tucson Speedway at Plumer	20.3%	(59)	23.9%	(67)	N

* Sample sizes in parentheses.
✓ Significant at the 0.10 level or better (p-values in parentheses).
X Significant but in the undesired direction.
N Not significant.
S Small sample size.

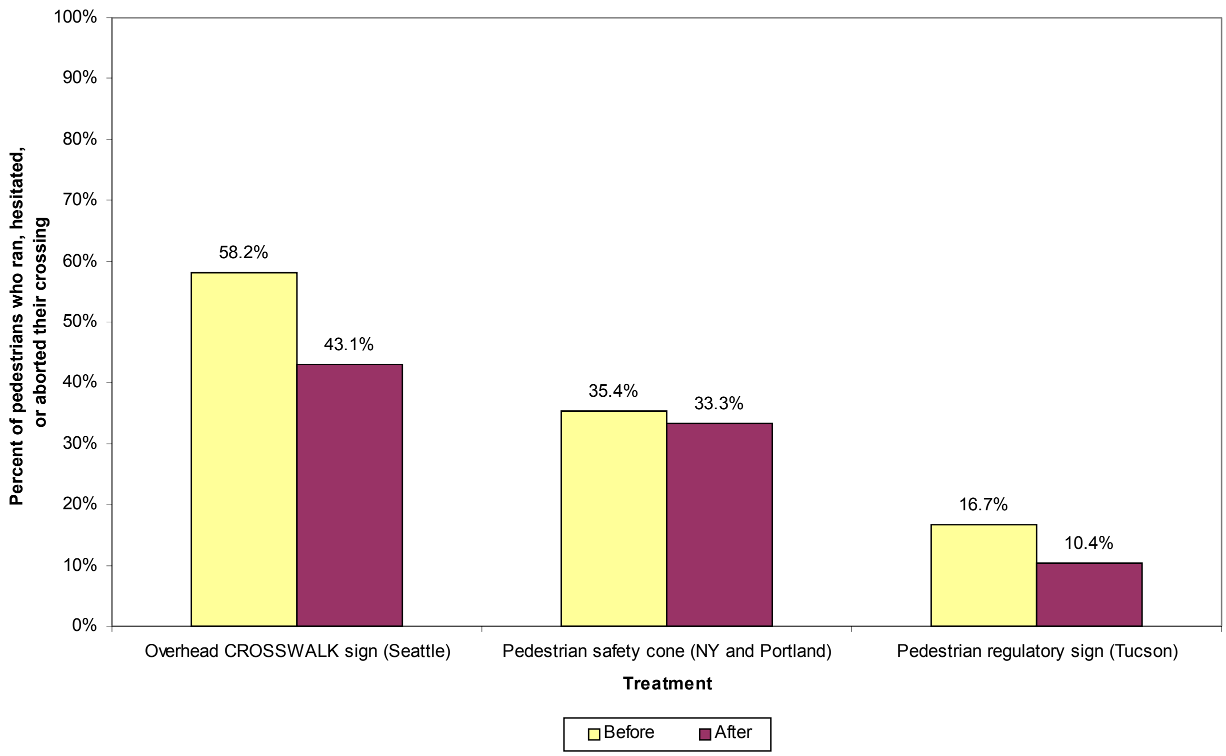

Figure 10. The effects of treatments on pedestrian behavior.

Percentage of Pedestrians Who Crossed in the Crosswalk

Crosswalk signs are intended to direct motorists' attention to pedestrians in the crosswalk. Crosswalks are primarily intended to provide guidance to pedestrians. It may be that pedestrians will be motivated to cross in the crosswalk if they feel they can benefit from the "safe haven" offered by the refuge island or from motorists' attention being directed to them. Thus, it was hypothesized that each treatment would increase the number of pedestrians who crossed in the crosswalk.

The chi-square statistic was used to compare the percentages of pedestrians who crossed in the crosswalk in the before and after periods (Table 6 and Figure 11). When all three treatments (and 11 study sites) are combined, 84.8 percent of pedestrians used the crosswalk in the before period compared with 83.1 percent of pedestrians in the after period. The differences were not significant, so the hypothesis that each treatment would increase the number of pedestrians who crossed in the crosswalk can be rejected.

It is not surprising that these treatments did not affect pedestrian use of the crosswalk. At most locations, the majority of pedestrians already crossed in the crosswalk before the devices were installed. Although many pedestrians do cross in the crosswalk, others do not for a variety of reasons. These treatments are directed at motorists – to call their attention to the crosswalk and/or to remind them of their legal obligation to stop for pedestrians. The treatments provide cues to pedestrians that they should cross at that specific place and not somewhere nearby.

Table 6. Percentage of Pedestrians Who Crossed in the Crosswalk.

TREATMENT	LOCATION	BEFORE		AFTER		SIGNIFICANCE
Overhead crosswalk sign	Seattle	100.0%	(410)*	100.0%	(550)	N
Ped. safety cone	Albany	42.0%	(624)	40.5%	(550)	N
Ped. safety cone	Ballston Spa	100.0%	(97)	100.0%	(144)	N
Ped. safety cone	Port Jefferson	100.0%	(418)	100.0%	(173)	N
Ped. safety cone	Saratoga Springs	93.4%	(484)	91.1%	(146)	N
Ped. safety cone	Schenectady	65.1%	(83)	79.2%	(48)	✓ (0.089)
Ped. safety cone	Troy	100.0%	(550)	100.0%	(532)	N
Ped. safety cone	Portland, OR	51.5%	(66)	63.2%	(323)	✓ (0.077)
Pedestrian regulatory sign	Tucson Euclid at 7th	94.7%	(303)	97.2%	(282)	N
Pedestrian regulatory sign	Tucson St. Mary's at Melrose	87.9%	(58)	85.7%	(63)	N
Pedestrian regulatory sign	Tucson Speedway at Plumer	100.0%	(56)	100.0%	(60)	N

* Sample sizes in parentheses.
✓ Significant at the 0.10 level or better (p-values in parentheses).
X Significant but in the undesired direction.
N Not significant.
S Small sample size.

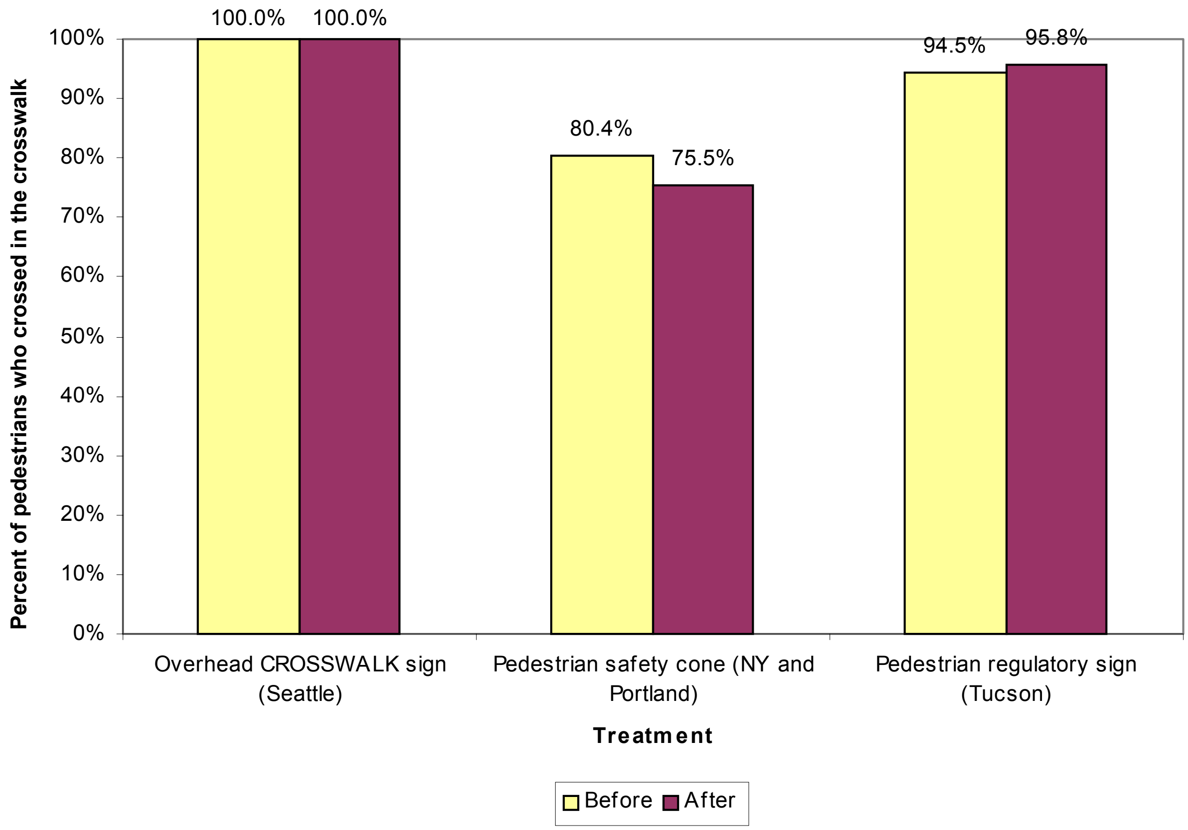

Figure 11. The effects of treatments on the percent of pedestrians who crossed in the crosswalk.

Summary of Results

Of the treatments that were evaluated, pedestrian safety cones were most likely to cause motorists to stop for pedestrians (Table 3 and Figure 8). Combining all seven study sites with the safety cones in New York State and Portland, motorists yielded to 81.2 percent of pedestrians. This compares with 69.8 percent in the before period. The increase was significant at the 0.001 level.

Most of the pedestrian safety cones were installed on low-speed, two-lane roads in urban areas, with parking on both sides, so vehicles were traveling at a relatively slow speed anyway, and could stop more easily. The message "STATE LAW - YIELD TO [pedestrian symbol] IN YOUR HALF OF ROAD" probably served to remind motorists of their legal obligation to stop. It is possible that their placement along the centerline was perceived by motorists as an obstruction for which they needed to slow down and proceed carefully around.

Despite it only being a warning sign, the overhead CROSSWALK sign in Seattle had better results than some of the regulatory signs. Motorists yielded to 45.5 percent of pedestrians in the before period and 52.1 percent in the after period. The increased level of yielding was significant at the 0.06 level.

In Tucson, motorists yielded for 62.9 percent of pedestrians before the STOP FOR PEDESTRIANS IN CROSSWALK signs were installed. This percentage decreased to 51.7 percent after the signs were installed (significant at the 0.01 level).

In Seattle, fewer pedestrians ran, aborted, or hesitated after the overhead crosswalk sign was installed (43.1 percent after vs. 58.2 percent before) (Table 5 and Figure 10). This difference was significant at the 0.001 level. The pedestrian safety cones in New York and Portland resulted in a slight decrease (but not statistically significant) in the percentage of pedestrians who ran, aborted, or hesitated, from 35.4 percent before to 33.3 percent after. Tucson's STOP FOR PEDESTRIAN IN CROSSWALK signs reduced pedestrian running/aborted crossings/hesitation from 16.7 percent before to 10.4 percent after. The reduction was significant at the 0.01 level.

The changes in pedestrian behavior (running, aborting, or hesitating) sometimes correlated with changes in the likelihood of motorists' stopping. Running was observed to be the predominant abnormal pedestrian behavior. Some pedestrians will run regardless of whether motorists are approaching or yielding. Thus, the effects of increased motorist stopping on reducing abnormal behavior may have been less than what might have been expected.

It is not surprising that most of these treatments did not significantly increase pedestrian use of the crosswalk (Table 6). At most locations, the majority of pedestrians already crossed in the crosswalk before the devices were installed. When all three treatments (11 study sites) are combined, 84.8 percent of pedestrians before and 83.1 percent of pedestrians after used the crosswalk. Although many pedestrians do cross in the crosswalk, others do not for a variety of reasons.

Comments on Data

At some locations, day-to-day variations in vehicle volumes and speeds and pedestrian volumes may influence the likelihood of motorists stopping for pedestrians, and whether pedestrians run, hesitate, or abort their crossing. The days and times when data were collected are a snapshot of long-term pedestrian and motorist behavior, and may or may not accurately portray long-term behavior. If a higher-than-average percentage of motorists stopped when before data were collected, and a lower-than-average percentage of motorists stopped when after data were collected, then the observed change will be less than what is actually the case, and may turn out to be insignificant.

DISCUSSION

Pedestrian Safety Cones, New York and Portland

The study findings confirm that pedestrian safety cones can improve conditions for pedestrians who benefit from motorists' yielding to them. This suggests that motorists were more likely to yield to pedestrians after the signs had been placed on the roadway. The design and placement of the cones makes them easy for motorists to see.

It is important that pedestrian safety cones display a consistent and accurate message, i.e., the relevant law for yielding to pedestrians. This tells motorists what they need to do and as they see the signs regularly, the message will be reinforced. If non-standard or misleading messages are used, motorists are likely to become confused as to what they are required to do.

Although one pedestrian safety cone vendor does offer a recessed anchoring point system for temporarily locking the cone to the pavement centerline, the flexibility and removability of the cones makes them prone to vandalism. It has been reported that some motorists are running over the cones, with the intent of damaging or destroying them. There have also been some problems with vandals on foot. It is recommended that criminal sanctions be imposed upon individuals who are convicted of vandalizing the cones (or any other traffic control device). Motorists who deliberately drive over the cones could be cited and prosecuted in the same manner as other "damage to property" violations.

Tucson Pedestrian Regulatory Signs

The limited effectiveness of the current Tucson pedestrian regulatory signs is very likely the result of the types of test locations where the devices were installed, i.e., on 4-lane and 6-lane arterial roads with a moderately high speed limit of 64 km/h (40 mi/h) (with some motorists clearly traveling faster than this posted speed limit) (Figure 12). Motorists often have difficulty stopping at such speeds, even though the pedestrian regulatory signs may be quite visible and give a clear message to motorists. The signs may have been more effective had they been installed on 2-lane roads with speed limits of 48 to 56 km/h (30 to 35 mi/h) instead. Also, Tucson motorists have a history of aggressive driving (e.g., disregarding traffic signals and speed limits, and not yielding the right of way to pedestrians in crosswalks). Out of the 78 U.S. cities with populations of 200,000 or more, Tucson had the fourth highest rate of fatal red light running crashes (5.11 per 100,000 population) for the years 1992 through 1996 (Retting et al., 1999).

Figure 12. The installation of the pedestrian regulatory signs on four- and six-lane arterial roads in Tucson may have limited their effectiveness.

The percentage of pedestrians who benefitted from having motorists yield to them was lower after the STOP FOR PEDESTRIANS IN CROSSWALK had been installed than before. Therefore, the local police began working with the city traffic engineers to initiate a special enforcement program at several sites, where the police issued citations to violators. The city traffic engineer is also investigating the use of red light cameras to be installed at selected intersections to cite motorists violating the signal. “Fire truck” signals are also being tested. When a pedestrian activates the “fire truck” signal, drivers first see a flashing amber signal warning them to be prepared to stop. The flashing amber is followed immediately by an alternating red signal requiring that drivers stop. Plans have also been made to evaluate the effectiveness of that device.

Another effort by Tucson city officials to improve driver compliance to the pedestrian signs is to make them more visible to motorists from a greater distance away by:

1. Reducing sun glare
2. Increasing the stroke width of the sign flashes
3. Changing the color from a deep red to an emergency red
4. Changing the message from “STOP FOR PEDESTRIANS IN CROSSWALK” to “STOP -- PEDESTRIAN IN CROSSWALK,” with the words, “PEDESTRIAN IN CROSSWALK” in high-intensity white to increase its conspicuity.

City engineers will continue to monitor the locations with the pedestrian regulatory signs and make needed revisions, as well as work with police to continue various levels of motorist compliance. Similar signs may be installed on some two-lane roads and/or lower-speed roads in the future. The goal is to improve pedestrian safety at these and other locations in Tucson.

Overhead CROSSWALK Sign, Seattle

The overhead CROSSWALK sign in Seattle was effective in encouraging motorists to yield to pedestrians and reducing the percentage of pedestrians who ran, aborted, or hesitated while crossing. It is likely that fewer pedestrians exhibited these behaviors in the after period because motorists yielded to pedestrians more often. Thus, people did not have to wait for a gap or run to get out of harm's way.

CONCLUSIONS

This study was a behavioral evaluation of 3 devices at a total of 11 locations. The three devices were used in different cities and under significantly different conditions. Ideally, a larger number of locations would have been used and data would have been collected on a more continuous basis to more accurately represent conditions at each site. Additional hours of data collection would have taken place at locations with low pedestrian activity. This longer-term and more comprehensive study would include an analysis of the effects of the devices on motor vehicle-pedestrian crashes.

Pedestrian safety cones and Seattle's overhead crosswalk sign appear to be promising tools for enhancing pedestrian safety at midblock crosswalks on low-speed, two-lane roads. The pedestrian-activated signs in Tucson may not have been as effective in increasing compliance as the other devices because they were installed on four- and six-lane, higher-speed arterials. The same percentage of motorists yielded to the Tucson signs as to the Seattle signs. The Tucson signs may have been at least as effective as the other devices had they been installed on low-speed, single-lane approach streets. It is recommended that the Tucson signs be installed on lower-speed, two-lane urban streets and evaluated. Police enforcement of motorist compliance at these devices is also desirable.

With regard to cost, the pedestrian safety cones are the cheapest, with a cost of a few hundred dollars per cone. The cost of the overhead CROSSWALK sign ranges from $1,000 to $4,000 per sign installed. The pedestrian regulatory signs in Tucson cost about $60,000 per site, which is still substantially cheaper than the $100,000 or more to install a full pedestrian signal at a location.

This study found that the New York, Tucson, and Seattle signs are generally effective in increasing the number of pedestrians for whom motorists yield. Thus, while it may be possible to conclude from these results that the signs can help improve pedestrian safety at unsignalized crossings, there is not a clear relationship between the percentage of motorists who yield to pedestrians and pedestrian crashes. For example, if a device increases motorist yielding to pedestrians from 50 percent to 100 percent, this would be a more clear indication of safety compared with an increase from 0 to 50 percent. This is because half of the vehicles in the second example still pose a clear risk to pedestrians, and pedestrians expecting all vehicles to stop for them as a result of a treatment could be at increased risk of a crash.

The reader is reminded that many other devices have been used to draw motorists' attention to crosswalks and to encourage them to yield to pedestrians. Site characteristics (such as number of lanes, vehicle and pedestrian volumes, and vehicle speeds), the incidence of pedestrian-motor vehicle conflicts and crashes, along with the cost of different treatments, all need to be considered when selecting one or more treatments for a specific unsignalized crossing. It may be more important to design friendlier pedestrian crossing environments than to try to make "unfriendly" crossing locations stand out more.

ACKNOWLEDGMENTS

This study was conducted as part of a research project funded by the Federal Highway Administration, under contract number DTFH61-92-C-00138. Carol Tan Esse served as the Contracting Officer's Technical Representative. The authors gratefully acknowledge the research assistance provided by Jim Ercolano (New York State DOT), Peter Lagerwey (City of Seattle, Washington), Jeff Olson (New York State DOT), and Ellen Vanderslice (City of Portland, Oregon). Don Freeman (Continental Safety Supply Company, Clifton, New Jersey) provided information concerning other communities' experiences with pedestrian safety cones. The authors wish to thank the numerous individuals who collected data. Bradley Keadey, Eric Rodgman, and J. Richard Stewart (all from University of North Carolina Highway Safety Research Center) made data analysis possible.

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