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Safety Strategies Study

by Ann H. Do, Kay Fitzpatrick, Susan T. Chrysler, Jim Shurbutt, William W. Hunter, and Shawn Turner

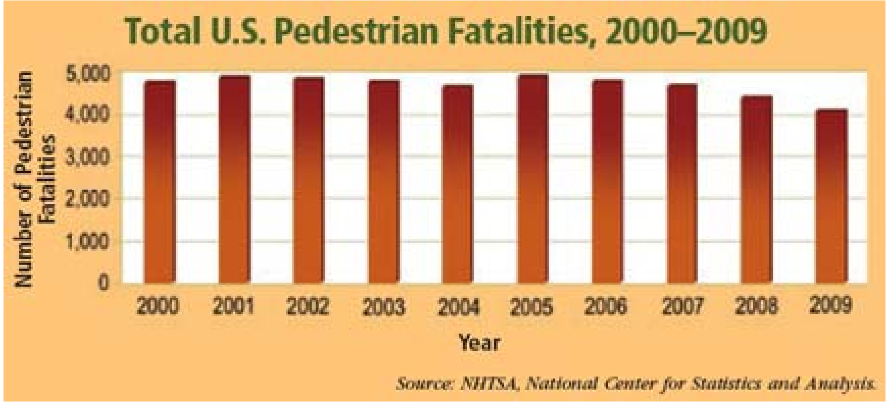
Findings from recent FHWA research point to effective medium- and low-cost engineering countermeasures for helping reduce fatalities and injuries among pedestrians and bicyclists.

Michael Frederick, City of St. Petersburg, FL

In this rectangular rapid-flashing beacon (RRFB) installation on U.S. 92 in St. Petersburg, FL, the sign assemblies are located on both roadsides and in the median. The device is activated by pedestrians.

In the United States, pedestrians killed in traffic crashes decreased 14 percent from 4,763 in 2000 to 4,092 in 2009. Bicyclist fatalities averaged 741 per year from 2004 to 2008 but decreased to 630 in 2009. Also in 2009, around 59,000 pedestrians and 51,000 bicyclists were injured. Although fatality and injury numbers have decreased slightly in recent years, pedestrians and bicyclists still face risks on the Nation's roadways.

To address this issue, the Federal Highway Administration (FHWA) continuously seeks to demonstrate and evaluate the effectiveness of existing and new engineering countermeasures that improve pedestrian and bicyclist safety. The aim of a recent FHWA project, Evaluation of Pedestrian and Bicycle Engineering Countermeasures, was to identify and quantify the effectiveness of selected medium- to low-cost strategies in improving safety and operations for pedestrians and bicyclists. The findings from this study can help State and local departments of transportation (DOTs) identify cost-effective techniques to implement on their highways and streets to help improve safety for pedestrians and bicyclists.



Source: NHTSA, National Center for Statistics and Analysis.

Identification of Countermeasures

The FHWA project focused on existing and emerging engineering countermeasures that have not yet been comprehensively evaluated. The process to identify potential countermeasures started with an extensive literature review of existing evaluations. The researchers also summarized requests sent to FHWA by public agencies for experimental pedestrian- and bicyclist-related traffic control devices not specifically addressed by the *Manual on Uniform Traffic Control Devices* (MUTCD).

Based on these evaluations, the researchers identified several candidate countermeasures, and then the FHWA staff selected a final list for the study. The countermeasures selected for evaluation were the rectangular rapid-flashing beacon (RRFB); the pedestrian hybrid beacon, formerly called High intensity Activated crossWalK (HAWK); shared lane markings for bicyclists (sharrows); and crosswalk markings as viewed by drivers.

The project also included the development of a report, *Pedestrian and Bicyclist Traffic Control Device Evaluation Methods* (FHWA-HRT-11-035) on the evaluation method for pedestrian and bicycle traffic control devices. The report's purpose is to educate practicing engineers, planners, and public works employees at the local, county, and State levels on how to conduct an evaluation of the effectiveness of traffic control devices.

Rectangular Rapid-Flashing Beacon

Past research studies have evaluated traffic control devices such as flashing yellow beacons intended to encourage drivers to yield to pedestrians at multilane crosswalks at uncontrolled locations with relatively high average daily traffic. Only devices that employ a red phase have consistently produced sustained high levels of yielding at these types of crosswalks. To address this problem, the rectangular rapid-flashing beacon flashes in an eye-catching sequence to draw drivers' attention to the sign and the need to yield to the waiting pedestrian. (See also "Evaluating Pedestrian Safety Countermeasures" in the March/April 2011 issue of PUBLIC ROADS.)

The RRFB is located roadside below pedestrian crosswalk signs and can be activated by a pedestrian either actively pushing a button or passively detected by sensors. Each side of a light-emitting diode (LED) flasher illuminates in a wig-wag sequence (left and then right).

During the baseline measurement phase, the researchers installed advance yield markings to reduce the risk of multiple-threat crashes, which occur when a driver stopping to let a pedestrian cross is too close to the crosswalk, masking the pedestrian from drivers in the adjacent lane. The advance yield markings were typically placed 30 feet (9 meters) in advance of the crosswalk unless a driveway or other issue was present, in which case they could be up to 50 feet (15 meters). The posted speed limit at the sites ranged between 30 and 40 miles per hour, mi/h (48 and 64 kilometers per hour, km/h).

The observers scored the percentage of drivers yielding and not yielding to pedestrians. Drivers were scored as yielding if they stopped or slowed and allowed the pedestrian to cross. Conversely, drivers were scored as not yielding if they passed in front of the pedestrian but would have been able to stop when the pedestrian arrived at the crosswalk.

Michael Frederick, City of St. Petersburg, FL

This photo shows a closeup shot of the RRFB installation on U.S. 92 in St. Petersburg, FL.

The study took place at 22 sites in St. Petersburg, FL, Washington, DC, and Mundelein, IL, and the RRFBs produced an increase in yielding behavior at all of those locations. During the baseline period before the introduction of the RRFB, yielding for individual sites ranged between 0 percent and 26 percent. The average yielding for all of the sites was 4 percent before installation of the RRFBs. A major change to 78 percent from the baseline condition occurred by day 7, a statistically significant increase (total of 82 percent) took place between day 7 and day 30, and similar yielding values occurred during the remaining observation days.

Data collected over a 2-year followup period at 18 of the sites confirm that the RRFBs continue to succeed at encouraging drivers to yield to pedestrians, even over the longer term. By the 2-year followup, the researchers determined that the introduction of the RRFB was associated with yielding that ranged between 72 and 96 percent. Therefore, the evidence for change was overwhelming and persisted for the duration of the study.

In July 2008 FHWA issued an interim approval for optional use of RRFBs as warning beacons to supplement standard pedestrian crossing or school crossing signs at crosswalks across uncontrolled approaches. (See http://mutcd.fhwa.dot.gov/resources/interim_approval/ia11/fhwamemo.htm.) Any jurisdiction interested in obtaining interim approval can submit a written request to FHWA, Director of the Office of Transportation Operations. Jurisdictions using RRFBs under the interim approval must agree to comply with the technical conditions detailed in the interim approval memo for all applicants. They also must agree to maintain an inventory of all locations where the devices are placed and to return the site to a condition that complies with the MUTCD if future incorporation of the RRFB into the MUTCD results in a different set of technical conditions, such as design, placement, etc.

Mike Cynecki, City of Phoenix, AZ

In this pedestrian hybrid beacon treatment in Tucson, AZ, the beacon head is located both on the mast arm and on a roadside pole, and consists of two red lenses above a single yellow lens. The operation of the device is activated by the pedestrian.

Pedestrian Hybrid Beacon

The pedestrian hybrid beacon is located both on the roadside and on mast arms over the major approaches to an intersection. The head of the pedestrian hybrid beacon consists of two red lenses above a single yellow lens. It is normally "dark," but when activated by a pedestrian, it first displays a few seconds of flashing yellow followed by a steady yellow change interval, and then displays a steady red indication to drivers, which creates a gap for pedestrians to use to cross the major roadway. During the flashing pedestrian clearance interval, the pedestrian hybrid beacon changes to a wig-wag flashing red to allow drivers to proceed after stopping if the pedestrian has cleared the roadway, thereby reducing vehicle delays. Richard Nassi, while transportation administrator for the city of Tucson, AZ, created the pedestrian hybrid beacon. At the time of this study, the beacons were installed at more than 60 locations throughout the city.

The researchers conducted a before-and-after evaluation of the safety performance of the pedestrian hybrid beacon. Using an empirical Bayes method, their evaluations compared the crash prediction for the after period without the treatment to the observed crash frequency after installation of the treatment. To develop the datasets used in the evaluation, the researchers counted the crashes that occurred during the study period, typically 3 years before and 3 years after the installation.

The researchers created two crash datasets. The first dataset included crashes coded as occurring at the intersecting streets (identified by using street names). The second dataset was a subset of the first dataset and only included those crashes that had "yes" for the intersection-related code in the police report.

The crash categories examined in the study included total, severe, and pedestrian crashes. From the evaluation that considered data for 21 pedestrian hybrid beacon treatment sites and 102 unsignalized intersections (reference group), the researchers found the following changes in crashes after installation of the pedestrian hybrid beacons:

- A 29 percent reduction in total crashes (statistically significant)
- A 15 percent reduction in severe crashes (not statistically significant)
- A 69 percent reduction in pedestrian crashes (statistically significant)

FHWA added the pedestrian hybrid beacon to the MUTCD in the 2009 edition (see Chapter 4F). However, the pedestrian hybrid beacons included in the FHWA safety study differ from the material in the 2009 MUTCD in the following ways because the installations included in the FHWA study preceded the MUTCD guidance:

- Section 4F.02 of the MUTCD states, "When an engineering study finds that installation of a pedestrian hybrid beacon is justified, then … the pedestrian hybrid beacon should be installed at least 100 feet [31 meters] from side streets or driveways that are controlled by STOP or YIELD signs." All 21 pedestrian hybrid beacons included in this study are located either at a minor intersection (where the minor street is controlled by a STOP sign) or at a major driveway (where the driveway is controlled by a STOP sign).
- The 2009 MUTCD depicts an R10-23 sign with the symbolic red circle and a white background for the word "crosswalk" on the sign. The signs typically used at the studied pedestrian hybrid beacon locations do not have the symbolic red circle, and the crosswalk background is yellow.

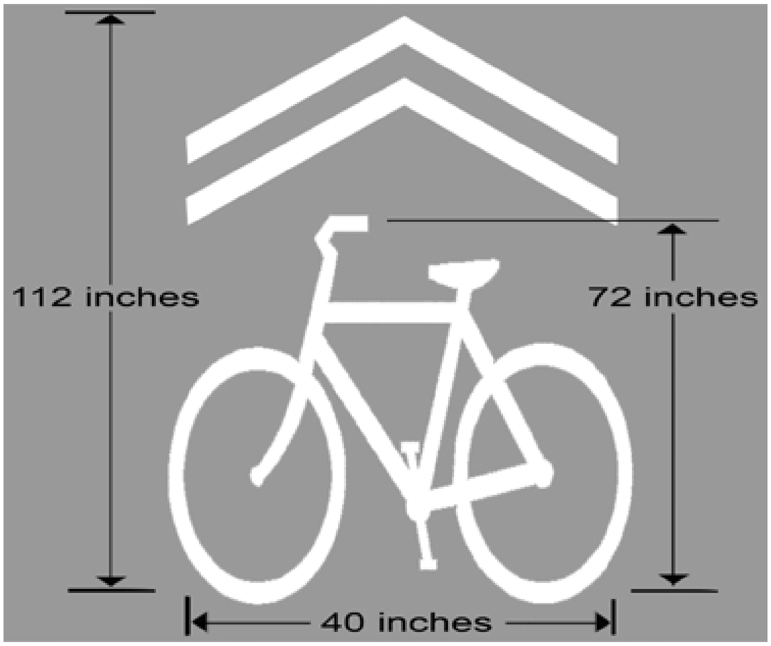
The MUTCD includes guidelines for the installation of the pedestrian hybrid beacons for low-speed roadways where speeds are 35 mi/h (56 km/h) or less, and high-speed roadways where speeds are more than 35 mi/h (56 km/h).

Shared Lane Markings

Shared lane markings, also known as "sharrows," convey the message that motorists and bicyclists must share the road. The arrow markings painted on the roadway indicate appropriate bicyclist positioning in the shared motor vehicle-bicycle lane. The purpose of the markings is to create improved conditions for bicyclists by clarifying where they are expected to ride and to notify motorists to expect bicyclists on the road.

The FHWA study aimed to evaluate the impact of shared lane pavement markings—specifically the so-called sharrow design—on operational and safety measures for bicyclists and motorists. The design incorporates two chevrons positioned over a bicycle outline and is placed on the pavement in the designated shared travel lane.

The researchers conducted experiments in three cities. In Cambridge, MA, local transportation officials were interested in experimenting with the placement of shared lane markings at a 10-foot (3-meter) spacing from the curb to prevent dooring, that is, when the occupant of a parked vehicle opens a door and hits an oncoming bicyclist. In Chapel Hill, NC, the researchers studied these markings placed on a busy five-lane corridor with wide outside lanes and no onstreet parking. In Seattle, WA, they evaluated shared lane markings placed in the center of the travel lane on the downhill portion of a busy street used by bicycle commuters. Prior to the treatment, a 5-foot (1.5-meter) bicycle lane was added to the uphill portion of the street in conjunction with shifting the center line.



Shared Lane Marking
2009 MUTCD

The study's researchers examined a variety of hypotheses such as: (1) The markings may help indicate a preferred travel path and thereby improve bicyclist positioning relative to parked motor vehicles when the cyclist is riding in shared lanes on a road that has onstreet parking, and (2) The markings may increase the distance of motor vehicles in the travel lane from parked motor vehicles or from the curb or pavement edge in the absence of bicyclists, thereby providing more operating space for bicyclists.

A number of variables related to the interaction and spacing of bicycles and motor vehicles showed positive effects. In Cambridge and Chapel Hill, more than 90 percent of bicyclists rode over the marking, indicating a high level of compliance with riding in the designated portion of the shared lane. In addition, motorists moved away from the marking to provide more operating space for bicyclists.

In Seattle, marking placement alone did not seem to result in an increase in the percentage of bicyclists using the lane. Bicyclists already were riding outside the dooring zone in the period before the treatment and stayed in this location in the after period. Shared lane markings had previously been installed 11 feet (3.3 meters) from the curb next to parked cars over a 2,000-foot (610-meter), four-lane section of Fremont Street leading into the section studied during the FHWA project. The researchers acknowledged the possibility that narrowing the travel lanes and adding the uphill bike lane had more effect on operations and spacing than the addition of shared lane markings.

Shared lane markings can be used in a variety of situations, and increased use should serve to boost motorists' awareness of bicycles, or the possibility of bicycles, in the traffic stream. Section 9C.07 of the MUTCD contains applicable requirements and guidance on design and placement of shared lane markings if they are used. As communities continue to use the markings, FHWA recommends similar trials in other locations and traffic settings, and then evaluation and reporting on those installations to gather more data for examination to help improve guidance for road agencies.

Crosswalk Markings

For the crosswalk marking study, the researchers investigated the relative daytime and nighttime visibility of three crosswalk marking patterns: bar pairs, continental, and transverse lines. The study collected information on the distance from the crosswalk at which 78 participant motorists verbally indicated visual recognition of the crosswalk under the different patterns. The participants were about evenly divided in gender between males and females and in age between younger than 55 years old and older than 55.

The FHWA researchers conducted the study in November 2009 using instrumented vehicles on a route along open roads on the campus of Texas A&M University in College Station, TX. The research team collected data during two periods: daytime (sunny and clear or partly cloudy) and nighttime (street lighting on). The tests used existing markings (six intersection and two midblock locations) and new markings installed for the study (nine midblock locations).

For the study sites, the findings indicate that the marking type (bar pair, continental, or transverse) was statistically significant. The detection distances to bar pairs and continental markings were statistically similar, and they were statistically longer than the detection distance to the transverse markings, both during the day and at night.

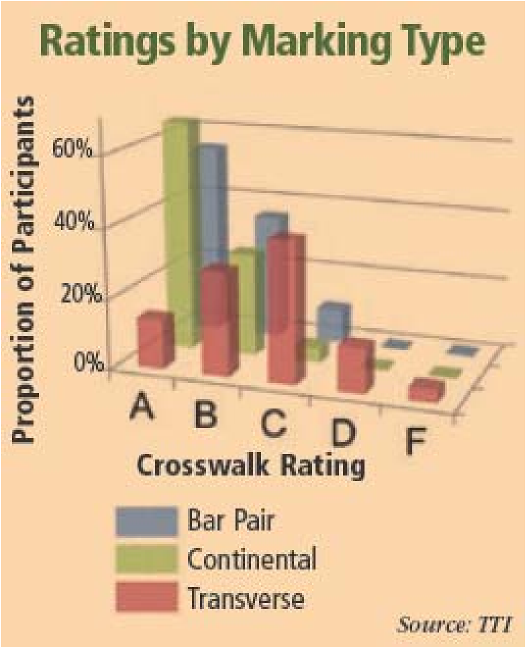
Texas Transportation Institute (TTI)

Researchers at Texas A&M University studied the visibility of three types of crosswalk patterns installed on campus: (a) bar pairs, (b) continental markings, and (c) transverse markings.

For the existing midblock locations, the drivers detected the continental markings at about twice the distance upstream as the transverse markings during daytime conditions. This increase in distance translates to 8 seconds of increased awareness of the presence of the crossing at 30-mi/h (48-km/h) operating speeds.

The participants also rated the appearance of markings on a letter-grade scale of A to F. The researchers compared those subjective ratings of visibility for all the groups and variables identified in the preceding analysis. The ratings for bar pairs and continental were consistent over various comparison groups, with better ratings for bar pairs and continental markings than for transverse markings. These results mirrored the findings from the evaluation of detection distances. Overall, participants preferred the continental and bar pairs markings over the transverse markings.

The research team is working with the National Committee on Uniform Traffic Control Devices to develop recommendations for incorporating the findings from the study into the MUTCD.



Evaluation Methods Report

The report on evaluation methods developed as part of the FHWA project offers information to traffic engineering practitioners on how to conduct an evaluation of traffic control devices for roadways used by pedestrians and bicyclists. The report is designed for use by practitioners such as employees of State DOTs, plus county and city engineers and planners.

The first step of any evaluation is to clearly formulate the research question by identifying the motorist, pedestrian, or bicyclist behavior that poses a safety or operations problem. Practitioners then identify candidate traffic control devices and other countermeasures as potential solutions to that problem.

Evaluation methods described in the guide include user surveys or interviews, visibility studies, driving performance studies, observational traffic studies, and crash analyses. The selection of the appropriate evaluation method involves weighing cost, time, research aims, available research equipment, and staff. The evaluations conducted in the FHWA study exemplify several of the study approaches described in the evaluation methods report and can serve as models for studies that use crash analysis (pedestrian hybrid beacons), traffic observations (RRFB and shared lane markings), and human factors (driver decisions regarding visibility of crosswalk markings).

Summary of Findings

FHWA's Pedestrian & Bicycle Safety Research Program's overall goal is to increase pedestrian and bicycle safety and mobility. From researching safer crosswalks, sidewalks, and pedestrian technologies to educational and safety programs, the program strives to make it safer and easier for pedestrians, bicyclists, and drivers to share roadways today and in the future. Under that program, this project focused on existing and emerging engineering countermeasures that have not yet been comprehensively evaluated in terms of effectiveness.

"These techniques, coupled with the critically necessary driver and pedestrian alertness, will assist the transportation profession in providing safer environments for the pedestrian and cycling community," says Nassi, who is currently traffic engineer for the Regional Transportation Authority, Pima Association of Governments.

The results of this study will be incorporated into the second versions of FHWA's online guides, Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE) and Bicycle Countermeasure Selection System (BIKESAFE). PEDSAFE and BIKESAFE were published in 2004 and 2005 respectively, and each provides general guidance on safety improvement, as well as a systematic approach to countermeasure selection. PEDSAFE Version 2 and BIKESAFE Version 2 are expected to be released in 2013.

Additional Information

Topics	Publications
RRFB	Shurbutt, J. and Van Houten, R. (2010). *Effects of Yellow Rectangular Rapid-Flashing Beacons on Yielding at Multilane Uncontrolled Crosswalks*, FHWA-HRT-10-043, Washington, DC. www.fhwa.dot.gov/publications/research/safety/pedbike/10043/10043.pdf
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Pedestrian Hybrid Beacons	Fitzpatrick, K. and Park, E. S. (2010). *Safety Effectiveness of the HAWK Pedestrian Crossing Treatment*, FHWA-HRT-10-042, Washington, DC. www.fhwa.dot.gov/publications/research/safety/10042/10042.pdf
	Fitzpatrick, K. and Park, E. S. (2010). TechBrief: "Safety Effectiveness of the HAWK Pedestrian Crossing Treatment," FHWA-HRT-10-045, Washington, DC. www.fhwa.dot.gov/publications/research/safety/10045/10045.pdf
Shared Lane Markings	Hunter, W. W., Thomas, L., Srinivasan, R., and Martell, C. A. (2010). *Evaluation of Shared Lane Markings*, FHWA-HRT-10-041, Washington, DC. www.fhwa.dot.gov/publications/research/safety/pedbike/10041/10041.pdf
	Hunter, W. W., Thomas, L., Srinivasan, R., and Martell, C. A. (2010). TechBrief: "Evaluation of Shared Lane Markings," FHWA-HRT-10-044, Washington, DC. www.fhwa.dot.gov/publications/research/safety/pedbike/10044/10044.pdf
Crosswalk Marking	Fitzpatrick, K., Chrysler, S. T., Iragavarapu, V., and Park, E. S. (2010). *Crosswalk Marking Field Visibility Study*, FHWA-HRT-10-068, Washington, DC. www.fhwa.dot.gov/publications/research/safety/pedbike/10068/10068.pdf
	Fitzpatrick, K., Chrysler, S. T., Iragavarapu, V., and Park, E. S. (2010). TechBrief: "Crosswalk Marking Field Visibility Study," FHWA-HRT-10-067, Washington, DC. www.fhwa.dot.gov/publications/research/safety/pedbike/10067/10067.pdf
Evaluation Methods Report	Chrysler, S. T., Fitzpatrick, K., Brewer, M. A., and M. Cynecki. (2011). *Pedestrian and Bicyclist Traffic Control Device Evaluation Methods*, FHWA-HRT-11-035, Washington, DC. www.fhwa.dot.gov/publications/research/safety/pedbike/11035/11035.pdf
Summary Report	Fitzpatrick, K., Chrysler, S. T., Van Houten, R., Hunter, W. W., and Turner, S. (2011). *Evaluation of Pedestrian and Bicycle Engineering Countermeasures: Rectangular Rapid-Flashing Beacon, HAWK, Sharrow, Crosswalk Markings, and the Development of an Evaluation Methods Report*, FHWA-HRT-11-039, Washington, DC. www.fhwa.dot.gov/publications/research/safety/pedbike/11039/11039.pdf

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