July 2018, Updated

U.S. Department of Transportation
Federal Highway Administration

EDC

Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations

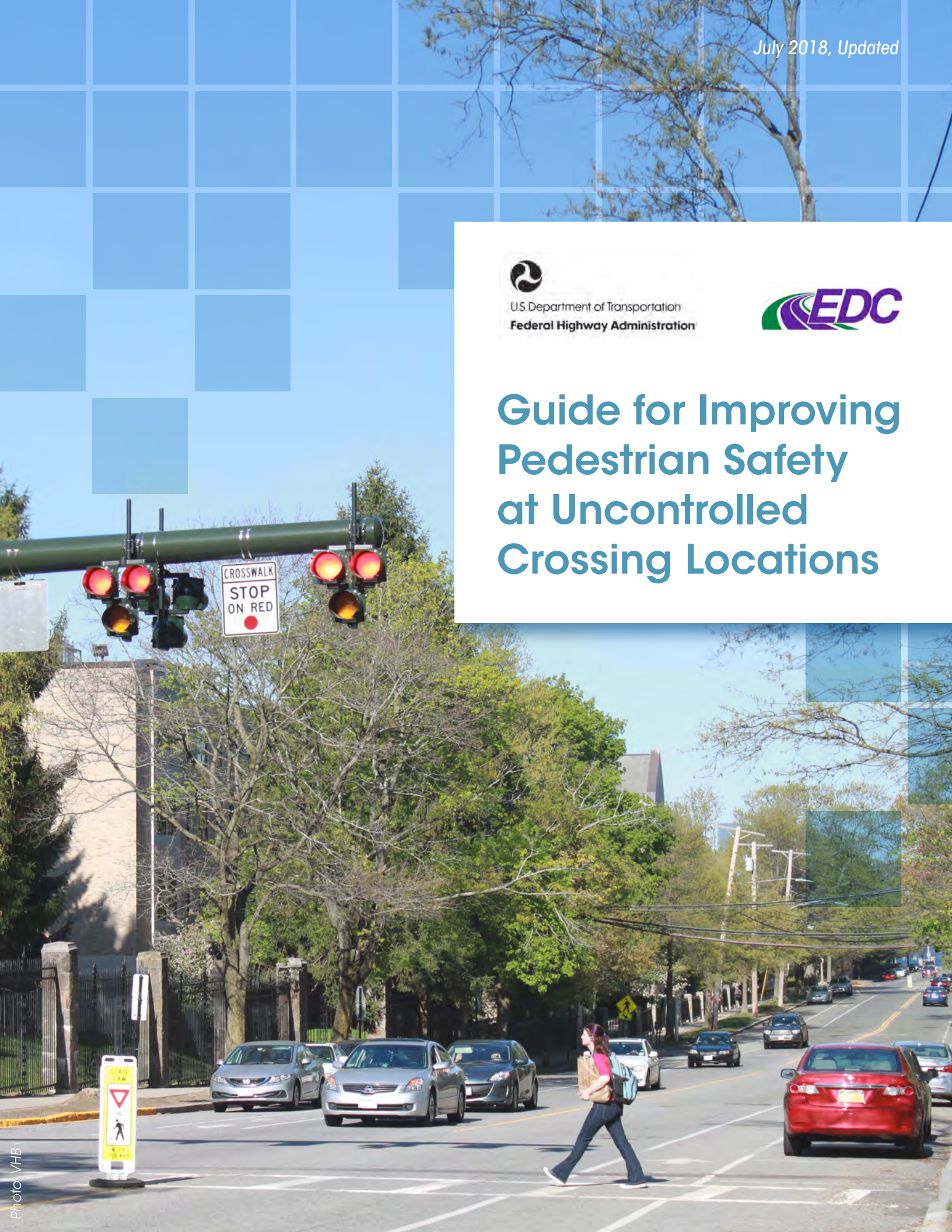


Photo: VHB

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

EDC

Technical Report Documentation Page

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
FHWA-SA-17-072		

4. TITLE AND SUBTITLE	5. REPORT DATE
Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations	January 2018 (July 2018, Updated)
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Lauren Blackburn (VHB), Charles Zegeer (HSRC), and Kristen Brookshire (HSRC)	

9. PERFORMING ORGANIZATION NAME & ADDRESS		10. WORK UNIT NO.
VHB 8300 Boone Boulevard, Suite 300 Vienna, VA 22182	The University of North Carolina at Chapel Hill Highway Safety Research Center (HSRC) 104 Airport Drive, Suite 2200 Chapel Hill, NC 27599-1350	11. CONTRACT OR GRANT NO. DTFH61-16-D-00005

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD
Federal Highway Administration Office of Safety 1200 New Jersey Ave., SE Washington, DC 20590	14. SPONSORING AGENCY CODE FHWA

15. SUPPLEMENTARY NOTES

The Task Order Contracting Officer's Representative (TOCOR) for this task was Rebecca Crowe.

16. ABSTRACT

This guide assists State or local transportation or traffic safety departments that are considering developing a policy or guide to support the installation of countermeasures at uncontrolled pedestrian crossing locations. This document provides guidance to agencies, including best practices for each step involved in selecting countermeasures. By focusing on uncontrolled crossing locations, agencies can address a significant national safety problem and improve quality of life for pedestrians of all ages and abilities. Agencies may use this guide to develop a customized policy or to supplement existing local decision-making guidelines.

The January 2018 version of this guide was updated to include the Rectangular Rapid-Flashing Beacon (RRFB). FHWA issued a new Interim Approval (IA-21) for the optional use of RRFBs in March 2018.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
pedestrian crash countermeasures, uncontrolled crossings, midblock crossings, Pedestrian Hybrid Beacon, Road Diet, crosswalk visibility enhancements, pedestrian refuge island, raised crosswalk, Rectangular Rapid-Flashing Beacon	No restrictions.

19. SECURITY CLASSIF. (OF THIS REPORT)	20. SECURITY CLASSIF. (OF THIS PAGE)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	38	

What is the *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations*?

State or local transportation or traffic safety departments should consider developing a policy or guide to support the installation of countermeasures at uncontrolled pedestrian crossing locations. This document provides guidance to agencies, including best practices for each step involved in selecting countermeasures. Agencies may use this guide to develop a customized policy or to supplement existing local decision-making guidelines.

This document was produced by the Federal Highway Administration (FHWA) as part of the Safe Transportation for Every Pedestrian (STEP) program. STEP is part of the fourth round of Every Day Counts. STEP's purpose is to help transportation agencies address crashes by promoting countermeasures with known safety benefits at uncontrolled crossing locations.

Uncontrolled pedestrian crossing locations occur where sidewalks or designated walkways intersect a roadway at a location where no traffic control (i.e. traffic signal or STOP sign) is present. These common crossing types occur at intersections (where they may be marked or unmarked) and at non-intersection or midblock locations (where they must be marked as crossings). Overall, uncontrolled pedestrian crossing locations correspond to higher pedestrian crash rates, often due to inadequate pedestrian crossing accommodations.

By focusing on uncontrolled crossing locations, local and State agencies can address a significant national safety problem and improve quality of life for pedestrians of all ages and abilities. STEP promotes the following six effective and lower-cost countermeasures that communities can deploy based on their specific needs:

- Crosswalk visibility enhancements (i.e., high-visibility crosswalk markings, parking restriction on crosswalk approach, improved lighting, advance Yield Here To [Stop Here For] Pedestrians sign and yield [stop] line, In-Street Pedestrian Crossing sign, and curb extension).
- Raised crosswalk.
- Pedestrian refuge island.
- Pedestrian Hybrid Beacon (PHB).
- Road Diet.
- Rectangular Rapid-Flashing Beacon (RRFB).

These countermeasures and their safety benefits are described further in this guide. The guide also includes best practices for identifying locations and installing countermeasures at uncontrolled pedestrian crossing locations.

Table of Contents

Introduction 1

1. Collect Data and Engage the Public 3

2. Inventory Conditions and Prioritize Locations 8

3. Analyze Crash Types and Safety Issues 12

4. Select Countermeasure(s) 15

5. Consult Design and Installation Resources 23

6. Identify Opportunities and Monitor Outcomes 24

Glossary 27

Appendix A: Framework for a Resolution Supporting Pedestrian Safety 29

Appendix B: CRF and CMF Summary Table 32

List of Figures

Figure 1. Process diagram for selecting countermeasures at uncontrolled pedestrian crossing locations. 1

Figure 2. Excerpt from "Walkability Checklist." 5

Figure 3. Example crossing inventory worksheet. 9

Figure 4. Crash cluster analysis map: Richmond, VA. 11

Figure 5. Pedestrian collision summary. 13

Figure 6. Rendering of a PHB. 20

List of Tables

Table 1. Application of pedestrian crash countermeasures by roadway feature. 16

Table 2. Safety issues addressed per countermeasure. 17

Table 3. CRFs and CMFs by countermeasure. 32

List of Abbreviations

AADT	annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
ADT	average daily traffic
CMF	crash modification factor
CRF	crash reduction factor
EDC	Every Day Counts
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GHSA	Governors Highway Safety Association
GIS	geographic information system
HSIP	Highway Safety Improvement Program
HSP	Highway Safety Plan
MUTCD	Manual on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
PHB	Pedestrian Hybrid Beacon
RRFB	Rectangular Rapid-Flashing Beacon
RSA	Road Safety Audit
SHSP	Strategic Highway Safety Plan
STBG	Surface Transportation Block Grant
STEP	Safe Transportation for Every Pedestrian
TZD	Toward Zero Deaths
VZ	Vision Zero

Introduction

Pedestrians are among the most vulnerable road users, accounting for approximately 16 percent of all roadway fatalities nationally in 2016, per the Fatality Analysis Reporting System (FARS).[1] Pedestrians are especially vulnerable at non-intersection locations, where 72 percent of pedestrian fatalities occur.[1]

This guide addresses safety issues at **uncontrolled pedestrian crossing locations**, which occur where sidewalks or designated walkways intersect a roadway at a location where no traffic control (i.e., traffic signal or STOP sign) is present. These common crossing types occur at intersections (where they may be marked or unmarked) and at non-intersection or midblock locations (where they must be marked as crossings). Overall, uncontrolled pedestrian crossing locations correspond to higher pedestrian crash rates than controlled locations, often due to inadequate pedestrian crossing accommodations.

How to Use this Guide

The guide includes steps to assist an agency in selecting appropriate countermeasures to help improve pedestrian safety, as illustrated in Figure 1. An agency that has an established process for identifying priority locations for pedestrian safety improvements should review the guidance in Steps 3 through 6. This information is most important for selecting pedestrian crossing countermeasures. An agency that is at the beginning stages of identifying priority locations should consult each of the steps described in this guide.

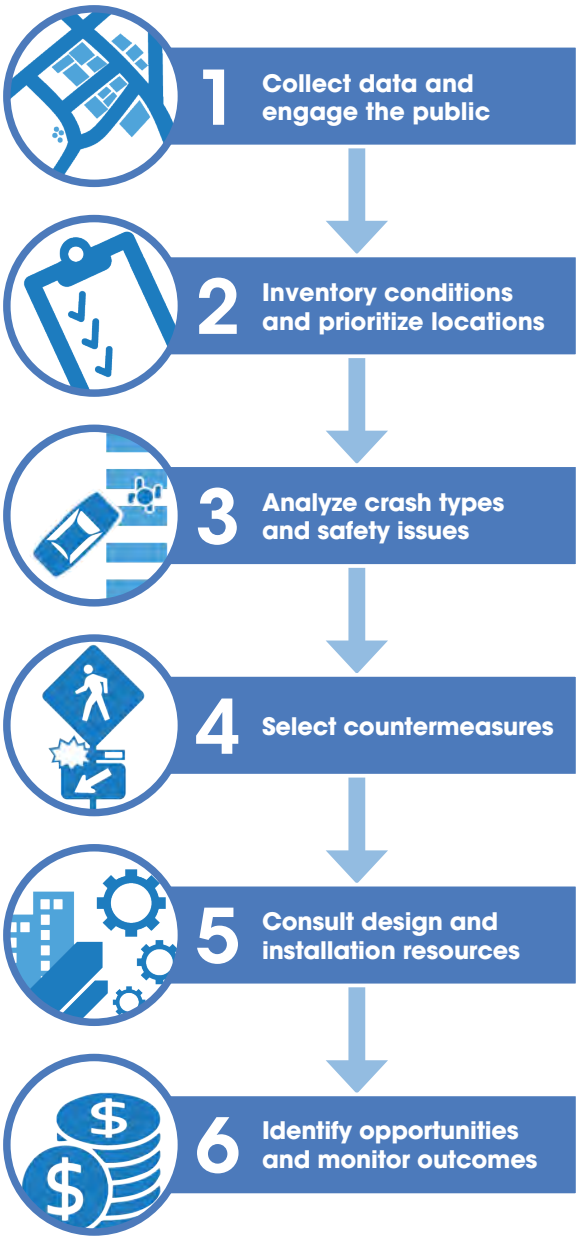


Figure 1. Process diagram for selecting countermeasures at uncontrolled pedestrian crossing locations.

[1]*NHSTA, "FARS Data Query: 2016 Data." Fatality Analysis Reporting System (FARS) Encyclopedia. (2017). https://www-fars.nhtsa.dot.gov//QueryTool/QuerySection/SelectYear.aspx*

Following the process in the guide results in possible countermeasure options based on road conditions, crash causes, and pedestrian safety issues. The guide provides two reference tables to help identify countermeasure options. Table 1 identifies countermeasures by roadway conditions such as vehicle speed limit, annual average daily traffic (AADT), and number of travel lanes. Table 2 helps further pinpoint the most appropriate countermeasures by common safety concerns such as failure to yield or excessive vehicle speeds. The guide does not include specific recommendations for countermeasures based on all criteria in design and reference manuals, such as actual speeds and pedestrian volumes. The agency should reference the Manual on Uniform Traffic Control Devices (MUTCD), American Association of State Highway and Transportation Officials (AASHTO) design guidelines, and State and local practices when selecting one or more specific countermeasures. The guide is followed by appendices including reference material for a local agency resolution and a summary of research cited for crash modification factors (CMFs).

The agency should note additional considerations for the application of this guide, such as costs to design, install, and maintain the treatments. The agency should apply engineering judgment and conduct field investigations to confirm data and observe driver and pedestrian behaviors when selecting countermeasures.

Building a safe and connected pedestrian network requires consideration of topics beyond what is included in this guide. This guide does not include methods for prioritizing sidewalk improvements, but agencies should consider giving special attention to connecting the pedestrian network with sidewalks, walkways, paved shoulders, and trails and paths. The ActiveTrans Priority Tool was created through the National Cooperative Highway Research Program and can provide agencies with automated resources to prioritize pedestrian and bicycle improvements.

Pedestrian crossings in or near school zones are not specifically addressed in this guide, as these crossings may be subject to other guidance or other considerations. Agencies may refer to the "Safe Routes to School Briefing Sheets: School Area Traffic Control" produced by the Institute of Transportation Engineers (ITE) for guidance on improving pedestrian crossings near schools.

This guide does not describe pedestrian crossing requirements per the Americans with Disabilities Act (ADA), although ADA requirements should be addressed as part of any pedestrian crossing improvements project. For more information about ADA accessibility requirements, the agency should consult the US Access Board's 1991 ADA Accessibility Guidelines (ADAAG), the 2010 Standards for Accessible Design, and the 2011 Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (proposed PROWAG).

1

Collect Data and Engage the Public

GUIDING PRINCIPLES

This section describes optional methods for describing existing pedestrian safety trends and engaging stakeholders. The following are important considerations for this step in the process of selecting countermeasures:

» Review existing plans for safety statistics and locations previously identified for safety improvements.

» Develop a resolution or policy statement in support of improving pedestrian safety at uncontrolled crossing locations.

» If a formal process is preferred, initiate a Pedestrian Safety Action Plan to engage the community and identify priority locations.

» If a less formal process is preferred, document public comments previously received or conduct a walkability audit to identify locations generally considered as less safe for pedestrians crossing.

Collect Pedestrian Crash and Safety Data

Crash reports completed by law enforcement agencies may include information about driver and pedestrian actions, as well as environmental conditions when and where the crash occurred. These data are helpful to understand safety issues in the area. Crash data may be geocoded and mapped. The agency can collect crash maps, request crash reports (as needed), and contact public health officials for other pedestrian injury data.

Review Existing Traffic Safety Plans

The Strategic Highway Safety Plan (SHSP) is a statewide-coordinated, data-driven safety plan that provides a comprehensive framework for reducing highway fatalities and serious injuries on all public roads. States are required to update the SHSP at least once every five years. The SHSP may include an emphasis area and strategies for improving pedestrian safety. The agency should review the SHSP for pedestrian crash statistics and strategies for pedestrian safety improvements.

The SHSP informs the State's Highway Safety Improvement Program (HSIP). The HSIP is a program of highway safety improvement

projects, activities, plans and reports. HSIP projects are selected through a data-driven approach and can include pedestrian crash countermeasures and intersection improvements. Some States set aside HSIP funding for pedestrian safety improvements, while other States use a common scoring process to consider safety projects for all travel modes. The agency should identify and understand pedestrian safety projects in the current HSIP, and consider how pedestrian safety projects are identified for potential funding and implementation. The Safety Performance Management Measures Final Rule (23 CFR 490) establishes requirements that support the HSIP, including a measure for the number of non-motorized fatalities and non-motorized serious injuries. This performance measure includes both pedestrians and bicyclists.

The State's Highway Safety Plan (HSP) must also be coordinated with the SHSP. The HSP is an annual strategy submitted by the State's Governor's Highway Safety Office to the National Highway Traffic Safety Administration (NHTSA). The HSP focuses on countermeasures that address driver and non-motorized behavior, and it provides an investment plan for activities such as law enforcement operations and public education programs. The HSP includes performance measures established by NHTSA and the Governors Highway Safety Association (GHSA), including one for pedestrian fatalities. Pedestrian safety initiatives are eligible for funding through the HSP. The agency should research pedestrian safety programs recommended in the HSP and consider how pedestrian crossing treatments can support the performance standards described in the HSP.

Evaluate Pedestrian Accommodation and Traffic Safety Policies

The agency may have a policy or guidance for how pedestrian improvements are incorporated into other roadway projects, such as a Complete Streets policy. The policy explains the process for integrating sidewalks and crossing treatments into routine street maintenance activities and large-scale highway projects. The agency should examine the linkages between Complete Streets and pedestrian safety and consider improvements to the process to better integrate pedestrian crossing improvements into roadway projects.

The agency may have adopted a policy for eliminating traffic-related fatalities, such as a Vision Zero or Toward Zero Deaths initiative. The programs focus on eliminating or significantly reducing traffic fatalities and prioritize strategies for the most vulnerable roadway users, such as pedestrians. These programs may summarize how all agency departments can improve pedestrian and traffic safety, and may include metrics that establish the need for safety at uncontrolled pedestrian crossings.

Review Pedestrian Master Plans for Proposed Projects

Another approach to identify pedestrian issues is to review existing local or regional plans, particularly those with a focus on pedestrians, for potential locations for safety projects and to identify needed countermeasures. A State or local pedestrian master plan may include recommendations for pedestrian safety projects, identified infrastructure deficiencies, and/or documentation

about safety concerns. This step leverages prior analyses and helps to identify countermeasures that that the agency is already considering.

Initiate a Pedestrian Safety Action Plan (PSAP)

Agency leaders and community stakeholders can begin a formal process to identify priority locations and key strategies for improving pedestrian safety. The agency may initiate a PSAP to increase community awareness and support for improving pedestrian safety. A PSAP considers the input of stakeholders from multiple disciplines and uses data analysis to identify potential locations for safety improvement.

Document Informal Public Comments

The agency can identify locations of significance within a jurisdiction by collecting concerns and requests from community partners. Agencies should set up a process for receiving, tracking, and responding to input from residents and visitors. Many local governments respond with traffic calming request applications or online forms for residents with concerns about pedestrian safety on high-speed arterials or collector streets. Agencies may also consider forming a committee or work group devoted to considering pedestrian safety and mobility, such as a pedestrian advisory committee. This type of group can collect input from stakeholders and present their concerns to agency staff or decision-makers.

Conduct a Walkability Audit

Community leaders and neighbors can conduct a walkability audit at priority locations or corridors to identify deficiencies in the pedestrian network at a small area or neighborhood scale. This is an informal method for engaging stakeholders and raising awareness about pedestrian safety. Leaders can organize an event and ask participants to follow a simple checklist to assess neighborhood streets. Figure 2 shows an excerpt from a sample "walkability checklist" that agencies may use to conduct a walkability audit.

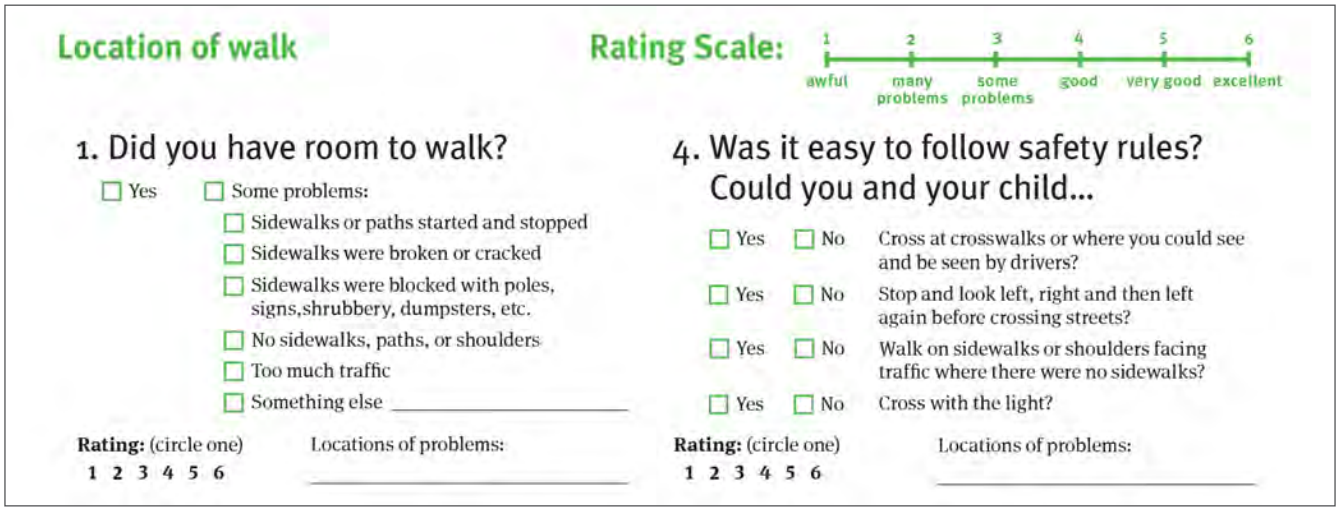


Figure 2. Excerpt from "Walkability Checklist."

Source: Pedestrian and Bicycle Information Center. Created in collaboration with FHWA, NHTSA, National Center for Safe Routes to School, and United States Environmental Protection Agency.

RESOURCES

NHTSA Pedestrian Safety Information

NHTSA publishes annual reports summarizing the latest pedestrian fatality statistics. These statistics are based on FARS and the reports describe pedestrian fatality trends per different socioeconomic groups and for each State.

Smart Growth America – National Complete Streets Coalition

Smart Growth America, a non-governmental advocacy organization, supports the National Complete Streets Coalition. This organization provides resources to support the development and implementation of Complete Streets policies. These policies encourage pedestrian mobility and safety by promoting street design that accommodates controlled and uncontrolled crossings. For example, the Massachusetts Department of Transportation Complete Streets program assists local governments developing Complete Streets policies and implementation plans.

FHWA State SHSP Resources

The FHWA Office of Safety posts a link to each State's current SHSP. This website also lists noteworthy practices. Many SHSP plans provide an emphasis on pedestrians and contain goals for reducing traffic fatalities and injuries.

The Ohio DOT 2015 SHSP has a pedestrian emphasis area that seeks to reduce fatalities and serious injuries through six strategies that include data collection, institutionalizing pedestrian accommodations, implementing proven countermeasures, and promoting law enforcement.

FHWA HSIP Resources

The HSIP includes the projects selected for implementation, an evaluation of past projects, and an annual status report. Projects can include pedestrian safety improvement programs and projects. For example, the 2016 Oregon HSIP Annual Report details how the its All Roads Transportation Safety Program sets aside funding to address systemic pedestrian crash locations.

State HSP Documents

NHTSA posts the States' current HSP outlining non-infrastructure strategies for improving roadway safety. A State HSP is likely to contain a pedestrian fatality and injury reduction goal, an associated performance measure, and describe non-infrastructure initiatives like enforcement and education programs. For example, Colorado DOT's 2017 HSP (called the 2017 Integrated Safety Plan) supports the Denver Police Department's "Decoy Pedestrian Program" to enforce driver yielding compliance at high-crash pedestrian crossings.

Vision Zero Network

This collaborative website posts case studies and tracks cities who are implementing Vision Zero plans or goals. The Vision Zero Network website also notes best practices by agencies who are working to eliminate traffic fatalities and serious injuries. Vision Zero goals are accompanied by policies, strategies, and target dates. For example, Columbia, Missouri's Vision Zero Action Plan contains an outreach campaign to educate pedestrians and drivers on new and potentially confusing infrastructure improvements like pedestrian hybrid beacons and enhanced pedestrian crosswalks.

FHWA How to Develop a Pedestrian and Bicycle Safety Action Plan (2017)

This document explains the process of developing pedestrian and bicycle safety action plans. The sources of data required for these plans may include police reports, roadway and intersection conditions, field visits of crash sites. For example, New Jersey's PSAP identified how its infrastructure prioritization programs could be revised to recognize locations with systemic pedestrian crash risk.

FHWA Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts (2016)

This resource focuses on flexibility and options for the design of pedestrian and bicycle networks designed to minimize crash conflicts, including case studies to illustrate various design treatments.

Walkability Checklist

This tool can be used by community leaders during a walkability audit to evaluate pedestrian infrastructure and traffic behavior.

2

Inventory Conditions and Prioritize Locations

GUIDING PRINCIPLES

This section describes how the agency can document field conditions (such as roadway characteristics) necessary for prioritizing locations and selecting countermeasures. The following are important considerations for this step:

» Create a worksheet or checklist of roadway characteristics to record in the field (see Figure 3).

» Document pedestrian volumes and driver behavior, especially where pedestrians are frequently expected such as at bus stop locations and near schools.

» Classify pedestrian crossings as either uncontrolled or controlled locations.

» Analyze data and create maps to show priority locations for pedestrian improvements.

Inventory Roadway Characteristics

The process of collecting roadway characteristics includes compiling geospatial data to create base maps for each of the priority sites. Roadway conditions are key criteria for selecting countermeasures. The agency may document and map the following roadway characteristics for priority sites (see Glossary for more information):

» Speeds, including posted speed limits and actual speeds (i.e., 85th percentile speeds).

» Number of travel lanes for each approach.

» Center turn lanes, medians, or refuge islands.

» Intersection turn lanes.

» Vehicle queue lengths at intersections.

» Width of roadway, from curb to curb.

» Traffic volumes (AADT or ADT).

» Large truck traffic volumes or large trucks as a percentage of total traffic.

» On-street parking, alignment, and marked or signed restrictions.

City of Boulder Pedestrian Crossing Treatment Installation Guidelines

Crossing Location Evaluation Worksheet

Rev. 11/2/11

STEP 1 - LOCATION DESCRIPTION

Major Street: _____ Crossing Location: _____

Is this a multi-use path crossing? ☐ Yes ☐ No Posted Speed Limit: _____ mph

Existing Traffic Control: ☐ Stop Sign ☐ Traffic Signal ☐ Uncontrolled

Existing Crossing Treatments (if any): _____

_____

Nearby Pedestrian Generators (School, transit stop, commercial, etc.): _____

_____

STEP 2 - PHYSICAL DATA

Roadway Configuration:
☐ 2-Lane
☐ 3-Lane w/Striped Median
☐ 3 Lane w/Raised Median
☐ 4 Lane
☐ 5 Lane w/Striped Median
☐ 5 Lane w/Raised Median
☐ 6 Lane
☐ Other: _____

Crossing Distance By Direction: _____ ft total _____ ft to median *(if applicable + note direction)* _____ ft to median *(if applicable + note direction)*

Nearest Marked or Protected Pedestrian Crossing: _____ Distance to: _____ft

(*For uncontrolled location only*) Stopping Sight Distance (SSD) = _____ ft _____ ft.

Is SSD ≥ 8x Speed Limit? ☐ Yes ☐ No If No, are improvements to SSD feasible? ☐ Yes ☐ No

Figure 3. Example crossing inventory worksheet.

Source: City of Boulder, Pedestrian Crossing Treatment Installation Guidelines (2011).

Inventory Pedestrian Crossings and Observed Traffic Behavior

The agency can also document pedestrian crossing conditions. Agency staff can visit the sites and record the following crossing site features:

- Crosswalk markings, presence, and types.
- Crosswalk distance (in feet) and crossing phase duration (in seconds).
- Signage, such as advance, crosswalk, and in-street.
- Traffic control devices and signals, such as pedestrian crossing signal, pedestrian signal detector, STOP sign, RRFB, and PHB.
- Signal phasing and restrictions, such as Leading Pedestrian Interval, split or concurrent phasing type, and turn restrictions.
- Vertical elements, such as refuge island or raised crosswalk.
- Horizontal elements, such as curb extensions, narrowed curb radii, Road Diet, or lane reconfiguration.
- Accessibility features, such as curb ramps, truncated domes, and accessible signal push buttons.
- Lighting and visibility enhancements, such as overhead lighting.
- Pedestrian volumes, including transit boarding volumes from nearby stops.
- Pedestrian crossing behaviors near important activity centers such as transit stops, schools, and in downtown districts.
- Driver behaviors at crosswalks and intersections.
- Sight distance and visual clearance of crossing.

Classify Pedestrian Crossings as Controlled or Uncontrolled

In addition to collecting inventory information about the priority sites, it is important that the agency categorize each crossing as either controlled or uncontrolled. Uncontrolled pedestrian crossing locations occur where sidewalks or designated walkways intersect a roadway at a location where no traffic control (i.e., traffic signal or STOP sign) is present. These common crossing types occur at intersections (where they may be marked or unmarked) and at non-intersection or midblock locations (where they must be marked as crossings). This guide describes countermeasures applicable to uncontrolled crossings. Some of these countermeasures can also be used for controlled crossings, and the agency should consult other guidance for specific implementation criteria at those sites.

Screen the Network for High-Crash or High-Risk Locations

By following a data-driven approach, the agency can readily explain and defend how it selected priority sites for improvement. An agency can study, or screen, the safety conditions for the road network within its jurisdiction. The screening process uses geo-coded pedestrian crash data and other information to identify different types of locations. Network screening may take the form of spot safety or systemic safety analysis. Spot safety analysis is based on crash history at individual locations and identified high-crash locations. The systemic approach analyzes crash history on an aggregate basis to identify roadways that have high-crash experience, as well as high-risk characteristics at other sites before crashes occur, so countermeasures can be selected to address these characteristics.

Analyze "Hot Spots" or Crash Cluster Locations

Spot safety analysis involves mapping the individual locations of crashes over a time period, preferably at least 5 years for pedestrian crash data. Mapping these crashes on a geographic information system (GIS) helps to visually reveal clusters, or "hot spots," of pedestrian crashes. Similarly, using the spot analysis approach may also reveal corridors or areas where pedestrian crashes tend to cluster. Grouping the clusters of crashes identified in the spot location process can show areas of potential pedestrian improvements. These areas may be corridors, roadways that share roadway design features, and/or areas of a similar land use. Figure 4 shows a map of pedestrian crash locations in an area.

Develop a Systemic Analysis Approach

Many areas may have low pedestrian crash rates, but still have a high risk for pedestrian crashes. The agency can identify these sites based on roadway characteristics combined with land use features of the area. The agency may select countermeasures to address these high-risk factors before pedestrian crashes occur.

The systemic analysis can cover different geographies; an agency may choose to analyze for an area of interest or the entire jurisdiction. Systemic analysis considers factors such as inadequate roadway design and traffic control devices, lighting conditions, vehicle speeds, and nearby pedestrian destinations. Combinations of these factors help identify countermeasures to address and prevent pedestrian crashes.

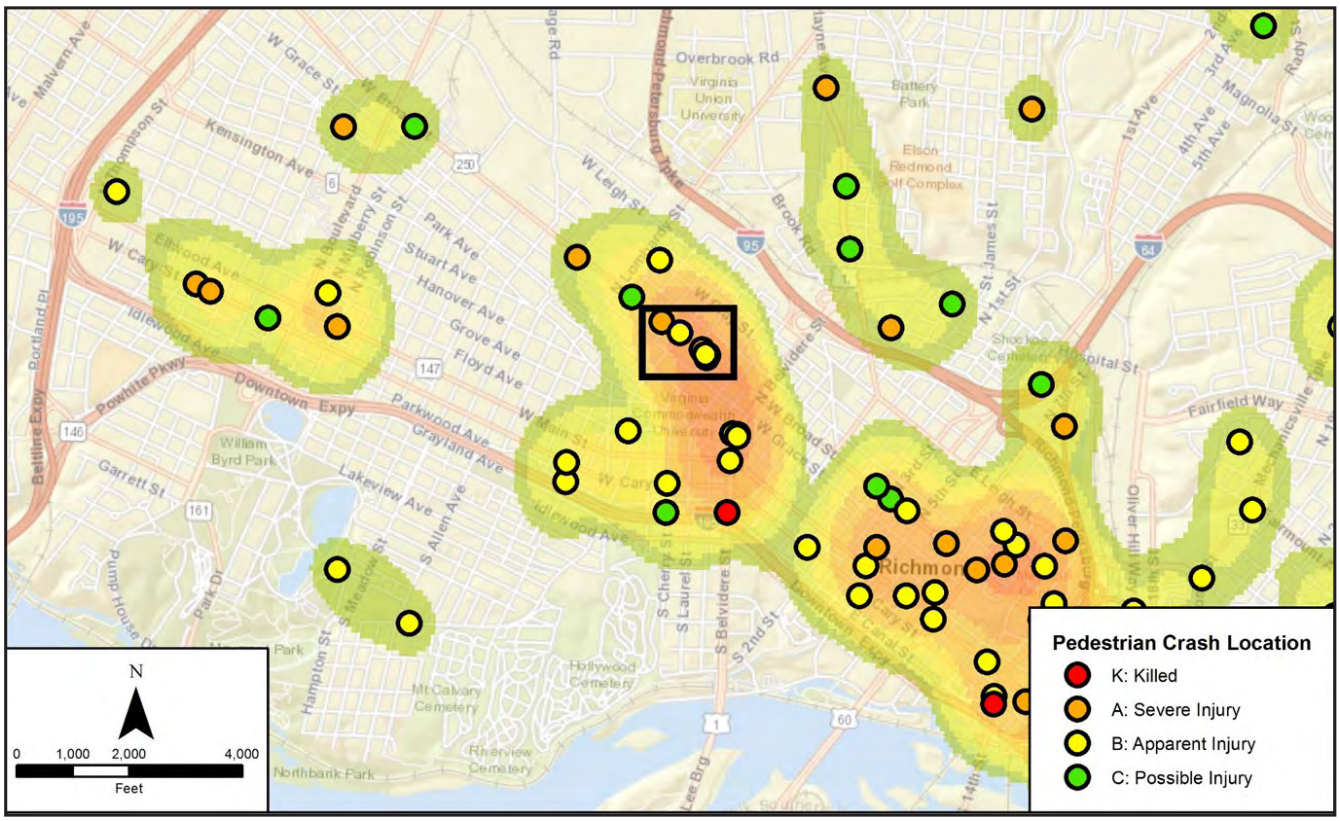
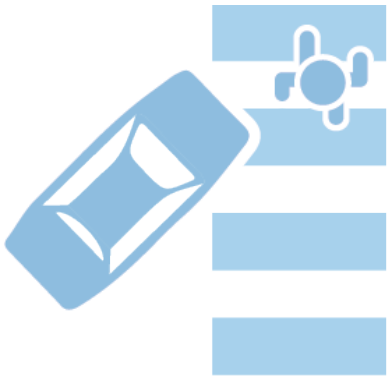


Figure 4. Crash cluster analysis map: Richmond, VA.

Source: Virginia Department of Transportation (2017).

3

Analyze Crash Types and Safety Issues



GUIDING PRINCIPLES

This section describes methods for summarizing pedestrian crash types and observed traffic safety issues. This information is important for selecting countermeasures. The following are important considerations for this step:

» Diagram crashes according to information included on crash reports (see Figure 5 for a sample diagram).

» Review the crash types described by the Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE).

» Conduct a pedestrian Road Safety Audit (RSA) to formally engage representatives from various departments and interest groups.

» Lead an informal site visit to engage stakeholders and describe conditions observed in the field.

Diagram Crash Reports

Crash diagrams are created to graphically illustrate crash data associated with a given site. Each crash is plotted on a schematic of the site at the approximate location where the crash occurred. Icons are used to represent crash types so that patterns are identifiable. Spatial analysis tools like GIS can also enhance the analysis. Crash diagrams are sometimes plotted on aerial imagery and cross referenced with a tabular listing of the associated crash data so that agency staff can easily access key information. Crash diagrams are useful when there are many crashes associated with a site. An agency may not have sufficient pedestrian crash history to reveal crash patterns, but the absence of crash data does not necessarily mean a safety problem does not exist. In these cases, an agency should consider systemic analysis.

Identify Crash Factors

Whether an agency is assembling the crash diagrams or simply conducting an exercise to identify potential factors for pedestrian crashes in their jurisdiction, these factors can be considered:

» Vehicle speed.

» Compliance with regulations and traffic devices.

» Pedestrian crossing behaviors.

» Built environment or area type.

- Intersection presence and types of traffic control devices.
- Pedestrian crossing distance.
- Time of day/day of week/seasonal factors.
- Alcohol involvement by pedestrians or drivers.
- Demographics.
- Special populations, such as school-aged children, older adults, and persons with disabilities.
- Presence of transit stops.

Conduct a Road Safety Audit (RSA)

An RSA is the formal safety performance examination of an existing or future road or intersection by an independent, multidisciplinary team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users. An RSA considers all users of the roadway and human factors and generates a formal report and response upon its conclusion. The agency can use the field conditions inventory and crash type summary during the RSA process. RSAs typically produce multiple planning-level countermeasure recommendations for the study corridor or area.

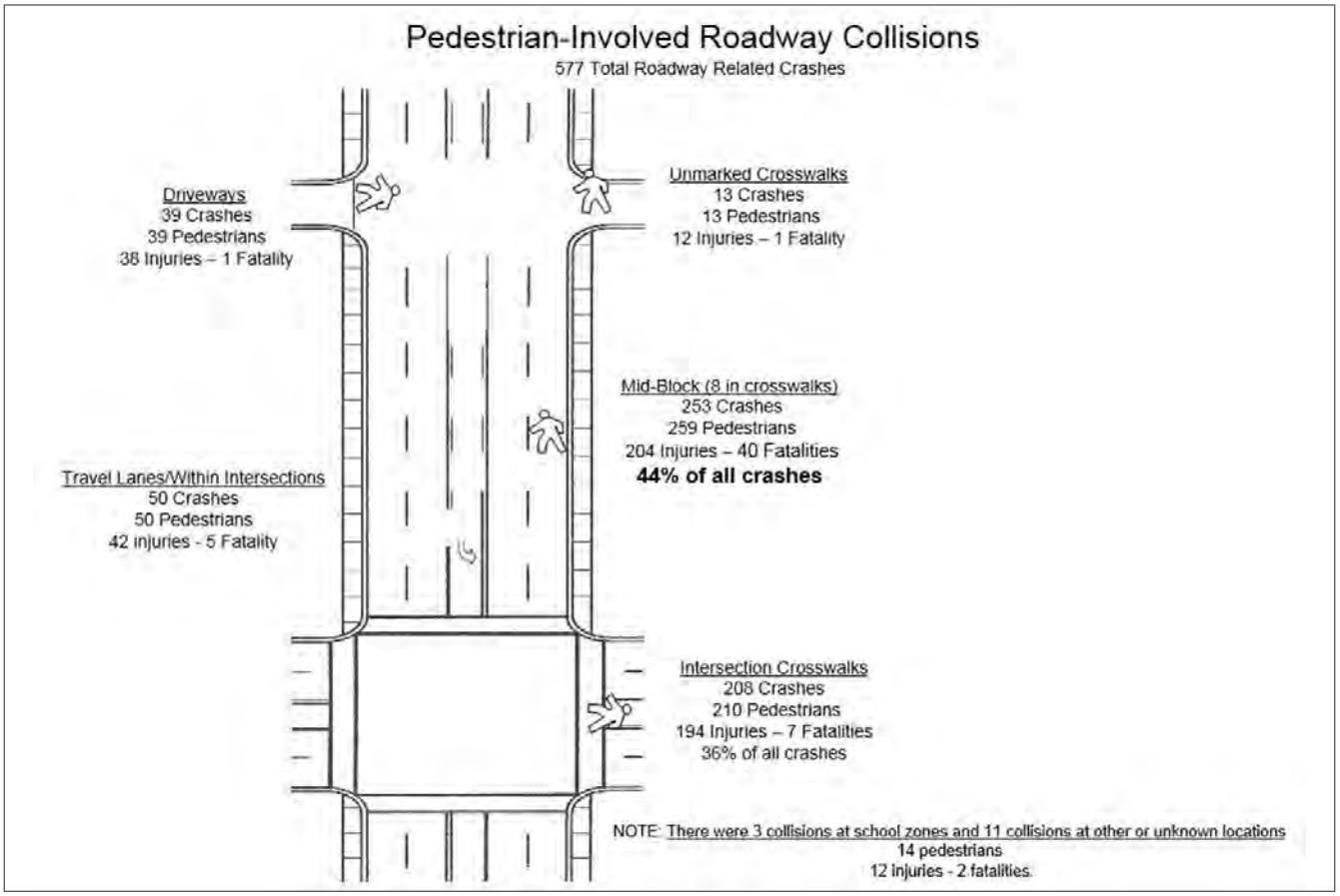


Figure 5. Pedestrian collision summary.

Source: City of Phoenix, AZ. 2015 Pedestrian Collision Summary (2015).

Like traditional RSAs, pedestrian RSAs are performed by a multidisciplinary team of experts or agency representatives, use structured prompt lists, and consider the surrounding socioeconomic and land use context. The materials for a pedestrian RSA provide more detail on pedestrian safety issues and examine elements such as signage, obstructions, signals, bus stop locations, drainage, and lighting. These tools can help identify possible deficiencies in the pedestrian network and potential locations for further investigation.

Lead an Informal Site Visit

An alternative to a formal RSA is an on-site evaluation of pedestrian conditions including representatives from multiple agency departments and stakeholder interest groups. An informal on-site evaluation can collect information about pedestrian crossings and traffic operations at the neighborhood or area-wide scale. Law enforcement, public health, community groups, neighborhood residents, street or transportation departments, planning, emergency response, schools, and public transportation agencies can be involved in the process. The findings from this informal evaluation should be documented and shared with participants.

RESOURCES

FHWA Model Road Safety Audit Policy (2014)

This resource outlines the steps typically taken to conduct an RSA and the roles of the stakeholders. Identifying safety issues is an element of the RSA that is accompanied by suggestions on how to enhance the specific road's safety.

Pedestrian RSA Guidelines and Prompt Lists (2007)

This resource complements practices for RSAs with additional guidance and a field manual for a pedestrian-focused RSA. An RSA team will use the knowledge of a diverse team, analysis of crash data, and a site visit to identify pedestrian safety issues.

Pedestrian RSA Case Studies (2009)

This website provides links to several examples of RSAs focused on identifying pedestrian safety risks and improvement strategies. For example, the City of Tucson, Arizona conducted an RSA of roadways with PHBs to improve the countermeasures' visibility and usability.

PEDSAFE: Pedestrian Crash Typing

PEDSAFE provides definitions for 12 key pedestrian crash types identified by the software package, the Pedestrian and Bicycle Crash Analysis Tool (PBCAT). PBCAT is still used by many agencies but may not be compatible with some current operating systems.

4

Select Countermeasure(s)

GUIDING PRINCIPLES

This section can help the agency select countermeasures based on information previously collected and assessed. The agency can use the following resources to select countermeasures:

» First, reference Table 1 to compare roadway and vehicle speed characteristics to countermeasure options.

» Then, reference Table 2 to compare crash types and other observed safety issues to countermeasure options.

» Review Appendix B for more information about countermeasure CRFs and CMFs.

Application of Countermeasures by Roadway Feature

Table 1 includes a comprehensive matrix and list of STEP pedestrian crash countermeasures suggested for application at uncontrolled crossing locations per roadway and traffic features. The countermeasures are assigned to specific matrix cells based on safety research, best practices, and established national guidelines. When a pedestrian crossing is established, the agency should review the countermeasure options in the cells before selecting the optimal group of crossing treatments. The agency should consider the previously obtained characteristics such as pedestrian volume, operational speeds, land use context, and other site features when selecting countermeasures.

The agency should also reference the MUTCD and other national, State, and local guidelines when making the final selection of countermeasures.

For example, the agency may evaluate a 5-lane road with no raised median, an AADT of 12,000, and a 35 mph posted speed limit. The matrix recommends the agency strongly consider high-visibility crosswalks, adequate lighting, and parking restrictions on the approaches. In addition, the agency should strongly consider adding advance Yield Here To (Stop Here For) Pedestrians signs and yield (stop) lines, pedestrian refuge islands, and PHBs. Other candidate treatments include implementing a Road Diet along the corridor and adding curb extensions.

Table 1 provides initial countermeasure options for various roadway conditions. Each matrix cell indicates possibilities that may be appropriate for designated pedestrian crossings. Not all of the countermeasures listed in the matrix cell should necessarily be installed at a crossing.

For multi-lane roadway crossings with vehicle AADTs exceeding 10,000, a marked crosswalk alone is typically insufficient (Zegeer, 2005). Under such conditions, more substantial crossing improvements (such as the refuge island, PHB, and RRFB) are also needed to prevent an increase in pedestrian crash potential.

Table 1. Application of pedestrian crash countermeasures by roadway feature.

Roadway Configuration	Posted Speed Limit and AADT								
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 lanes (1 lane in each direction)	❶ 2 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6 7 9	① 5 6 7 9	① 5 6 ❾
3 lanes with raised median (1 lane in each direction)	❶ 2 3 4 5 7 9	❶ ❸ 5 7 9	① ❸ 5 ❼ ❾	① 3 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① ❸ 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❾
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 ❾	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 ❾	① ❸ 4 5 6 7 9	① ❸ 5 6 ❾	① ❸ 5 6 ❾
4+ lanes with raised median (2 or more lanes in each direction)	❶ ❸ 5 7 8 9	❶ ❸ 5 7 8 9	① ❸ 5 8 ❾	① ❸ 5 7 8 9	① ❸ 5 ❼ 8 9	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 9	① ❸ 5 8 ❾	① ❸ 5 8 ❾
4+ lanes w/o raised median (2 or more lanes in each direction)	❶ ❸ 5 6 7 8 9	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ ❼ 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 8 ❾

Given the set of conditions in a cell,

- # Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1 High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2 Raised crosswalk
3 Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4 In-Street Pedestrian Crossing sign
5 Curb extension
6 Pedestrian refuge island
7 Rectangular Rapid-Flashing Beacon (RRFB)**
8 Road Diet
9 Pedestrian Hybrid Beacon (PHB)**

**Refer to Chapter 4, 'Using Table 1 and Table 2 to Select Countermeasures,' for more information about using multiple countermeasures.*

***It should be noted that the PHB and RRFB are not both installed at the same crossing location.*

This table was developed using information from: Zegeer, C.V., J.R. Stewart, H.H. Huang, P.A. Lagerwey, J. Feaganes, and B.J. Campbell. (2005). Safety effects of marked versus unmarked crosswalks at uncontrolled locations: Final report and recommended guidelines. FHWA, No. FHWA-HRT-04-100, Washington, D.C.; FHWA. Manual on Uniform Traffic Control Devices, 2009 Edition. (revised 2012). Chapter 4F, Pedestrian Hybrid Beacons. FHWA, Washington, D.C.; FHWA. Crash Modification Factors (CMF) Clearinghouse. http://www.cmfclearinghouse.org/; FHWA. Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE). http://www.pedbikesafe.org/PEDSAFE/; Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N.J. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. (2017). NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. Transportation Research Board, Washington, D.C.; Thomas, Thirsk, and Zegeer. (2016). NCHRP Synthesis 498: Application of Pedestrian Crossing Treatments for Streets and Highways. Transportation Research Board, Washington, D.C.; and personal interviews with selected pedestrian safety practitioners.

Safety Issues Addressed per Countermeasure

The results of the crash analysis, road safety audit, and/or stakeholder input provide the agency with a better understanding of the risk factors at uncontrolled crossing locations. The countermeasures listed in this guide can improve the visibility of crossing locations and reduce crashes, and they each address at least one additional safety concern associated with a higher risk of collision and/or severe injury. These additional safety issues include the following: excessive vehicle speed, inadequate conspicuity/visibility, drivers not yielding to pedestrians in crosswalks, and insufficient separation from traffic.

Table 2 shows the specific safety issues that each countermeasure may address. For example, the addition of PHBs has been consistently shown to improve motorist yielding by 90 percent or greater, when compared with no traffic control or warning type devices.

Table 2. Safety issues addressed per countermeasure.

Pedestrian Crash Countermeasure for Uncontrolled Crossings	Safety Issue Addressed				
	Conflicts at crossing locations	Excessive vehicle speed	Inadequate conspicuity/ visibility	Drivers not yielding to pedestrians in crosswalks	Insufficient separation from traffic
Crosswalk visibility enhancement	✓	✓	✓	✓	✓
High-visibility crosswalk markings*	✓		✓	✓	
Parking restriction on crosswalk approach*	✓		✓	✓	
Improved nighttime lighting*	✓		✓		
Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line*	✓		✓	✓	✓
In-Street Pedestrian Crossing sign*	✓	✓	✓	✓	
Curb extension*	✓	✓	✓		✓
Raised crosswalk	✓	✓	✓	✓	
Pedestrian refuge island	✓	✓	✓		✓
Pedestrian Hybrid Beacon	✓	✓	✓	✓	
Road Diet	✓	✓	✓		✓
Rectangular Rapid-Flashing Beacon	✓		✓	✓	✓

*These countermeasures make up the STEP countermeasure "crosswalk visibility enhancements." Multiple countermeasures may be implemented at a location as part of crosswalk visibility enhancements.

Using Table 1 and Table 2 to Select Countermeasures

Table 1 provides initial countermeasure options for various roadway conditions. Each matrix cell indicates possibilities that may be appropriate for designated pedestrian crossings. Not all of the countermeasures listed in the matrix cell should necessarily be installed at a crossing. Agency officials should also review safety issues referenced in Table 2, the surrounding land development context, pedestrian travel patterns, countermeasure effectiveness, and costs when considering what countermeasure(s) are best suited for the crossing.

A marked crosswalk is useful to show pedestrians and drivers preferred crossing locations. However, for multi-lane roadway crossings where vehicle AADTs are in excess of 10,000, a marked crosswalk alone is typically not sufficient (Zegeer, 2005). Under such conditions, more substantial crossing improvements are also needed to prevent an increase in pedestrian crash potential. Examples of more substantial treatments include the refuge island, PHB, and RRFB. Refer to the symbols used in Table 1 for when a marked crosswalk should be paired with one or more of the other countermeasures described.

To further increase visibility of pedestrian crossings, agencies often integrate multiple countermeasures. For example, the Pedestrian Hybrid Beacon is often installed in conjunction with advance stop markings and signs. Also, Road Diets present opportunities for adding pedestrian refuge islands and curb extensions at key crossing locations. Agencies should consider roadway geometry and the MUTCD when integrating multiple countermeasures.

Countermeasure Descriptions

This subsection describes considerations for implementation of each of the countermeasures included in Tables 1 and 2. The agency can review other guidance—such as the MUTCD, the AASHTO Pedestrian Guide, and/or agency policies and practices—to identify and select countermeasures for implementation.

Crosswalk visibility enhancements

High-visibility crosswalks may include a variety of crosswalk striping designs, such as ladder, continental, or bar pairs. A high-visibility crosswalk is much easier for an approaching motorist to see than the traditional parallel lines. The agency should strongly consider providing high-visibility crosswalks at all established midblock pedestrian crossings. The high-visibility markings may be supplemented with the pedestrian crossing warning signs (sign W11-2 in the MUTCD) on each approach to the crosswalk. MUTCD Section 2C.50—*Non Vehicular Warning Signs* and Section 3B.18—*Crosswalk Markings* provide additional information.

The agency should also strongly consider implementing parking restrictions on the crosswalk approach at all established

pedestrian crossings (both approaches) so there is adequate sight distance for motorists on the approaches to the crossings and ample sight distance for pedestrians attempting to cross. The minimum setback is 20 feet where speeds are 25 mph or less, and 30 feet between 26 mph and 35 mph. If this cannot be done, the curbs should be "bulbed out" to allow the pedestrian to see past the parked vehicle along the street. Adjacent bus stops should be placed downstream of the crosswalk and not on the crosswalk approach.

The agency should consider providing an appropriate level of lighting at all established pedestrian crossings. Consideration should be given to placing the lights 10 to 15 feet in advance of the crosswalk on both sides of the street and on both approaches to better light the front of the pedestrian and avoid silhouette lighting (where possible).

In-street Pedestrian Crossing sign

In-street signs are placed in the middle of the road at a crossing and are often used in conjunction with refuge islands. These signs may be appropriate on 2-lane or 3-lane roads with speed limits of 30 mph or less. On higher-speed, higher-volume, and/or multilane roads, this treatment may not be as visually prominent; therefore, it may be less effective (drivers may not notice the signs in time to stop in advance of the crosswalk). For such roadways, more robust treatments will be needed. When making the choice to use these signs, the agency should consider making a plan and securing a funding source for the maintenance and prompt replacement of damaged signs. The MUTCD permits in-street pedestrian signs for installation on centerlines and along lane lines. MUTCD Section 2B.12—*In-Street and Overhead Pedestrian Crossing Signs* contains additional information about these signs.

Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line

Advance Yield Here To (Stop Here For) Pedestrians signs are placed between 30 and 50 feet in advance of the marked crosswalk along with the stop line or "shark's teeth" yield line. This is a candidate treatment for any uncontrolled pedestrian crossing, and should be strongly considered for any established pedestrian crossing on roads with four or more lanes and/or roads with speed limits of 35 mph or greater. Stop Here For Pedestrians signs should only be used where the law specifically requires that a driver must stop for a pedestrian in a crosswalk. MUTCD Section 2B.11—*Yield Here To Pedestrians Signs and Stop Here For Pedestrians Signs* and Section 3B.16—*Stop and Yield Lines* contain additional information.

Curb extension

A curb extension or "bulbout" extends the sidewalk or curb line into the street or parking lane, thus reducing the street width and improving sight distance between the driver and pedestrian. A curb extension is a candidate treatment for any uncontrolled pedestrian crossing, particularly where parking lanes exist. Curb extensions should not extend into paths of travel for bicyclists.

Raised crosswalk

Raised crosswalks function as an extension of the sidewalk and allow a pedestrian to cross the street at a constant grade. A raised crosswalk is typically a candidate treatment on 2-lane or 3-lane roads with speed limits of 30 mph or less and AADTs below 9,000. Raised crossings are generally

avoided on truck routes, emergency routes, and arterial streets. Drainage needs to be accommodated. See MUTCD Section 3B.25—*Speed Hump Markings* for additional information about markings that can be used alongside raised crosswalks.

Pedestrian refuge island

A pedestrian island is typically constructed in the middle of a 2-way street and provides a place for pedestrians to stand and wait for motorists to stop or yield. This countermeasure is highly desirable for midblock pedestrian crossings on roads with four or more lanes, and should be considered for undivided crossings of four or more lanes with speed limits of 35 mph or greater and/or AADTs of 9,000 or greater. Median islands may also be a candidate treatment for uncontrolled pedestrian crossings on 3-lane or 2-lane roads, especially where the street is wide and/or where vehicle speed or volumes are moderate to high. Consideration should be given to creating a two-stage crossing with the island to encourage pedestrians to cross one direction of traffic at a time and look towards oncoming traffic before completing the second part of the crossing. The minimum pedestrian refuge island width is approximately 6 feet. MUTCD Section 3B.10—*Approach Markings for Obstructions*, Section 3B.18—*Crosswalk Markings*, and Section 3B.23—*Curb Markings* provide additional information.

Pedestrian Hybrid Beacon (PHB)

A PHB head consists of two red lenses above a single yellow lens, and is used in conjunction with pedestrian signal heads installed at each end of a marked crosswalk. Figure 6 shows a rendering of a PHB. The PHB has been referred to as the High-Intensity Activated crossWalK beacon (HAWK), but the MUTCD refers to this device as the PHB.

Unlike a traffic signal, the PHB rests in dark until a pedestrian activates it via pushbutton or other form of detection. When activated, the beacon displays a sequence of flashing and solid lights that control vehicular traffic while the pedestrian signal heads indicate the pedestrian walk interval and a pedestrian clearance interval.

The PHB should meet the installation guidelines—based on speed, pedestrian volume, vehicular volume, and crossing length—as provided in Section 4F.01 of the MUTCD (See Figure 4F-1 for speeds of 35 mph or less; Figure 4F-2 for speeds greater than 35 mph). Research indicates that PHBs are most effective at roads with three or more lanes that have AADTs above 9,000. PHBs should be strongly considered for all midblock crossings where the roadway speed limits are equal to or greater than 40 mph. Refer to Table 1 for other conditions where PHBs should be strongly considered. It should be noted that the PHB and RRFB are not both installed at the same crossing location.

PHBs have also been installed successfully at intersections under certain conditions. Since the current MUTCD guidance is to locate PHBs at least 100 feet away from an intersection, engineering judgment/ engineering study must be carefully applied if considering an installation at an intersection.

Figure 6. Rendering of a PHB.

Source: FHWA STEP Countermeasure Tech Sheets.
(Note: Drawing not to scale.)

Road Diet

A road diet reconfigures the roadway. A frequently-implemented Road Diet involves converting a 4-lane, undivided roadway into a 3-lane roadway with a center turn lane. This is a candidate treatment for any undivided road with wide travel lanes or multiple lanes that can be narrowed or repurposed to improve pedestrian crossing safety.

After conducting a traffic analysis to consider its feasibility, the agency may determine that a Road Diet is a good candidate for use on roads with four or more lanes and traffic volumes of approximately 20,000 or less. In some cases, agencies have successfully implemented Road Diets on roads with AADTs of up to 25,000. By reducing the width of the roadway, pedestrians benefit from shorter crossing distances and often bike lanes or streetscape features can be added. Road Diets are often effectively accomplished during pavement resurfacing.

Rectangular Rapid-Flashing Beacon (RRFB)

An RRFB is a pedestrian-actuated conspicuity enhancement used in combination with a pedestrian, school, or trail crossing warning sign to improve safety at uncontrolled, marked crosswalks. The device includes two rectangular-shaped yellow indications, each with an LED-array-based light source, that flash with high frequency when activated.

RRFBs may be used to enhance the conspicuity of standard pedestrian and school crossing warning signs at uncontrolled marked crosswalks. RRFBs are placed on both ends of a crosswalk. If the crosswalk contains a pedestrian refuge island or other type of median, an RRFB should be placed to the right of the crosswalk and on the median (instead of the left side of the crosswalk). The RRFB's irregular flashing pattern pattern is unlit when not activated and can be activated manually by pedestrians using a push button or passively by a pedestrian detection system. This device is not currently included in the MUTCD, but FHWA has issued Interim Approval 21 (IA-21) for the use of the RRFB. State and local agencies must request and receive permission to use this interim approval before they can use the RRFB. IA-21 provides additional information about the conditions of use, including dimensions, placement, and flashing requirements. IA-21 does not provide guidance or criteria based on number of lanes, speed, or traffic volumes.

The RRFB is a treatment option at many types of established pedestrian crossings. Research indicates RRFBs can result in motorist yielding rates as high as 98 percent at marked crosswalks. However, yielding rates as low as 19 percent have also been noted. Compliance rates varied most per the city location, posted speed limit, crossing distance, and whether the road was one- or two-way.[1] RRFBs are particularly effective at multilane crossings with speed limits less than 40 mph. Consider the PHB instead of RRFBs for roadways with higher speeds. Table 1 provides specific conditions where practitioners should strongly consider the PHB instead of the RRFB.

[1]*Fitzpatrick, K., M. Brewer, R. Avelar, and T. Lindheimer.* Will You Stop for Me? Roadway Design and Traffic Control Device Influences on Drivers Yielding to Pedestrians in a Crosswalk with a Rectangular Rapid-Flashing Beacon. *Report No. TTI-CTS-0010. Texas A&M Transportation Institute, College Station, Texas. June 2016.* https://static.tti.tamu.edu/tti.tamu.edu/documents/TTI-CTS-0010.pdf

RESOURCES

PEDSAFE, Pedestrian Safety Guide and Countermeasure Selection System
This online tool includes links to research studies, crash reduction statistics, and case studies for nearly 70 pedestrian safety countermeasures. Its Countermeasure Selection Tool provides countermeasure recommendations for uncontrolled crossing locations based upon variables such as AADT, vehicle speed, and number of lanes.

Manual on Uniform Traffic Control Devices (MUTCD)
This manual provides transportation engineers and planners with detailed guidance for the design and application of traffic control devices, including signage, roadway markings, and intersection controls. Refer to the specific sections of the MUTCD listed in the countermeasure descriptions and consult State-level supplements for additional information.

FHWA Road Diet Desk Reference (2015)
This resource includes sample policy, case studies, and design guidance for agencies and decision-makers considering Road Diets. The benefits of Road Diets include reducing vehicle speeds, reducing number of lanes to cross, and allocating space for pedestrian refuge islands.

Highway Safety Manual
This manual provides detailed guidance for the collection, analysis, and evaluation of roadway crash data, as well as related CMFs and treatment selection guidance.

FHWA Design Resource Index
This resource directs practitioners to the specific location of information about pedestrian and bicycle treatments or countermeasures, across various design guidelines published by organizations such as AASHTO, the Institute of Transportation Engineers, and National Association of City Transportation Officials.

Informational Brief: Treatments for Uncontrolled Marked Crosswalks (2017)
FHWA provided this information about optional treatments for uncontrolled pedestrian crossing locations.

TCRP REPORT 112/NCHRP REPORT 562: Improving Pedestrian Safety at Unsignalized Crossings (2006)
This document recommends treatments to improve safety for pedestrians crossing high-volume, high-speed roadways at unsignalized intersections, with particular focus on roadways served by public transportation.

NHTSA "A Primer for Highway Safety Professionals" (2016)
This resource outlines a comprehensive approach to improving safety for bicyclists and pedestrians and offers a summary of the most frequently used engineering, enforcement, and education safety measures. The resource identifies how certain treatments may be placed in relation to other treatments, such as the coordinated installation of a pedestrian refuge island and lighting.

CMF Clearinghouse
The CMF Clearinghouse is an online database of countermeasures and corresponding CMFs. The database describes the confidence of the study that produced the CMF with an assigned "star quality rating." The clearinghouse includes CMFs for most of the STEP countermeasures.

NCHRP Report 841: Development of CMFs for Uncontrolled Pedestrian Crossing Treatments (2017)
This report describes the safety benefits and CMFs for four types of pedestrian crossing treatments—rectangular rapid flashing beacons, PHBs, pedestrian refuge islands, and advance crosswalk signs and pavement markings.

NCHRP Synthesis 498: Application of Pedestrian Crossing Treatments for Streets and Highways (2016)
This is a compilation of existing practices regarding the selection and implementation of pedestrian crossing improvements, as well as a literature review of research on more than 25 pedestrian crossing treatments.

5

Consult Design and Installation Resources

GUIDING PRINCIPLES

This section identifies additional resources that refine countermeasure options for priority sites. The following are important considerations for this step:

» Consult the MUTCD for recommendations for signage and roadway markings for all countermeasures.

» Review the MUTCD (Part 4) for more considerations, including pedestrian volumes and vehicle operating speeds, for the installation of PHBs.

» Consult local and national design guidance for the preferred width and placement of these countermeasures.

Review Agency Design Guidelines

The agency can review and, if needed, enhance local guidance for traffic engineers and roadway designers to follow when installing countermeasures. The agency's roadway design manual can include details, such as design and installation guidance, for each of the countermeasure options. The agency may also consider creating additional warrant and threshold guidance for countermeasures such as the Road Diet, considering local conditions.

Consult the MUTCD

The agency may focus on three parts of the MUTCD for additional considerations when installing countermeasures:

» Part 2: Signs.

» Part 3: Markings.

» Part 4: Highway Traffic Signals (includes detailed guidance for installing Pedestrian Hybrid Beacons based on traffic speeds, traffic volumes, and pedestrian volumes).

RESOURCE

AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities, 1st Edition (2004)

This guide provides recommendations for the planning, design, and operation of accommodations for pedestrians on public rights-of-way. This guide also discusses the impact of land use and site design on pedestrian safety and connectivity.

6

Identify Opportunities and Monitor Outcomes

GUIDING PRINCIPLES

This section describes possible options for funding and implementation of the countermeasures described in this guide. The following are important considerations for this step:

» Review the State's HSIP process for considering and funding pedestrian crossing countermeasures.

» Review local traffic calming and land development policies for opportunities to install pedestrian crossing countermeasures.

» Consider the costs to design, install, and maintain selected countermeasures.

» Collect usage and crash data for at least three years after countermeasures are installed at priority sites.

» Continue to monitor priority sites not funded for countermeasure installation.

» Provide information to the public about planned countermeasure projects. Information should address the safety benefits and possible impacts to traffic operations.

Consider Funding Options

A major consideration when selecting a safety project or program is identifying and securing the funding to design, construct, operate, and maintain the project or program. FHWA, NHTSA, and other Federal agencies distribute funding to States and other jurisdictions for transportation safety projects. If local funding is scarce, agencies may approach the State Departments of Transportation for safety improvement funding consideration. Some projects may require a local match to leverage State or Federal dollars. The agency may consider the following steps:

» Submit high-priority pedestrian crash locations as HSIP projects.

» Consider other State safety funding programs for low-cost pedestrian safety improvements.

» Address gaps in pedestrian accommodations through other State or Federal funding programs such as Transportation Alternatives Program, Congestion Mitigation and Air Quality, and Surface Transportation Block Grant (STBG).

Identify Opportunities for Successful Implementation

The agency can look beyond safety-focused funding programs to help implement countermeasures. By incorporating safety treatments into roadway maintenance or traffic operation projects, the agency can realize cost savings. For example, the agency should consider how resurfacing and operational projects may include countermeasures such as Road Diets and pedestrian crossing signal improvements.

The agency can also engage the community prior to programing the project. The treatments are likely to affect traffic operations, and the public may respond negatively to the change without sufficient notice and education. The agency can develop public education materials describing the benefits and costs of the countermeasures. Law enforcement, pedestrian safety advocates, public health officials, and other community partners may be able to help distribute the materials.

It is important for the agency to work with local partners to coordinate early in the process of designing or improving a roadway to identify opportunities for improved pedestrian crossing safety. If the agency has a Complete Streets policy in place, the policy describes how pedestrian crossing treatments and sidewalks are incorporated into roadway projects. Roadway project design should identify locations and countermeasure options for pedestrian crossings. Developing preliminary cost estimates early for these improvements will help local partners make decisions about funding for pedestrian crossing treatments.

The agency can also work with land developers to incorporate pedestrian crossing treatments into site plans and connecting roadways. Land development policies provide an opportunity to integrate pedestrian and multimodal improvements, connectivity, and accommodations into site plans and nearby roadways. The agency can examine development policies or ordinances for requirements to install sidewalks and pedestrian crossing treatments.

Construct Improvements

The public may have questions about the improvements as construction activities begin. The agency should post information about the improvements and a timeline for construction to a public-facing website and consider issuing a press release about the project. The agency should also provide detailed information to neighbors and business owners impacted by construction activities about the project. Pedestrians will maintain access through the work zone area by way of temporary walkways, curb ramps, and traffic control signage.

The agency may consider phasing in the improvements. For example, a refuge island can be implemented initially by pavement markings and flexible delineators in the center lane. The agency can later add a raised median and appropriate landscaping at the refuge island.

Monitor Results of Implementation

The agency should consider monitoring the impacts of countermeasures per defined performance measures. Specific performance measures can be outlined in plans, such as a PSAP. The PSAP may

also list priority locations and proposed countermeasures.

The first measure of success for a project or program is public support. States and local governments can prepare public information for countermeasures that are new to the community or may change traffic patterns. Public information about the projects may describe the crash history or risks noted at the site, as well as the benefits of the proposed countermeasure.

States and local government can also collect and analyze crash and traffic data related to countermeasure sites for at least 3 years following the installation of the project. This time allows for data to be collected to compare crash rates and severity with the same data collected before the installation. The agency should work with their State HSIP to evaluate projects by continuing to collect data, and it is essential that the treatment installation date be documented. In addition to the safety performance of the treatment, agency staff should consider assessing the durability and life cycle maintenance needs for in-service devices.

In addition to crash data, it is important to collect data on pedestrian volumes, traffic speeds, and interactions between pedestrians and drivers. Pedestrian volume data can help demonstrate the benefits of implementing safety countermeasures. Information about traffic speeds and behaviors also help confirm the effectiveness of installing these countermeasures. As more pedestrian crossing treatments are implemented, State and local agencies can use these data to research the effectiveness of countermeasures and best practices for installation. Evaluation also helps an agency demonstrate the value of the investment in countermeasures to community leaders and the public.

RESOURCES

FHWA Federal-aid Program Administration

This website includes links to guidance for local and State governments administering federally-funded projects, such as those funded by HSIP or STBG.

FHWA Guidebook for Developing Pedestrian and Bicycle Performance Measures (2016)

This resource identifies a wide variety of potential metrics for setting goals, prioritizing projects and evaluating outcomes of bicycle and pedestrian plans, including plans for pedestrian safety improvements. Performance measures may include pedestrian levels of service or pedestrian fatality rates.

FHWA Pedestrian and Bicycle Funding Opportunities Summary (2016)

This resource includes a matrix comparing eligibility of various federal transportation funding programs for different types of bicycle and pedestrian projects.

NCHRP Report 803: Pedestrian and Bicycle Transportation Along Existing Roads—ActiveTrans Priority Tool Guidebook (2015)

This resource includes an interactive tool and guidance to help agencies prioritize pedestrian and bicycle improvements, including safety projects, either as standalone or incidental to a roadway project.

Glossary

Annual Average Daily Traffic (AADT)

The total volume of traffic passing a point or segment of a highway facility in both directions for one year divided by the number of days in the year.

Average Daily Traffic (ADT)

The average 24-hour volume of traffic passing a point or segment of a highway in both directions.

Complete Streets

Complete Streets are designed and operated to enable safe access for all users, including pedestrians, bicyclists, motorists, and transit riders of all ages and abilities. (Smart Growth America, National Complete Streets Coalition.)

Controlled pedestrian crossing

A pedestrian crossing where motorists are required to stop by either a STOP sign, traffic signal, or other traffic control device.

Crash modification factor (CMF)

A multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure. If available, calibrated or locally developed State estimates may provide a better estimate of effects for the State. (Crash Modification Factors Clearinghouse.)

Crash reduction factor (CRF)

The percentage crash reduction that might be expected after implementing a given countermeasure at a specific site.

Curb extensions

A roadway edge treatment where a curb line is bulbed out toward the middle of the roadway to narrow the width of the street. Curb extensions are sometimes called "neckdowns."

Highway Safety Improvement Program (HSIP)

A Federal-aid program with the purpose to achieve a significant reduction in traffic fatalities and serious injuries on all public roads, including non-State-owned roads and roads on tribal land. The HSIP requires a data-driven, strategic approach to improving highway safety on all public roads with a focus on performance. (FHWA.)

High visibility crosswalk

A pedestrian crossing location marked by patterns such as zebra, ladder, or continental markings as described by the MUTCD.

Marked crosswalk

A pedestrian crossing that is delineated by white crosswalk pavement markings.

Parking restriction

Parking restriction can include the removal of parking space markings, installation of new "parking prohibition" pavement markings or curb paint, and signs.

Pedestrian Hybrid Beacon (PHB)

A traffic control device with a face that consists of two red lenses above a single yellow lens. Unlike a traffic signal, the PHB rests in dark until a pedestrian activates it via pushbutton or other form of detection.

Raised crosswalk

Raised crosswalks are ramped speed tables spanning the entire width of the roadway, often placed at midblock crossing locations.

Rectangular Rapid-Flashing Beacon (RRFB)

RRFBs are pedestrian-actuated conspicuity enhancements used in combination with a pedestrian, school, or trail crossing warning sign to improve safety at uncontrolled, marked crosswalks. The device includes two rectangular-shaped yellow indications, each with an LED-array-based light source, that flash with high frequency when activated. RRFBs are placed on both ends of a crosswalk. If the crosswalk contains a pedestrian refuge island or other type of median, an RRFB should be placed to the right of the crosswalk and on the median (instead of the left side of the crosswalk). The flashing pattern is pedestrian-activated by pushbuttons or automated detection and is unlit when not activated.

Refuge island

A median with a refuge area that is intended to help protect pedestrians who are crossing the road. This countermeasure is sometimes referred to as a crossing island or pedestrian island.

Road Diet

A roadway reconfiguration resulting in a reduction in the number of travel lanes. The space gained by eliminating lanes is typically used for other uses and travel modes. (FHWA.)

Road Safety Audit (RSA)

A formal examination of an existing or future road or intersection by a multidisciplinary team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users. (FHWA.)

Toward Zero Deaths (TZD)

TZD is a traffic safety framework that seeks to eliminate highway fatalities by engaging diverse safety partners and technology to address traffic safety culture. (See also: Vision Zero.)

Uncontrolled pedestrian crossing

An established pedestrian crossing that does not include a traffic signal, beacon, or STOP sign to require that motor vehicles stop before entering the crosswalk.

Vehicle queue

A line of stopped vehicles in a single travel lane, commonly caused by traffic control at an intersection.

Vision Zero (VZ)

Similar to TZD, Vision Zero is a vision to eliminate traffic fatalities and serious injuries within the transportation system. VZ employs comprehensive strategies to address roadway design, traffic behavior, and law enforcement.

Appendix A: Framework for a Resolution Supporting Pedestrian Safety

Agency policies respond to a need or opportunity, such as pedestrian safety crash and fatality trends. A resolution may help decision-makers, including elected officials or appointed commissioners, better understand the need for pedestrian crash countermeasure policy or design guidance.

The following is a list of possible elements for a local or Statewide resolution in support of a pedestrian crossing policy. These elements may be developed into "Whereas" statements or be included as explanatory text introducing the policy. The list of resolution elements is presented as four categories covering a spectrum of pedestrian safety issues.

1. Example statistics that may raise awareness of pedestrian safety trends.

» Percent pedestrian fatalities of total traffic fatalities.

» Number of total pedestrian crashes/ fatalities per year.

» Percent of pedestrian crashes occurring outside the intersection.

SAMPLE LANGUAGE

"Whereas the number of pedestrian crashes per year and the percent of pedestrian fatalities out of all traffic fatalities in [*State*] demonstrate the need for improved pedestrian safety at roadway crossings…"

2. List of broad issues that agencies commonly consider when discussing pedestrian safety and crash countermeasures.

» Safety is a priority for all road users.

» Crossings are essential to a complete network for pedestrian mobility.

» Pedestrian safety is part of overall quality of life and improved public health.

» Improvements to pedestrian safety often improve safety for all road users.

» Pedestrian countermeasures are genreally lower-cost treatments.

» Many pedestrian crash countermeasures have been evaluated as highly effective.

SAMPLE LANGUAGE

"Whereas [*Agency/State*] recognizes that safety is a priority for all road users, and improvements to pedestrian safety often improve safety for all road users…"

3. List of example planning documents that frequently discuss Statewide pedestrian safety concerns and may include statistics or other compelling reasons for implementing pedestrian crossing treatments.

» State Strategic Highway Safety Plan includes pedestrian safety as an emphasis area.

» State Highway Safety Plan includes pedestrian safety programs or enforcement support.

» State Roadway Design Manual includes guidance for countermeasure design.

» Highway Safety Improvement Program includes safety performance targets for non-motorists.

SAMPLE LANGUAGE

"Whereas [*State*]'s Strategic Highway Safety Plan addresses pedestrian safety as an emphasis area…"

4. List of Statewide opportunities for promoting, planning, and funding the construction of pedestrian crossing treatments.

» Highway Safety Improvement Program includes specific focus or funding for pedestrian crash countermeasures.

» Complete Streets Policy directs the inclusion of pedestrian accommodations as part of other transportation projects.

» Vision Zero or Towards Zero Deaths initiative strives to reduce or eliminate all traffic-related fatalities, including pedestrians.

SAMPLE LANGUAGE

"Whereas [*Agency*]'s Highway Safety Improvement Program includes specific funding for pedestrian crash countermeasures…"

Appendix B: CRF and CMF Summary Table

Table 3. CRFs and CMFs by countermeasure.

Countermeasure	CRF	CMF	Basis	Reference
Crosswalk visibility enhancement[1]	—	—	—	—
Advance STOP/YIELD signs and markings	25%	0.75	Pedestrian crashes[2]	Zegeer, et. al. 2017
Add overhead lighting	23%	0.77	Total injury crashes	Harkey, et. al. 2008
High-visibility marking[3]	48%	0.52	Pedestrian crashes	Chen, et. al., 2012
High-visibility markings (school zone)[3]	37%	0.63	Pedestrian crashes	Feldman, et. al. 2010
Parking restriction on crosswalk approach	30%	0.70	Pedestrian crashes	Gan, et. al., 2005
In-street Pedestrian Crossing sign	UNK	UNK	N/A	N/A
Curb extension	UNK	UNK	N/A	N/A
Raised crosswalk (speed tables)	45%	0.55	Pedestrian crashes	Elvik, et. al., 2004
	30%	0.70	Vehicle crashes	
Pedestrian refuge island	32%	0.68	Pedestrian crashes	Zegeer, et. al., 2017
PHB	55%	0.45	Pedestrian crashes	Zegeer, et. al., 2017
Road Diet – Urban area	19%	0.81	Total crashes	Pawlovich, et. al., 2006
Road Diet – Suburban area	47%	0.53	Total crashes	Persaud, et. al., 2010
RRFB	47%	0.53	Pedestrian crashes	Zegeer, et. al. 2017

[1]This category of countermeasure includes treatments which may improve the visibility between the motorist and the crossing pedestrian.

[2]Refers to pedestrian street crossing crashes, and does not include pedestrians walking along the road crashes or "unusual" crash types.

[3]The effects of high-visibility pavement markings (e.g., ladder, continental crosswalk markings) in the "after" period is compared to pedestrian crashes with parallel line markings in the "before" period.

References

1. Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N.J. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. *NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments.* NCHRP, Transportation Research Board, Washington, DC, 2017.

2. Harkey, D.L., R. Srinivasan, J. Baek, F. Council, K. Eccles, N. Lefler, F. Gross, B. Persaud, C. Lyon, E. Hauer, and J. Bonneson. *NCHRP Report 617: Accident Modification Factors for Traffic Engineering and ITS Improvements.* NCHRP, Transportation Research Board, Washington, DC, 2008.

3. Chen, L., C. Chen, R. Ewing, C.E. McKnight, R. Srinivasan, and M. Roe. "Safety Countermeasures and Crash Reduction in New York City—Experience and Lessons Learned." *Accident Analysis and Prevention*, 2012.

4. Feldman, M., J. Manzi, and M. Mitman. "An Empirical Bayesian Evaluation of the Safety Effects of High-Visibility School (Yellow) Crosswalks in San Francisco, California." *Transportation Research Record: Journal of the Transportation Research Board,* No. 2198, Transportation Research Board, Washington, D.C., 2010, pp. 8-14.

5. Gan, A., J. Shen, and A. Rodriguez. "Update of Florida Crash Reduction Factors and Countermeasures to Improve the Development of District Safety Improvement Projects." Final report. Florida Department of Transportation, Tallahassee, FL, 2005.

6. Elvik, R., P. Christensen, and A. Amundsen. "Speed and Road Accidents An Evaluation of the Power Model." Transportokonomisk Institutt, Oslo, Norway, 2004.

7. Pawlovich, M.D., W. Li, A. Carriquiry, and T. Welch. "Iowa's Experience with Road Diet Measures—Use of Bayesian Approach to Assess Impacts on Crash Frequencies and Crash Rates." *Transportation Research Record: Journal of the Transportation Research Board,* No. 1953, Transportation Research Board, Washington, D.C., 2006.

8. Persaud, B., B. Lan, C. Lyon, and R. Bhim. "Comparison of empirical Bayes and full Bayes approaches for before–after road safety evaluations." *Accident Analysis & Prevention,* Volume 42, Issue 1, 2010, pp. 38-43.

FHWA-SA-17-072

July 2018, Updated

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

EDC