Transportation Commission

June 10, 2025
Town Hall
2121 Cross Timbers Road
Flower Mound, TX 75028

6:30 p.m.

AGENDA

A. CALL TO ORDER

B. PLEDGE OF ALLEGIANCE TO THE AMERICAN FLAG

C. PUBLIC COMMENT

The purpose of this item is to allow the public an opportunity to address the Board/Commission regarding any item on this agenda that is not a “Public Hearing.” Issues regarding daily operational or administrative matters should first be dealt with by calling Town Hall at 972- 874-6000 during business hours. To speak to the Board/Commission during public comment, please fill out a comment form, which is located in the lobby of Town Hall.

In accordance with the Texas Open Meetings Act, the Board/Commission is restricted from discussing or acting on items not listed on the agenda.

- Speakers are limited to 3 minutes; a tone will sound at 30 seconds left and when time has expired, and times may be adjusted by the Chair depending on the number of speakers.
- Speakers must address their comments to the Board/Commission.
- Please state your name and address when speaking.

D. ASSISTANT DIRECTOR REPORT

1. Update status report related to operational issues, capital improvement projects, and TxDOT projects
2. Future Transportation Meeting dates - July 8th & August 12th
3. Future Agenda Items
4. Micromobility Update

E. CONSENT ITEM(S)

This part of the agenda consists of non-controversial, or “housekeeping” items required by law. Items may be removed from Consent by any Commissioner by making such request prior to a motion and vote.

1. Consider approval of the minutes from 05/13. - Consider approval of the minutes from May 13, 2025.

F. WORK SESSION

1. Discussion regarding the development of community outreach policy for the installation of streetlights
2. Discussion on the Development of a Town Crosswalk Policy

G. ADJOURN

I do hereby certify that the Notice of Meeting was posted on the bulletin board at the Town Hall for the Town of Flower Mound, Texas, in a place convenient and readily accessible to the general public at all times and said Notice was also posted on the Town's website in accordance with GC Section 551.056 on the following date and time: June 6, 2025, at 5:30 p.m., at least 72 hours prior to the scheduled time of said meeting.

Tina Wells, Administrative Secretary

The Flower Mound Town Hall and Jody Smith Hall are wheelchair-accessible. Requests for accommodation or interpretive services must be made 48 hours prior to this meeting by contacting Town Hall at 972.874.6000. Additional time limits will be provided for members of the public that need to address the Town Council through a translator.

Transportation Commission

May 13, 2025
Town Hall
2121 Cross Timbers Road
Flower Mound, TX 75028

6:30 p.m.

DRAFT MINUTES

A. CALL TO ORDER

Meeting was called to order by Chair Chris Reed at 6:31 p.m.

The Transportation Commission met in a regular meeting with the following members present:

Chris Reed, Place 6, Chair
Bjorn Vandug, Place 1
Bob Morreira, Place 2
Jason Huse, Place 4
Erica Mulder, Place 5
Charlie Landry, Place 7
Ricky Clark, Place 8, Alternate
Barbara Barrios, Place 9, Alternate

with the following member(s) absent:

Ron Hogue, Place 3, Vice Chair

constituting a quorum with the following members of the Town Staff participating:

Matthew Hotelling, Assistant Director Public Works/Transportation
Thomas Peppers, Project Engineer
Tina Wells, Administrative Secretary
Manny Palacios, Assistant Director Public Works/Operations
Darren Branch, Lieutenant Professional Services - Police
Barbara Hill, School Crossing Guard Supervisor - Police

B. PLEDGE OF ALLEGIANCE TO THE AMERICAN FLAG

Chair Chris Reed led the pledge.

C. PUBLIC COMMENT

The purpose of this item is to allow the public an opportunity to address the Board/Commission regarding any item on this agenda that is not a “Public Hearing.” Issues regarding daily operational or administrative matters should first be dealt with by calling Town Hall at 972- 874-6000 during business hours. To speak to the Board/Commission during public comment, please fill out a comment form, which is located in the lobby of Town Hall.

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- Speakers must address their comments to the Board/Commission.
- Please state your name and address when speaking.

None present

D. ASSISTANT DIRECTOR REPORT

1. Update status report related to operational issues, capital improvement projects, and TxDOT projects

2. Future Transportation Commission meeting dates - June 10th

3. Future Agenda Items

4. Annual Commission reporting by Chair/Vice Chair to Town Council - May 15

5. Fairway Drive Closure - Grapevine

6. Bond Election Results

E. CONSENT ITEM(S)

This part of the agenda consists of non-controversial, or “housekeeping” items required by law. Items may be removed from Consent by any Commissioner by making such request prior to a motion and vote.

1. Consider approval of the minutes from 04/08. - Consider approval of the minutes from April 8, 2025.

ACTION:	Bjorn Vandug moved to approve E.1. as presented in the agenda caption. Charles Landry seconded the motion.
AYES:	Bjorn Vandug, Jason Huse, Erica Mulder, Charles Landry, Robert Morreira, Ricky Clark
NAYS:	None
ABSTAIN:	None
RESULT:	6 : 0

F. REGULAR ITEM(S)

1. Community Outreach Policy for the Installation of Streetlights. - Consider a recommendation to staff on the adoption of a proposed community outreach policy for the installation of streetlights.

ACTION:	Jason Huse moved to postpone Item F1 to the June 10, 2025, Commission meeting for further discussion. Bjorn Vandug seconded the motion.
AYES:	Bjorn Vandug, Jason Huse, Erica Mulder, Charles Landry, Robert Morreira, Ricky Clark
NAYS:	None
ABSTAIN:	None
RESULT:	6 : 0

2. Sidewalk Links - 2025 - Consider a recommendation to staff for proposed sidewalk links locations for inclusion in the FY2025-2026 Sidewalk Links Construction Project, through the Annual Budget process.

ACTION:	Bjorn Vandug moved to approve F.2. as presented in the agenda caption. Robert Morreira seconded the motion.
AYES:	Bjorn Vandug, Jason Huse, Erica Mulder, Charles Landry, Robert Morreira, Ricky Clark
NAYS:	None
ABSTAIN:	None
RESULT:	6 : 0

G. WORK SESSION

1. Sharing of information related to School Crossing Guard Index for May 2025

2. Capital Improvement Project Review for Streets and Street Reconstruction for FY 25-26

H. ADJOURN

Motion to adjourn made by Erica Mulder and seconded by Robert Morreira, all in favor. Meeting adjourned at 8:32 p.m.

TRANSPORTATION COMMISSION AGENDA F.1. WORK SESSION

DATE: June 10, 2025
FROM: Thomas Peppers, Project Engineer
ITEM: **Discussion regarding the development of community outreach policy for the installation of streetlights**

BACKGROUND: As part of the Town's Road Safety Enhancement Program, the need for better visibility on roadways at night was identified as a priority. To address this, staff have been tasked with presenting potential locations where streetlights could be installed to improve safety and visibility at night. Potential locations for streetlights are typically identified in one of two ways: through resident requests or recommendations by staff. For a new streetlight to be considered, the proposed location must meet the Town's current design standards, which require streetlights to be installed at intersections, cul-de-sacs, significant curves in the roadway, and at mid-block locations where the block length or spacing between existing streetlights exceeds 600 feet.

Once a location is determined to meet these standards, staff will add it to the streetlight priority list. This list is presented to the Transportation Commission (TRC) for review and recommendation on which locations should be prioritized for installation as part of the annual streetlight installation program. Following the Commission's recommendation, staff will coordinate with the utility provider and, when applicable, impacted property owners to facilitate the installation of the streetlights.

At the April 8, 2025, TRC meeting, the Commission requested staff to develop a formal policy to standardize the Town's community outreach process for new streetlight installations. This request was prompted by the recognition that the Town's existing outreach practices can vary across projects, creating inconsistencies and uncertainty in how community input is collected and considered. At the May 13, 2025, TRC meeting, staff presented the proposed community outreach policy for new streetlight installations. During the meeting, the Commissioners expressed concerns that the policy was too complex and recommended that staff simplify the policy's structure and procedures.

This work session presents two simplified versions of the proposed community outreach policy. The first version, preferred by staff, is provided in Attachment 1. It contains two scenarios which define who is responsible for conducting community outreach and the procedures to be followed. The two scenarios are:

- Individual Citizen Streetlight Requests/Town-Initiated Streetlight Projects
- Homeowners Association (HOA) - Initiated Streetlight Requests

The second version, included in Attachment 2, simplifies the policy further by assigning full responsibility for community outreach to staff, regardless of who initiates the streetlight request. Both versions define criteria for when community outreach is required and establish a consistent process for notifying and engaging property owners impacted by proposed streetlight installations.

The proposed policy would only apply to new streetlight installations at locations that meet the Town's design standards and are recommended by the TRC. It would not apply to streetlights installed as part of new residential subdivisions or commercial/industrial developments.

CURRENT PROCEDURE/PRACTICE: Currently, there is no formal policy in place to guide public engagement for streetlight installations. Instead, community outreach is conducted on a project-by-project basis based on the context and location of the project. For streetlight requests in neighborhoods without an HOA, or for Town-initiated projects, the current practice is for staff to lead the outreach effort. This includes identifying property owners directly impacted by the proposed installation and mailing each a notice. Staff then review the responses received and, based on community input, determine whether to proceed with the installation, revise the proposed location, or postpone the project.

For streetlight requests initiated by an HOA or located within a neighborhood managed by an HOA, staff works with the HOA to conduct the community outreach. This approach is generally more efficient than staff trying to contact property owners directly, as HOAs typically maintain current contact information for residents and can distribute information quickly. In these cases, the HOA is asked to notify impacted property owners, gather their feedback, and submit the collected responses to staff for consideration in determining next steps for the project.

KEY COMPONENTS OF THE POLICY

Outreach Requirement: When a proposed streetlight is located within 150 feet of a residential property, the Town will initiate a formal community outreach process. This will ensure that property owners have a chance to voice their opinions and concerns before any installation moves forward. Staff will identify which properties will be impacted according to this policy. Each impacted property owner will be notified and asked to submit feedback, which will be considered during the decision-making process.

For the purposes of this policy, "Impacted property owners" are defined as any property owner that has all or a portion of their property located within a 150-foot radius of a proposed streetlight and directly abuts the street(s) where the streetlight is to be installed.

A 150-foot radius was selected as a reasonable distance to identify properties impacted by the illumination of a streetlight. A visual representation of the typical light distribution for a residential streetlight is included in Attachment 3. As illustrated in the attachment, most of the light from the streetlight extends approximately 75 feet to either side of the fixture and about 40 feet to the front and rear. This light distribution is based on the same type of streetlight that was recently installed in the Terracina subdivision. The only difference is that those fixtures were mounted on 14-foot poles instead of 12-foot poles. CoServ is currently in the process of switching out the poles to the correct height.

Outreach Process: The following summarizes the outreach responsibilities and required procedures for each scenario in both versions of the simplified community outreach policy:

1. Individual Citizen Streetlight Requests/Town initiated Streetlight Projects

Staff will conduct community outreach following the same procedures as currently. Property owners will have 30 days to respond to the notice. If a property owner does not respond within the initial 30-day notice period, Staff will initiate the follow-up process described below:

- Second mailed notice, providing an additional 30-day response period.

- If no response is received, a door hanger will be placed at the property, allowing 15 more days for a reply.
- If no response is received after both follow-up attempts, the property is recorded as supporting the installation.

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If the project is located within a neighborhood managed by an HOA, Staff will notify the HOA of the project. While feedback received from the HOA will be acknowledged, final decisions regarding the installation of a streetlight will be made based on the feedback collected from impacted property owners.

2. HOA-Initiated Streetlight Requests

The HOA is responsible for conducting community outreach. Staff will define the outreach area and provide a list of impacted properties. The HOA must notify each impacted property owner by sending a notice. The notice must include:

- Project description
- Location of the proposed streetlight
- Request for feedback
- Staff contact information

The HOA must also:

- Collect feedback from the property owner(s) where the streetlight is proposed to be installed.
- Submit all notices, proof of delivery, and feedback to staff.

If an impacted property owner does not respond to the HOA's outreach efforts or if their feedback cannot be verified, Staff will attempt to contact the property owner directly, following the outreach procedures established for Town-Initiated projects. If a response is still not received after all these efforts, the property owner will be considered in support of the project.

Waiver of Community Outreach Requirement: The community outreach process may be waived when a streetlight installation is necessary to address a public safety concern on a Town-designated thoroughfare. This applies in cases where there is clear evidence of a safety issue, such as a pattern of nighttime-related crashes, poorly illuminated crosswalks, or other hazardous conditions. The decision to waive community outreach must be justified with supporting documentation, including crash data, field evaluations, or similar evidence. Regardless of the waiver, impacted property owners will continue to receive notice of the planned streetlight installation.

Decision Thresholds: To Identify how feedback collected from impacted property owners will influence decisions regarding proposed streetlight installations. Community support thresholds have been established as part of this policy. The thresholds are based on a simple majority vote and are as follows:

- If more than 50 percent of the impacted property owners support the project, staff will proceed with the installation.
- If feedback is evenly split (50 percent in support and 50 percent in opposition), the request will be referred to the TRC for formal review and recommendation.

- If less than 50 percent of impacted property owners support the project, the installation will be deferred.

BOARD REVIEW/CITIZEN FEEDBACK: At the May 13, 2025, TRC meeting, the Commission reviewed the proposed community outreach policy for new streetlight installations and provided feedback to Staff. The general consensus form the Commission was that the policy was too complex. The Commission recommended staff revise and simplify the proposed policy.

ALTERNATIVES: Feedback from the TRC will be taken into consideration.

FISCAL IMPACT: N/A

LEGAL REVIEW: N/A

ATTACHMENTS:
1. Community Outreach Policy for the Installation of Streetlights Version 1
2. Community Outreach Policy for the Installation of Streetlights Version 2
3. Typical Light Distribution for a Residential Streetlight

DRAFT MOTION: No formal action. This item is for discussion and to gather the Commission's feedback.

Community Outreach Policy for the Installation of Streetlights

PURPOSE:

The purpose of this policy is to establish a standardized process for engaging residents in the decision-making process regarding the installation of new streetlights within residential areas. By standardizing outreach procedures, the Town aims to ensure that lighting decisions reflect community input and are made in a consistent and equitable manner.

STATEMENT OF POLICY:

This policy shall govern the installation of new streetlights at locations determined to meet the standards established by the Town and recommended by the Transportation Commission. It applies to all standalone street lighting projects not associated with new residential subdivisions or new commercial and/or industrial developments.

DEFINITIONS:

- **HOA:** The homeowner's association representing the interests of property owners within a specific residential subdivision or neighborhood.
- **Impacted Property Owner:** Any property owner that has all or a portion of their property located within a 150-foot radius of a proposed streetlight and directly abuts the street(s) where the streetlight is to be installed.
- **Town:** Town of Flower Mound.
- **Transportation Commission:** The advisory body appointed by the Town Council responsible for reviewing and providing recommendations to Staff on transportation-related matters.
- **Staff:** Refers to employees of the Town responsible for the evaluation, administration, and management of streetlight requests.

STANDARDS AND GUIDANCE:

For the installation of a streetlight to be considered, the proposed location must meet current Town standards as outlined in the latest *Engineering Services Design Criteria and Construction Standards Manuals.*

New streetlights will not be approved to illuminate private yards, driveways, or other privately owned areas, which should be illuminated by private security lighting at the property owner's expense. Exceptions to this policy may be considered on a case-by-case basis. Streetlights are intended to illuminate public streets and thoroughfares, and, in some limited instances, public pedestrian ways providing linkage to parks, schools, and other public areas where pedestrian safety is a concern.

OUTREACH REQUIREMENT:

If a proposed streetlight is located within 150 feet of a residential property, the Town will initiate a formal outreach process to gather community input. All impacted property owners will be notified and given the opportunity to provide feedback on the proposed installation.

OUTREACH PROCESS:

The responsibility for conducting community outreach and the specific procedures to be followed, will depend on one of the two scenarios described below:

Individual Citizen Streetlight Requests and Town-Initiated Streetlight Projects

For streetlight requests submitted by individuals or for Town-initiated projects, Staff shall be responsible for conducting community outreach. Staff will identify all impacted property owners, as defined in this policy, and mail each a written notice of the Town's plan to install a streetlight near their property. The notice will include:

- A description of the proposed project
- A map showing the proposed location of the streetlight
- Instructions and contact information for submitting feedback
- A statement that recipients have thirty (30) days from the mailing date to submit their feedback

To ensure that all impacted property owners are given a reasonable opportunity to provide input. If a property owner does not respond within the initial 30-day notice period, Staff will mail a follow-up notice, providing an additional 30 days to submit feedback. If no response is received after the second notice, Staff will make a final attempt by placing a door hanger on the property, providing 15 more days for the property owner to respond. If there is still no response after this final attempt, the property owner will be considered in support of the project.

If a proposed streetlight is located within a neighborhood managed by an HOA, Staff will notify the HOA of the project and offer the HOA the option to assume responsibility for notifying and obtaining feedback from impacted property owners. If the HOA chooses to take this responsibility, it must follow the outreach procedures outlined in the HOA-Initiated section of this policy. While feedback received from the HOA will be acknowledged, final decisions regarding the installation of a streetlight will be made based on the feedback collected from impacted property owners.

HOA-Initiated Streetlight Requests

For a streetlight request initiated by an HOA, the HOA shall be responsible for conducting community outreach. Staff will identify the outreach area and provide the HOA with a list of all impacted properties that must be included in the outreach effort. The HOA must notify each impacted property owner by sending a written notice through one of the following methods: mail, email, hand delivery with signed confirmation, or other approved method. The notice must include:

- An explanation of the proposed project
- A map or description of the proposed location of the streetlight.
- A request for feedback
- Contact information for Town Staff

Once community outreach is complete, the HOA must submit copies of all notices sent, corresponding proof of delivery, and all feedback received to the Town. Staff will review these materials to confirm that all outreach requirements have been met. If an impacted property owner does not respond to the HOA's outreach efforts or if their feedback cannot be verified, Staff will attempt to contact the property owner directly following the outreach procedures established for Town-Initiated projects. If a response is still not received after all these efforts the property owner will be considered in support of the project.

WAIVER OF OUTREACH REQUIREMENT:

If a proposed streetlight is located on a Town-designated thoroughfare and is being installed to address a public safety concern, the Assistant Director of Public Works/Transportation, or their designee, may waive the community outreach requirement. In such cases, staff must document the decision by preparing a written statement that describes why the requirement is being waived and provides supporting evidence of the safety concern, such as a pattern of nighttime-related crashes, poorly illuminated crosswalks, or other hazardous conditions that could be mitigated by the installation of a streetlight.

The statement and any supporting documentation shall be retained in the project file and made available upon request. Although the requirement may be waived, staff will still notify impacted property owners as a courtesy, providing them with information about the planned streetlight installation.

DECISION THRESHOLDS:

The final decision on whether to install a streetlight will be based on the overall level of support collected through the community outreach process. Staff will use the following response thresholds to determine whether the project should move forward, require further review, or be deferred.

- If greater than 50 percent of the impacted property owners are in support of the project, the Town will proceed with the installation of the streetlight.

- If the collected feedback returns an even split (50 percent support and 50 percent opposition), the request will be brought to the Town's Transportation Commission for a formal review and recommendation on whether to proceed with installing the streetlight.

- If less than 50 percent of the impacted property owners are in support of the project, the installation of the streetlight will be deferred. Staff may re-evaluate the location if conditions change or no sooner than twelve months from the original decision date, unless there are significant changes warranting a re-evaluation.

This policy was presented and approved at the May 13, 2025, Transportation Commission meeting by a vote of _____to _____.

_____

Chris Reed, Chair, TRC

_____

Matthew Hotelling, Assistant Director of Public Works/Transportation

Community Outreach Policy for the Installation of Streetlights

PURPOSE:

The purpose of this policy is to establish a standardized process for engaging residents in the decision-making process regarding the installation of new streetlights within residential areas. By standardizing outreach procedures, the Town aims to ensure that lighting decisions reflect community input and are made in a consistent and equitable manner.

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OUTREACH PROCESS:

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- A map showing the proposed location of the streetlight
- Instructions and contact information for submitting feedback
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To ensure that all impacted property owners are given a reasonable opportunity to provide input. If a property owner does not respond within the initial 30-day notice period, Staff will mail a follow-up notice, providing an additional 30 days to submit feedback. If no response is received after the second notice, Staff will make a final attempt by placing a door hanger on the property, providing 15 more days for the property owner to respond. If there is still no response after this final attempt, the property owner will be considered in support of the project.

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WAIVER OF OUTREACH REQUIREMENT:

If a proposed streetlight is located on a Town-designated thoroughfare and is being installed to address a public safety concern, the Assistant Director of Public Works/Transportation, or their designee, may waive the community outreach requirement. In such cases, staff must document the decision by preparing a written statement that describes why the requirement is being waived and provides supporting evidence of the safety concern, such as a pattern of nighttime-related crashes, poorly illuminated crosswalks, or other hazardous conditions that could be mitigated by the installation of a streetlight.

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File Help Tools

Visual Template Tool ™

AcuityBrands.

Settings

Units: Feet - Lux

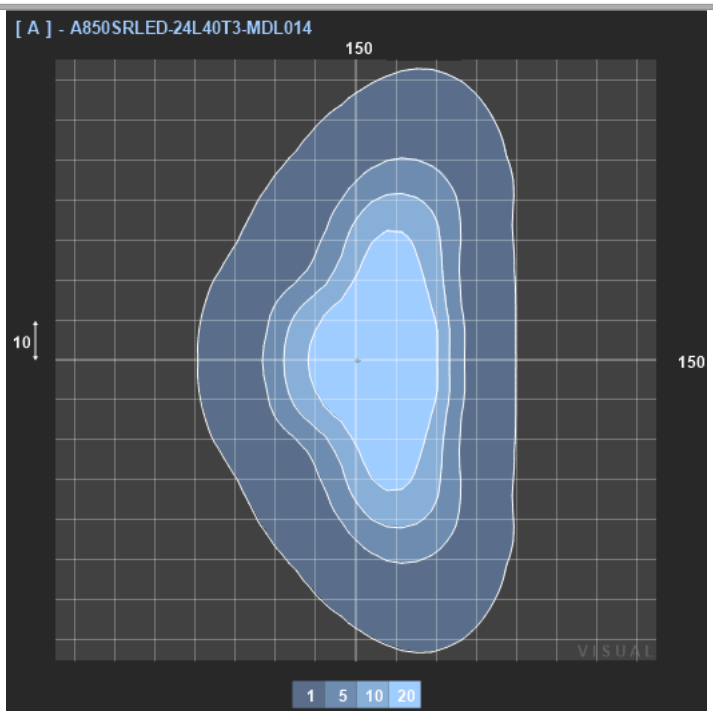
Precision: 0

Calculation Area

Area Length	150	ft
Area Width	150	ft
Point Spacing X	10	ft
Point Spacing Y	10	ft
Gridlines	10	ft

Criteria

Illuminance	20	lux



Calculation Results

Calculation Area	150 by 150		ft
Point Spacing	10 by 10		ft
	A	--	
Max Illuminance	102.3	--	lux
Area > 20 lux	1420	--	ft²

Display

Points

A --

1	lux
5	lux
10	lux
20	lux

Project Information

A

No Photo Available

Sternberg Lighting

[A] - A850SRLED-24L40T3-MDL014

Configuration	Single	Light Loss Factor	1	Lamp Quantity	1
Mounting Height	12	Orientation	90	Lumens Per Lamp	10240
Support Length	0	Tilt	0	Wattage	87

Copyright 2011-2025, Acuity Brands Lighting, Inc. Visual Template Tool version: 2.0.1.0. Results generated by this tool are provided for informational purposes only, without any warranty as to accuracy, completeness, reliability or otherwise. The calculated results may be dependent on user provided data or data provided from publicly available sources, and do not take into account all factors and circumstances. The Visual Support Center is available at VisualSupport@AcuityBrands.com .

TRANSPORTATION COMMISSION AGENDA F.2. WORK SESSION

DATE: June 10, 2025
FROM: Thomas Peppers, Project Engineer
ITEM: **Discussion on the Development of a Town Crosswalk Policy**

BACKGROUND: As the town continues to grow, the need to ensure safe, accessible, and efficient pedestrian infrastructure becomes increasingly important. Crosswalks are a foundational component of pedestrian infrastructure. Beyond their functional purpose, crosswalks contribute to broader goals, such as promoting walkability, encouraging active transportation, and reducing the risk of pedestrian-related crashes when properly planned and designed. Currently, crosswalk requests are evaluated on a case-by-case basis using engineering judgment and recognized best practices. While this method provides some flexibility, it often results in inconsistencies in crosswalk placement and treatment. Without a formalized policy, it can be challenging for staff to determine the most appropriate locations and conditions for installing marked crosswalks.

To address this challenge, staff propose the development of a formal crosswalk policy. This policy would establish a consistent and transparent procedure for evaluating crosswalk requests and implementing improvements on Town-owned and maintained roadways. It would provide a structured framework for assessing the need for crosswalks based on factors such as traffic volume, pedestrian activity, crash history, and roadway design. It would also identify a range of treatments, such as pavement markings, signage, lighting, and geometric modifications to help pedestrians cross roadways safely.

By creating a formal crosswalk policy, staff aim to make the Town's pedestrian infrastructure safer and more consistent. The policy will standardize how crosswalk requests are evaluated, guide design and placement decisions, and outline procedures for installation on Town roadways. At the September 10, 2024, TRC meeting, staff presented a preliminary draft of the crosswalk policy to introduce its framework, outline key components, and solicit feedback from the Commission. Building on that discussion, this work session will present a refined version of the proposed crosswalk policy which is provided in Attachment 1.

The updated Crosswalk Policy provides comprehensive guidance on the installation, enhancement, relocation, and removal of crosswalks on Town roadways. The policy outlines the function of crosswalks, their legal basis under the Texas Transportation Code, and discusses both the benefits and limitations of marked crosswalks. It also establishes criteria for when crosswalks are warranted, details best practices for their design and placement at intersections and mid-block locations and presents a range of crossing treatments that can be used to improve pedestrian safety.

The information presented in the draft crosswalk policy is based on extensive research drawn from crosswalk policies adopted by various agencies across the United States, as well as nationally recognized best practices in pedestrian safety. To provide additional context, Attachment 2 presents crosswalk policies from several municipalities to give insight into how other jurisdictions address similar challenges related to crosswalk design and placement. Attachment 3 complies with relevant national and state-level publications focused on improving pedestrian crossing safety.

The proposed policy is organized into two main sections:

1. Marking Crosswalks at Controlled Locations
2. Marking Crosswalks at Uncontrolled Locations

Controlled locations refer to intersection approaches or mid-block locations regulated by traffic control devices such as traffic signals, stop signs, or yield signs. For these locations, the policy establishes criteria for when crosswalks should be marked and provides guidance on the appropriate design, placement, and implementation of crosswalk improvements.

Uncontrolled locations refer to intersection approaches or mid-block locations not regulated by a traffic control device. Pedestrian crossings at these locations require careful consideration during planning and design, as drivers are not always required to stop. Instead, drivers must recognize the presence of a pedestrian crossing and yield the right-of-way as required by state law. This reliance on driver awareness can present significant safety issues at uncontrolled crossings, if proper markings, signage, and other treatments are not implemented.

To address this, the policy establishes a four-step evaluation process to determine whether a marked crosswalk is warranted, based on factors such as traffic volume, pedestrian demand, roadway design, and overall safety. The process is as follows:

1. **Field Review and Preliminary Data Collection:** Assess existing conditions to identify potential safety or operational concerns.
2. **Comprehensive Data Collection:** Gather detailed information on crossing location, roadway geometry, traffic conditions, and multimodal usage.
3. **Evaluation of Candidate Location**: Use the Uncontrolled Crossing Evaluation Flowchart (Attachment 4) to determine whether the location qualifies for a marked crosswalk or additional improvements.
4. **Further Analysis and Treatment Selection**: If warranted, conduct a more in-depth analysis to determine appropriate geometric modifications and identify targeted safety treatments using the Uncontrolled Crossing Treatment Matrix (Attachment 5).

To support the installation of marked crosswalks and associated crossing treatments on Town roadways, the policy includes a series of supplemental policies to ensure crossings are appropriately placed and designed to prioritize pedestrian safety.

BOARD REVIEW/CITIZEN FEEDBACK: During the September 10, 2024, TRC meeting, the Commission reviewed the initial draft crosswalk policy and provided several recommendations. Commissioners requested that crash history be incorporated into the evaluation process and sought clarification on how pedestrian volumes will be collected, especially for seasonal and weekend activity.

ALTERNATIVES: Feedback from TRC will be taken into consideration.

FISCAL IMPACT: N.A

LEGAL REVIEW: N/A

ATTACHMENTS:

1. Draft Town Crosswalk Policy
2. Combined Crosswalk Policies
3. Combined Best Practice Publications
4. Draft Uncontrolled Crossing Evaulation Flowchart
5. Draft Uncontrolled Crossing Treatment Matrix

DRAFT MOTION: No formal action. This item is for discussion and feedback from the Commission only



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TOWN OF FLOWER MOUND

CROSSWALK POLICY

PREPARED BY:

TOWN OF FLOWER MOUND

TRANSPORTATION DIVISION

JUNE 2025

Table of Contents

1. Introduction 3

1.1 Purpose and Scope 3

1.2 Flexibility and the Role of Engineering Judgement 3

1.3 How to Use this Guidance 3

2. Background 4

3. Crosswalk Fundamentals 4

3.1 Crosswalk Types 4

3.2 Why Mark a Crosswalk? 5

3.3 TMUTCD Guidance 6

3.4 Texas State Statute 7

4. Crosswalk Signing and Marking 9

4.1 Signing at Crosswalks 9

4.2 Crosswalk Markings 10

5. Marking Crosswalks at Controlled Locations 11

5.1 Signalized Intersections 11

5.2 Enhancing Pedestrian Safety at Signalized Intersections 12

5.3 Stop & Yield--Controlled Intersections 13

5.4 Roundabouts 14

6. Marking Crosswalks at Uncontrolled Locations 15

6.1 Evaluation Process 15

6.1-1 Field Review and Preliminary Data Collection 16

6.2-2 Data Collection 16

6.2-3 Evaluate Candidate Crossing Location 18

6.3 Criteria Definitions 19

6.4 Further Analysis and Selection of Crossing Treatments 22

6.5 Treatment Selection Guidance 24

6.6 Additional Crossing Treatments 26

7. Supplemental Policies 28

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1. Introduction

The Town of Flower Mound receives numerous requests each year for the installation of crosswalks. To clarify Town Policies and provide a standardized procedure for addressing crosswalk requests, the Town has developed a formal Crosswalk Policy. This policy aims to establish a consistent process for evaluating requests for crosswalks using objective criteria and best practices in pedestrian safety. The development of this policy will help town staff make informed decisions that balance community needs with the responsible allocation of town resources.

Creating safe pedestrian crossings is a complex process. Simply marking a crosswalk does not guarantee safety. This document aims to enhance pedestrian safety and mobility by establishing clear, consistent guidelines for the installation, enhancement, relocation, and removal of crosswalks on Flower Mound roadways. It provides an overview of the purpose and function of crosswalks, their legal basis under the Texas Transportation Code, and discusses both the benefits and limitations of marked crossings. The policy also defines the conditions under which crosswalks are warranted, outlines best practices for their design and placement at both intersections and mid-block locations, and presents a variety of crossing treatments that can be used to help achieve the goal of getting pedestrians safely across roadways.

1.1 Purpose and Scope

Flower Mound is committed to providing safe, accessible, and efficient pedestrian facilities. A key factor influencing pedestrians' decisions to travel is their perceived ability to safely and easily cross roads along their route. The purpose of this document is to establish criteria, procedures, and policies to guide town staff in determining where and how crosswalks should be implemented on roadways owned and maintained by the town. Adhering to these policies will ensure uniformity in the placement, design, installation, and maintenance of crosswalks throughout Flower Mound. This policy applies to all future crosswalk requests and new installations. Existing crosswalks installed on roadways owned and maintained by the town prior to the adoption of this policy are not subject to its provisions.

1.2 Flexibility and the Role of Engineering Judgement

The guidance provided in this document aims to strike a balance between prescriptive requirements, engineering analysis, and the flexibility provided by engineering judgment. In certain cases, prescriptive requirements may not be sufficient to determine the need for a marked crosswalk. When this occurs, the Director of Public Works or their designee should apply engineering judgment or conduct an engineering study to assess whether a marked crosswalk can and should be applied.

1.3 How to Use this Guidance

To determine whether a marked crosswalk is appropriate at a specific location, begin by identifying whether the crossing is located at a location controlled by a traffic signal, stop sign, or yield sign.

- If the location is controlled by a traffic control device, refer to the *Marking Crosswalks at Controlled Locations* section of this policy.
- If the location is not controlled by a traffic control device (i.e., traffic flows freely), refer to the *Marking Crosswalks at Uncontrolled* Locations section of this policy. Follow the evaluation process outlined in that section and use the attached *Uncontrolled Crossing Evaluation Flowchart.*

For detailed guidance on how to apply the flowchart, refer to the *Criteria Definitions* and *Evaluating Candidate Locations* sections of this policy. If the evaluation determines that a marked crosswalk is appropriate, consult the *Uncontrolled Crossing Treatment Matrix* to identify the recommended crossing treatments based on the specific site conditions.

2. Background

Roadway crossings can present significant barriers to pedestrian travel. The decision to travel as a pedestrian is in part dependent upon the actual and perceived ability to safely and efficiently cross roadways along the pedestrian's intended travel route. To encourage pedestrian travel and promote a more walkable community, it is essential to provide safe, accessible, and efficient crossing opportunities.

A variety of treatments can be implemented to facilitate safer pedestrian crossings, including marked crosswalks, enhanced crosswalks, Pedestrian Hybrid Beacons (PHBs), traffic signals, and grade separation. Crosswalk enhancements may include high-visibility pavement markings, signage, pedestrian-activated warning devices, i.e., Rectangular Rapid Flashing Beacons (RRFBs), and geometric improvements designed to increase pedestrian visibility and reduce crossing distance. Examples of geometric improvements include curb extensions, pedestrian refuge islands, raised crosswalks, lane reductions, and roadway design modifications.

While marked crosswalks are widely recognized as safety improvements and legally grant pedestrians the right-of-way when within them, research shows that they often lead pedestrians to feel overly confident when crossing. This overconfidence or "false sense of security" often leads pedestrians to assume that drivers will always stop for them, even in situations where it may not be possible to do so. This type of aggressive behavior often puts pedestrians in hazardous situations and contributes to a higher rate of pedestrian related accidents at marked crosswalks.

In contrast, pedestrians using unmarked crosswalks tend to feel less secure and less certain that the drivers will stop prompting them to exercise more caution and wait for a safe gap in traffic before crossing. As a result, unmarked crosswalks tend to experience fewer accidents. Despite these concerns, marked crosswalks are still a valuable safety tool when properly planned and designed.

3. Crosswalk Fundamentals

Pedestrian crossing and right-of-way laws can vary from state to state, often leading to confusion for both drivers and pedestrians about when and where it is legal to cross. This section describes the different types of crosswalks, the reasons behind marking them, their advantages and disadvantages, the state's guidance on marking them, and where crossing the road is legally permitted in Texas.

3.1 Crosswalk Types

Crosswalks can be classified into two types:

- ***Unmarked Crosswalks*** These are crossings that are <u>not</u> delineated by pavement markings, typically found at intersections where pedestrian pathways continue across the roadway.
- ***Marked Crosswalks*** These are crossings that are designated with pavement markings and are often placed at intersections or mid-block locations to enhance visibility and safety of the pedestrian crossing.

In this document, the term "crosswalk" may refer to a crosswalk either with or without markings. The term "crossing" is used to refer to a location where pedestrians cross that may or may not be a crosswalk.

Crossings are generally categorized into three types based on location and the presence of traffic control devices:

- ***Grade-separated crossings*** These are crossings where pedestrians cross a roadway using either an overpass or underpass and are not exposed to conflicts with vehicular traffic.
- ***Controlled Crossings*** These are crossings where the road crossed is controlled at the crossing by a traffic signal, PHB, STOP or YIELD sign. Controlled crossings are most commonly located at intersections.
- ***Uncontrolled Crossings*** These are crossings where the road crossed is free flowing and not controlled by a traffic control device at the crossing point. Uncontrolled crossings are typically located at mid-block locations or low-volume intersections.

3.2 Why Mark a Crosswalk?

It is important to provide designated facilities for pedestrians to use the transportation network safely and without unreasonable delay. Crosswalks provide an important connection for pedestrians. The pedestrian network should be located and designed in such a way that pedestrians are not unreasonably forced to wait for a gap in traffic or walk out of their way for a marked crosswalk. When proper crossing opportunities are not provided, pedestrians are often forced to make unsafe or undesirable choices, such as:

- Walking longer distances to reach crossings controlled by traffic signals or signs.
- Using intersections where crossings are legal but lack proper safety measures or control.
- Crossing mid-block at risky locations, particularly between two signalized intersections.

Crosswalks that are appropriately marked and enhanced provide pedestrians with a convenient and safer opportunity to cross the road.

A marked crosswalk has three primary functions:

- Provide a clear indication of where pedestrians are expected to cross. This not only gives pedestrians a defined path to follow but also helps drivers anticipate pedestrian crossings.
- Improve predictability of pedestrian behavior. This reduces the likelihood of sudden or unexpected movements that could result in accidents.
- Guide pedestrians to designated crossing points, ensuring they cross at the safest, most appropriate locations.

Marked crosswalks offer the following benefits:

- At complex or heavily trafficked intersections, marked crosswalks provide clear guidance for pedestrians on where it is safe to cross.
- Often lead pedestrians to the shortest and most direct path, minimizing their exposure to traffic and improving the efficiency of their crossing.
- By directing pedestrians to designated crossing points, marked crosswalks help to reduce the risk of accidents and improve overall pedestrian safety when properly designed.

Potential drawbacks of marked crosswalks include:

- May create a "false sense of security" for pedestrians, leading them to assume that drivers will always yield, which may not always be the case.
- On multi-lane roads with, moderate to high traffic volumes, marked crosswalks can increase the potential for accidents unless supplemented with additional safety measures.
- Require regular maintenance to remain effective, including restriping and ensuring that associated signage and crossing treatments are visible and functional.

3.3 TMUTCD Guidance

The Texas Manual on Uniform Traffic Control Devices (TMUTCD) serves as the state's guidance and standard for the design and installation of signs, markings, and signals across Texas. The town has adopted the latest edition of the TMUTCD as the town standard for traffic control devices. According to the TMUTCD, the decision to mark a crosswalk like the decision to install any other traffic control device should be guided by the fundamental principles that define an effective traffic control device. These principles include:

- Fulfill a need
- Command attention
- Convey a clear, simple meaning
- Command respect from road users
- Give adequate time for proper response

For Controlled Crossing Locations

The TMUTCD offers the following guidance for the installation of marked crosswalks at controlled intersections:

> *At locations controlled by traffic control signals or on approaches controlled by STOP or YIELD signs, crosswalk lines should be installed where engineering judgment indicates they are needed to direct pedestrians to the proper crossing path(s).*

For Uncontrolled Crossing Locations

The TMUTCD offers the following guidance for the installation of marked crosswalks at uncontrolled locations:

> *Marked crosswalks should not be used indiscriminately. An engineering study should be performed before a marked crosswalk is installed at a location away from a traffic control signal or an approach controlled by a STOP or YIELD sign. The engineering study should consider:*
>
> - *Total number of approach lanes*
> - *Presence of a median*
> - *The distance from adjacent signalized intersections/controlled crossings*
> - *Pedestrian and bicyclist volumes, paths of travel, and delays*
> - *Pedestrian ages and abilities*
> - *Average daily traffic (ADT)*
> - *Speed limit or the 85th-percentile speed,*
> - *The horizontal and vertical geometry of the crossing location,*
> - *The possible consolidation of multiple crossing points,*
> - *The availability of street lighting,*

New marked crosswalks alone, without other measures designed to reduce traffic speeds, shorten crossing distances, enhance driver awareness of the crossing, and/or provide active warning of pedestrian presence, should not be installed across uncontrolled roadways where the speed limit exceeds 40 mph and either:

- *The roadway has four or more lanes of travel without a raised median or pedestrian refuge island and an ADT of 12,000 vehicles per day or greater; or*
- *The roadway has four or more lanes of travel with a raised median or pedestrian refuge island and an ADT of 15,000 vehicles per day or greater*

3.4 Texas State Statute

In the State of Texas, both pedestrians and motorists have defined rights and responsibilities when traveling along or across roadways. At intersections pedestrians have the right-of-way in crosswalks regardless of whether the crossing is marked or not, unless the crossing is explicitly prohibited by signage or traffic signals. However, at locations outside of intersections, crosswalks are only legally recognized if marked. Sections 552.001 through 552.005 of the Texas Transportation Code define what constitutes a legal crosswalk, establish the rights and responsibilities of both pedestrians and drivers, and specify when and where drivers are required to stop and yield the right-of-way. The definitions and legal language presented in this section form the foundation for how pedestrian crossings are viewed in Texas and serves as the basis for this policy.

Texas state law defines a "crosswalk" as:

> (a) The portion of a roadway, including an intersection, designated as a pedestrian crossing by surface markings, including lines; or
>
> (b) The portion of a roadway at an intersection that is within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or, in the absence of curbs, from the edges of the traversable roadway.

Based the state-law definition of "crosswalk", a crosswalk legally exists across every approach of an intersection, regardless of whether crosswalk markings are provided. As such, pedestrians and motorists are afforded the same rights and responsibilities at both marked and unmarked crosswalks located at intersections.

Texas state law defines a "sidewalk" as:

> The portion of a street that is between the curb lines or the lateral lines of a roadway and the adjacent property lines and that is intended for the use of pedestrians.

The state-law definition of "sidewalk" is somewhat different than the word's common usage. According to state law, a sidewalk exists even if an area is "intended" for use by pedestrians. A sidewalk does not need to be paved or otherwise improved to meet the state-law definition. Sidewalks exist along almost all roadways as long as the roadside is traversable by pedestrians.

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Section. 552.001 Describes Pedestrian Right-of-Way if No Pedestrian Signals are Present:

(a) A traffic signal displaying green, red, and yellow lights or lighted arrows applies to a pedestrian as provided by this section unless the pedestrian is otherwise directed by a special pedestrian signal.

(a) A pedestrian facing a green signal may proceed across a roadway within a marked or unmarked crosswalk unless the sole green signal is a turn arrow.

(b) A pedestrian facing a steady red signal alone or a steady yellow signal may not enter a roadway.

Section. 552.002 Describes Pedestrian Right-of-Way if Pedestrian Signals are Present

(a) A pedestrian signal displaying "Walk," "Don't Walk," or "Wait" applies to a pedestrian as provided by this section.

(a) A pedestrian facing a "Walk" signal may proceed across a roadway in the direction of the signal, and the operator of a vehicle shall stop and yield the right-of-way to the pedestrian.

(b) A pedestrian may not start to cross a roadway in the direction of a "Don't Walk" signal or a "Wait" signal. A pedestrian who has partially crossed while the "Walk" signal is displayed shall proceed to a sidewalk or safety island while the "Don't Walk" signal or "Wait" signal is displayed.

Section. 552.003 Describes Right-of-Way at a Crosswalk

(a) The operator of a vehicle shall stop and yield the right-of-way to a pedestrian crossing a roadway in a crosswalk if:

1. no traffic control signal is in place or in operation; and
2. the pedestrian is:
   A. on the half of the roadway in which the vehicle is traveling; or
   B. approaching so closely from the opposite half of the roadway as to be in danger.

(b) Notwithstanding Subsection (a), a pedestrian may not suddenly leave a curb or other place of safety and proceed into a crosswalk in the path of a vehicle so close that it is impossible for the vehicle operator to stop and yield.

(c) The operator of a vehicle approaching from the rear of a vehicle that is stopped at a crosswalk to permit a pedestrian to cross a roadway may not pass the stopped vehicle.

Section. 552.005 Describes Right-of-Way at a Point Other Than a Crosswalk

(a) A pedestrian shall yield the right-of-way to a vehicle on the highway if crossing a roadway at a place:

1. other than in a marked crosswalk or in an unmarked crosswalk at an intersection; or
2. where a pedestrian tunnel or overhead pedestrian crossing has been provided.

(b) Between adjacent intersections at which traffic control signals are in operation, a pedestrian may cross only in a marked crosswalk.

(c) A pedestrian may cross a roadway intersection diagonally only if and, in the manner, authorized by a traffic control device.

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4. Crosswalk Signing and Marking

This section provides an overview of the various signs and markings typically used at crosswalks, as well as factors to consider when selecting the most appropriate signage and markings for specific crossing locations. To ensure consistency and compliance with state regulations, the town adheres to the guidelines set forth in the latest edition of the TMUTCD when installing signs and markings on town roadways.

4.1 Signing at Crosswalks

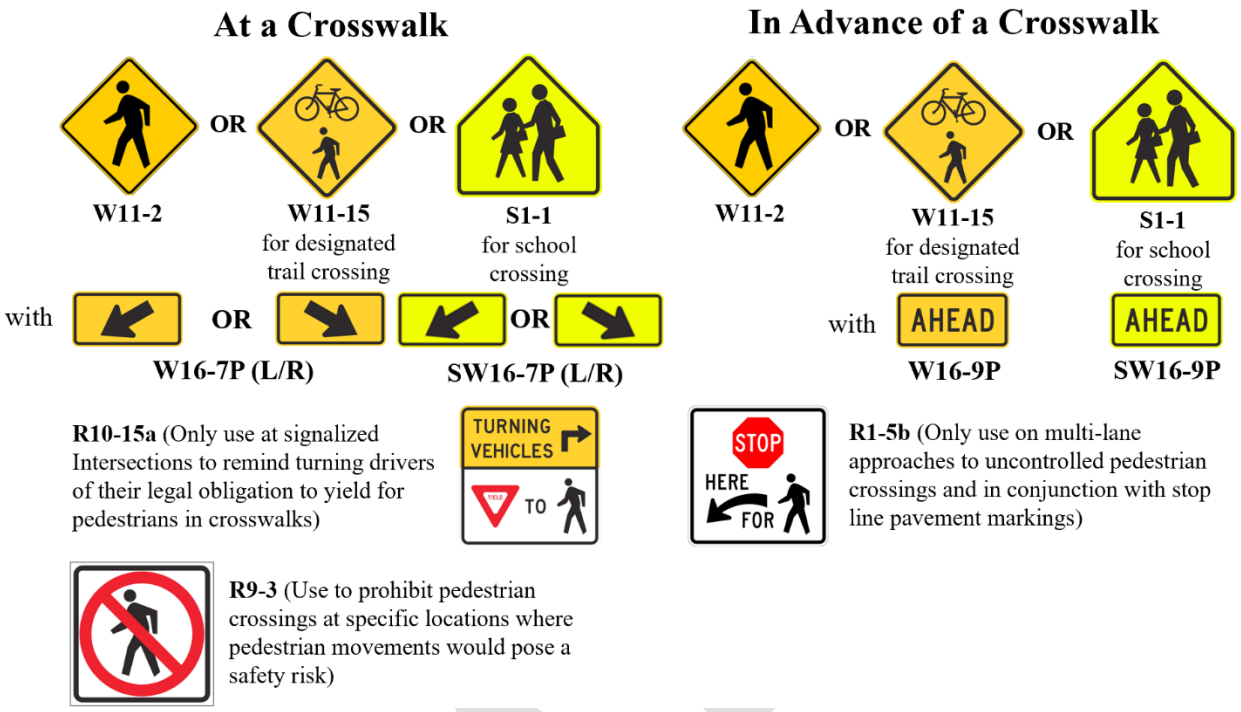
The Town employs a range of warning and regulatory signs at both marked and unmarked pedestrian crossings to enhance visibility and improve safety.The following signs are typically used:

- S1-1 (School): Used at pedestrian crossings associated with schools.
- W11-2 (Pedestrian): Used to indicate general pedestrian crossing locations.
- W11-15 (Trail): Used to identify shared-use path or trail crossings.
- R1-5b (Stop Here for Pedestrians): Used to direct drivers to stop at a designated point in advance of the crosswalk to allow pedestrians to cross.

To designate a specific crossing location, signs S1-1, W11-2, or W11-15 shall be installed with a downward-pointing arrow plaque (W16-7P) at the crossing point. Additional warning signs supplemented with “AHEAD” plaques (W16-9P) should be installed ahead of a crossing to provide advanced warning to road users. The placement of advanced warning signs should follow the TMUTCD's guidance for the advance placement of warning signs.

Fluorescent yellow-green backgrounds may be used for the warning signs described above to improve conspicuity of the crossing. For school-related warning signs, the use of fluorescent yellow-green backgrounds is required. All signage shall comply with TMUTCD standards for color, size, and mounting height.

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4.2 Crosswalk Markings

Crosswalk markings play an important role in enhancing pedestrian safety by clearly defining where pedestrians are expected to cross. The TMUTCD provides guidance on the use of crosswalk markings to enhance the visibility of crosswalks. While the TMUTCD does not specifically use the terms "standard" and "high visibility," these classifications are widely recognized in industry practice and are defined as follows:

Standard Crosswalk Markings:

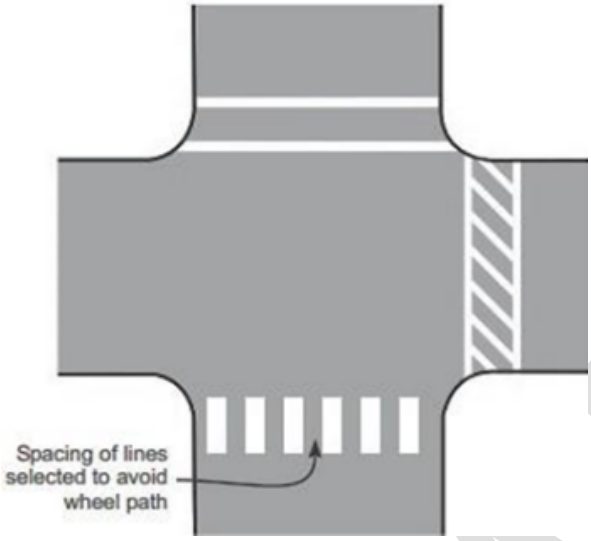
Standard crosswalks consist of two parallel solid white lines that define the edges of the pedestrian crossing path. While not as attention-grabbing as high-visibility patterns, standard crosswalks still provide basic delineation of the pedestrian crossing and are effective in areas where the need for high visibility is not as critical.

High-Visibility Crosswalk Markings:

High-visibility crosswalks use additional markings to enhance visibility of the crosswak to approaching motorists.The TMUTCD allows for the use of diagonal or longitudinal lines within the crosswalk, which may be used in conjunction with or in place of the standard transverse lines. Common high-visibility patterns include:

- **Continental**: Characterized by a series of thick white rectangles perpendicular to the direction of travel.
- **Ladder:** Combines the standard parallel lines with perpendicular lines (similar to the continental pattern) to form a ladder-like appearance.
- **Zebra:** Features wide, angled alternating dark and light stripes across the crosswalk.

The Federal Highway Administration (FHWA) recommends the use of high-visibility crosswalks at uncontrolled pedestrian crossings and mid-block locations to improve safety. High visibility. patterns are particularly effective in areas with high pedestrian traffic, near schools, or where the crossing is unexpected by drivers.



The Town utilizes the standard or continental crosswalk patterns for new crosswalk installations, as these patterns provide adequate visibility while remaining cost-effective.

The following provisions in the TMUTCD apply to crosswalk markings:

- Crosswalks shall be at least 6 feet wide.
- Crosswalk markings shall extend across the full width of the pavement or to the edge of the intersecting crosswalk.
- Crosswalk markings shall be located so the curb ramps are entirely within the extension of the crosswalk markings.

5. Marking Crosswalks at Controlled Locations

This section outlines the guidelines for evaluating and installing marked crosswalks at controlled locations. Controlled locations refer to pedestrian crossings located at intersections or mid-block locations that are controlled by a traffic signal, stop, or yield sign.

5.1 Signalized Intersections

Marked crosswalks should generally be installed on all signalized intersection approaches (i.e., all legs of an intersection) unless specific site conditions warrant an exception, as determined by engineering judgment. When determining whether to mark a crosswalk on a signalized intersection approach, the following factors should be considered:

- **Heavy Right or Left-Turn Volumes**: Approaches with high volumes of right or left-turning traffic during the same signal phase as pedestrian movements pose significant safety risks. Drivers focused on navigating turns may overlook pedestrians, increasing the likelihood of accidents.
- **Sight Distance:** Approaches with limited or obstructed visibility can prevent both pedestrians and drivers from seeing each other in time to avoid potential accidents.
- **Presence of Curb Ramps or Sidewalk Connections**: Approaches lacking curb ramps or sidewalk connections create barriers to safe and accessible pedestrian movement.

Crosswalk Design

- The standard and continental crosswalk patterns are the preferred options for marking crosswalks at signalized intersections.
- The minimum crosswalk width shall be 6 feet. If the pedestrian facility approaching the crosswalk is wider than 6 feet, the crosswalk should match the width of the sidewalk, path or trail. At locations with high pedestrian traffic, wider crosswalks (e.g., 8–10 feet) should be considered to accommodate larger volumes of pedestrians.

Signs, Markings, & Lighting

- Crossing warning signs should not be used at or in advance of crosswalks across approaches controlled by a traffic signal.
- RRFBs shall not be used at crosswalks across approaches controlled by a traffic signal.
- When a crosswalk is installed on a signalized intersection approach, a stop line shall also be installed. The stop line must be 24 inches wide, white in color, and placed at least 4 feet before the nearest crosswalk line. The distance should be measured by the gap between the stop line and the closest crosswalk marking.
- Adequate street lighting shall be provided at all signalized intersections.

5.2 Enhancing Pedestrian Safety at Signalized Intersections

At signalized intersections, a variety of treatments can be implemented to improve pedestrian safety. The treatments presented below are particularly effective in locations with high pedestrian volumes or frequent pedestrian-vehicle conflicts.

High Number of Turning Vehicles

- **Leading Pedestrian Interval (LPI)**: A LPI gives pedestrians a head start when entering an intersection, by activating the "Walk" signal several seconds before the green signal for vehicles. LPI's provide pedestrians with the opportunity to begin crossing the street before vehicles are permitted to proceed. This allows pedestrians to establish a presence in the crosswalk, which increases their visibility to drivers and reduces conflicts with turning vehicles. FHWA reports that LPIs can reduce accidents involving pedestrians by up to 13%.
- **"Yield to Pedestrians" Signs**: A Turning Vehicles Yield to Pedestrians (R10-15) sign may be installed on an intersection approach to remind drivers making turns to yield to pedestrians. The signs should be placed on the far side of the intersection and be clearly visible to drivers making turns.
- **Elimination of Free-Flow Right Turns**: Whenever possible, intersections adjacent to pedestrian generators should be designed without "free rights" (free-flow right-turn lanes) to minimize pedestrian-vehicle conflicts.

High Number of Pedestrians

- **Pedestrian "Scramble" Phase:** A pedestrian scramble phase allows pedestrians to cross the intersection in any direction, including diagonally, while all vehicle traffic is stopped. This phase eliminates conflicts between turning vehicles and crossing pedestrians by providing a dedicated

time for pedestrians to move freely in all directions. This treatment is appropriate where pedestrian volumes are exceptionally high.

- **"No Right Turn on Red" Restrictions:** Prohibiting right turns on red can reduce conflicts between vehicles and pedestrians. However, this restriction may impact intersection capacity and increase delay, so it should be applied on a case-by-case basis where pedestrian volumes warrant it.
- **Protected Left Turn Signal Phasing:** Permissive left turns create significant safety risks for pedestrians, as they allow drivers to turn left while pedestrians may be crossing in the parallel crosswalk. This conflict increases the likelihood of accidents as drivers often focus on oncoming traffic while making a left turn rather than pedestrians in the crosswalk. Protected left turn phasing eliminates this conflict by providing an exclusive phase for left turns during which oncoming traffic is stopped and pedestrian crossings are not permitted. Under protected phasing, left turns are only allowed when a green left-turn arrow is displayed. This treatment is ideal for intersections with a history or risk of left-turn accidents based on pedestrian and vehicle volumes or roadway design. While protected phasing improves safety, it can reduce intersection capacity, impact signal coordination, and increase delays. Therefore, its implementation should be carefully evaluated.

The information above provides a general overview of marking crosswalks at signalized intersections. For comprehensive guidance on crosswalk design, placement, and best practices for marking crosswalks at these locations, refer to the latest editions of the TMUTCD and the FHWA Informational Guide for Signalized Intersections.

5.3 Stop & Yield--Controlled Intersections

Marked crosswalks should be installed across stop or yield-controlled intersection approaches when engineering judgment determines that doing so will improve pedestrian safety and help guide pedestrians to the proper crossing location. Generally marked crosswalks should not be installed at residential intersections within subdivisions or across commercial driveways unless there are compelling reasons for a crosswalk to be marked.

Key factors to consider when deciding whether to mark a crosswalk on a stop or yield-controlled approach include:

- Accident History
- Distance to nearby marked crosswalks
- Pedestrian volume
- Proximity to destinations (e.g., schools, parks, and shopping centers)
- Traffic volume
- Turning volume
- Visibility

Crosswalk Design

- The standard and continental crosswalk patterns are the preferred options for marking crosswalks at stop and yield-controlled intersections.
- The minimum crosswalk width shall be the same as specified for signalized intersections.

Signs, Markings, & Lighting

- Crossing warning signs shall not be installed at or in advance of crosswalks located at approaches controlled by stop or yield signs.
- RRFBs shall not be used at crosswalks across approaches controlled by stop or yield signs.
- A stop or yield line is not required when a crosswalk is installed on a stop or yield-controlled approach but may be considered, based on engineering judgment.
- Adequate lighting shall be provided at all stop and yield-controlled intersections.

For further guidance on marking crosswalks at stop or yield-controlled intersections, refer to the latest edition of the TMUTCD.

5.4 Roundabouts

Marked crosswalks should generally be installed across all approaches to a roundabout unless specific site conditions warrant an exception, as determined by engineering judgment. When determining whether to mark a crosswalk on a roundabout approach, the following factors should be considered:

- **Sight Distance**: Approaches with limited or obstructed visibility can prevent both pedestrians and drivers from seeing each other in time to avoid potential accidents.
- **Presence of Curb Ramps or Sidewalk Connections:** Approaches lacking curb ramps or sidewalk connections create barriers to safe and accessible pedestrian movement.

Crosswalk Design

- The standard and continental crosswalk patterns are the preferred options for marking crosswalks at roundabouts.
- The minimum crosswalk width shall be the same as specified for signalized intersections.
- Marked crosswalks shall be placed a minimum of 20 feet in advance of the edge of the circulatory roadway. Crosswalks shall not be marked to or from the central island of roundabouts.
- Crosswalk markings shall extend across the full width of the entrance and exit of each approach and across any right-turn bypass lanes.
- All roundabout approaches with crosswalks must include raised splitter islands with a minimum width of 6 feet to provide adequate refuge. The walkway through the island shall be cut through rather than ramped, and its width shall either match that of the crosswalk or be no less than 10 feet.

Signs, Markings, & Lighting

- Pedestrian crossing signs (W11-2 with downward arrow plaque W16-7p) shall be installed at each end of the crosswalk on all entrances and exits to a roundabout The signs shall be placed in advance of the crosswalk adjacent to the travel lane and not obstruct the view of the yield sign.
- Additional pedestrian crossing signs (W11-2) supplemented with an "AHEAD" plaque (W16-9p) should be installed in advance of the crosswalk on each approach to a roundabout. The advanced warning signs shall be placed in accordance with the latest edition of the TMUTCD.
- "Yield Here to Pedestrians" (R1-5) and "Stop Here for Pedestrians" (R1-5b) signs shall not be used in advance of crosswalks that cross an approach to or from a roundabout.
- RRFBs may be used on a roundabout approach to enhance pedestrian safety and visibility. If used RRFB's must be installed on both sides of the crosswalk, i.e. one on the entrance and one on the exit of the roundabout. If a raised splitter island is present, an additional RRFB shall be installed on the island. RRFB's shall only be used to supplement the Pedestrian crossing sign (W11-2 with a downward arrow plaque W16-7p) and be placed in advance of the crosswalk adjacent to the travel lane. RRFB's shall not obstruct the view of the yield sign.
- Adequate lighting shall be provided at all roundabouts.

The information above offers a general overview of marking crosswalks at roundabouts. For more detailed guidance, please refer to the latest editions of the TMUTCD and the FHWA Informational Guide for Roundabouts. These resources provide comprehensive information and best practices for crosswalk design and placement at roundabouts.

6. Marking Crosswalks at Uncontrolled Locations

This section provides a process for evaluating and implementing marked crosswalks at uncontrolled approaches of intersections and mid-block locations. Uncontrolled refers to locations where pedestrians cross a roadway without traffic control devices such as traffic signals, stop signs, or yield signs. These crossings require careful consideration during planning and design, as drivers are not always required to stop. Instead, drivers must recognize the presence of a pedestrian crossing and yield the right-of-way as required by state law. This reliance on driver awareness can present significant safety issues at uncontrolled crossings, if proper markings, signage, and other treatments are not implemented.

6.1 Evaluation Process

Determining whether a marked crosswalk is appropriate at an uncontrolled location requires a thorough review of the crossing's unique characteristics. The following steps provide a methodical data-driven process to determine whether a crosswalk is warranted, considering factors such as traffic volume, pedestrian demand, roadway design, and overall safety. Each location should be evaluated using engineering judgment in conjunction with the guidelines outlined in this section to ensure that decisions regarding the installation of marked crosswalks are consistent, effective, and in line with engineering best practices.

1. **Field Review and Preliminary Data Collection:** Assess the current conditions at the crossing to identify any potential safety concerns or operational issues. This initial assessment will help determine if a more detailed analysis is needed.

2. **Comprehensive Data Collection:** Following the initial field evaluation, collect all relevant data to perform a detailed analysis of the crossing. This should include:

- Location of the Crossing
- Roadway Geometry and Configuration
- Traffic and Operational Characteristics
- Multimodal Data

3. **Evaluation of Candidate Location:** Evaluate the candidate crossing location using the attached flowchart and review the collected data to determine if the location meets the criteria for the installation of a marked crosswalk or potential crossing improvements.

4. **Further Analysis and Selection of Crossing Treatments**: If the flowchart indicates that a marked crosswalk is appropriate, proceed with a further analysis of the crossing location, which includes:

    - Assessing current and projected traffic volumes at the crossing to determine appropriate roadway and lane configurations.

    - Evaluating the feasibility of using geometric modifications such as lane narrowing, curb extensions, or pedestrian refuge islands to improve visibility and reduce crossing distances.

    - Identifying and selecting targeted crossing improvements that address the unique needs of the crossing and maximize pedestrian safety.

6.1-1 Field Review and Preliminary Data Collection

The evaluation process starts by identifying a crossing location either proactively (anticipating changes due to future development or capital improvement projects) or reactively (responding to resident requests, recent crashes, or safety concerns). Once a location is identified, an initial field review should be conducted to assess the current site conditions. This helps provide important insights into the existing conditions of the crossing and guide future decisions.

During the field review, the following factors should be assessed:

- Physical characteristics of the crossing.
- Pedestrian and vehicle traffic volumes and behaviors at the crossing.
- Roadway design and its suitability for safe pedestrian crossing.
- Available sightlines at the crossing for both pedestrians and drivers.
- The presence and condition of safety features, such as signage, lighting, and pavement markings at the crossing.

It is also important to consider the surrounding environment, including nearby land uses such as schools, parks, and commercial areas, and how these land uses may affect pedestrian traffic patterns and safety at the crossing. This first step will help determine if any issues are present, whether other mitigation measures outside the scope of this policy can be implemented, or if no further action is needed.

6.1-2 Data Collection

Data collection is a critical step in the evaluation process. The following data points must be gathered tin order to perform a comprehensive review of the crossing location. Ensuring the accuracy and completeness of the data collected is essential to effectively assessing the need for a marked crosswalk.

Crossing Identification

- Identify the primary street being crossed at the location under review.
- Identify the connecting minor street at an intersection or the specific location for a mid-block crossing.
- Identify land uses or destinations within a 600-foot radius of the crossing that are likely to generate significant pedestrian or cyclist traffic. These may include schools, parks, shopping centers, healthcare facilities, and community centers. Proximity to these locations is often associated with higher crossing volumes, making it important to evaluate their influence when determining the need for a marked crosswalk.

Roadway Characteristics

- Determine whether the cross-section is urban (curb and gutter) or rural (shoulder and ditch).
- Identify the roadway layout at the crossing location, including the total number of lanes and whether it is divided or undivided.
- Measure the available stopping sight distance (SSD) in both directions at the crossing location to ensure adequate visibility is available. The adequacy of SSD shall be assessed in accordance with the latest edition of the *American Association of State Highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets.*

Traffic and Operational Characteristics

- If the crossing under review is at an intersection, identify, the type of traffic control in place, such as side-street stop control, all-way stop control, or a traffic signal.
- Identify the posted speed limit at the crossing location.
- Collect hourly speed and vehicle volume data for the major roadway at the crossing, ideally coinciding with the pedestrian data collection.
- Gather and review crash data from the past 3 years in the vicinity of the crossing, with a focus on accidents involving pedestrians or cyclists crossing the road.
- Observe if any vehicular queues extending from downstream traffic signals or intersections back up into the crossing location. Document any impacts on safety and discrepancies in lane-to-lane queuing.

Multimodal Data

- Determine whether the crossing under review connects directly to an existing sidewalk or multi-use trail.
- Identify whether curb ramps are present at the crossing under review. If curb ramps exist evaluate their condition and compliance with accessibility standards.
- Collect multimodal crossing volumes during peak crossing times, for a minimum of two hours. Note that peak crossing hours may not always coincide with peak vehicular traffic hours. If the peak crossing hours are unknown, it is desirable to conduct a 12-hour count of crossing activity to determine the peak times. The peak crossing hours for some locations (such as parks or athletic fields) may occur on the weekend. For locations near schools, data collection may only require two hours corresponding to school opening and closing. Whenever possible, data should be collected during warm-weather months and during fair weather conditions to represent peak crossing activity.
    - Volume counts should include and differentiate between pedestrians and bicyclists and should note separately the number of young, elderly, or disabled individuals crossing.
    - If the crossing location is anticipated to be used as a school crossing, the volume of student pedestrians should be counted separately. The counts for school pedestrian volumes should be conducted on school days when classes are in session. A school crossing is defined as a crossing location where ten or more student pedestrians cross per hour or where the Police Department has assigned a crossing guard.

  Given the potential fluctuation in pedestrian traffic from day to day, it may be necessary to collect up to three days of crossing volume data to determine if a marked crosswalk is warranted. Daily collection should be as follows:

    - Day 1: If pedestrian volumes meet the minimum threshold, no additional data collection is required. If at least 50% of the minimum pedestrian volumes are observed but the threshold is not met, proceed to Day 2.
    - Day 2: If minimum pedestrian volumes are met, data collection is complete. If at least 50% of the minimum volumes are observed but the threshold is still not met, proceed to Day 3.
    - Day 3: If minimum pedestrian volumes are not met on the third day, the installation of a marked crosswalk may not be warranted.
- Measure the distance (in feet) from the crossing under review to the nearest marked or controlled crosswalk.
- Measure the total distance (in feet) to cross the entire roadway, from curb ramp to curb ramp, or from curb face to curb face if no curb ramps are present.
- Assess whether the crossing location is adequately illuminated especially where nighttime crossings are prevalent.

6.1-3 Evaluate Candidate Crossing Location

Once data collection is complete, the candidate crossing location should be evaluated using the attached "Uncontrolled Crossing Evaluation Flowchart." Start at the top left and move through each criterion,

following the path based on whether the data meets the specified requirements. Continue through the flowchart until reaching one of the three outcomes described below:

- **No Action Recommended:** The crossing location does not meet one or more of the required criteria and is not recommended. Directing users to the nearest marked crosswalk should be considered to reduce risk taking behavior. The nearest marked crosswalk should be consistent with the guidelines defined in this evaluation process or approved following staff review and engineering judgement.
- **Consider an Unmarked Crossing**: An "unmarked crossing" refers to any treatment that improves a person's ability to cross a roadway, short of a marked crosswalk with signage or other enhancements at the crossing location. The installation of this type of crossing is subject to staff review and engineering judgement and must include ADA compliant curb ramps, appropriate crossing warning signage, streetlights and where applicable, roadway geometric improvements to enhance crossing safety. No markings or additional signage beyond crossing warning signs are provided to promote the use or attempt to attract new users to the crossing. An unmarked crossing is intended to function as a safety improvement at low-volume locations where pedestrians are already crossing and are expected to continue to do so.
- **Consideration of a Marked Crosswalk is Appropriate**: The crossing location qualifies for the installation of a marked crosswalk. Proceed with further analysis to evaluate whether additional infrastructure improvements are necessary to support the crosswalk. This analysis should focus on the specific characteristics of the crossing location to ensure that the selected crossing treatments effectively address the location's specific needs.

6.2 Criteria Definitions

This section defines the thresholds and key considerations for evaluating the need for a marked crosswalk at an uncontrolled location. Adherence to these guidelines ensures that crosswalks are installed where they are most needed and will be effective in improving pedestrian safety.

Minimum Vehicle Volumes

On roads with low traffic volumes, pedestrians can often cross safely without the need for marked crosswalks. Given the limited resources available for implementing crossing treatments across the town, it is generally not recommended to install a marked crosswalk on roadways with an ADT of less than 1,500 vehicles per day. Exceptions to this guideline may be considered under the following conditions:

- School Crossings: Marked crosswalks should be considered near schools if peak-hour traffic exceeds 150 vehicles per hour and at least 10 students cross during the same hour.
- Park Crossings: Marked crosswalks should be considered near town parks if peak-hour traffic exceeds 150 vehicles per hour and 20 or more pedestrians cross during the same hour.

For roadways with an ADT greater than 1,500 vehicles per day, the installation of marked crosswalks and associated treatments should be evaluated using the criteria and process outlined in this policy.

Minimum Multimodal Crossing Volumes

Research across various communities has demonstrated a strong correlation between driver compliance (e.g., yielding behavior) and multimodal crossing volumes. As crossing activity increases, drivers typically become more aware of the crossing, leading to higher compliance rates. However, at locations with low crossing activity, drivers tend to become less attentive to crossing treatments leading to reduced compliance rates. Data indicates there is a significant decline in compliance rates when crossing volumes drop below 20 crossings per hour. Based on these findings, the following volume thresholds have been established.

- 20 or more crossings per hour during any single hour of an average day.
- 15 or more crossings per hour during any two hours of an average day.
- 10 or more crossings per hour during any three hours of an average day.

it is important to note that the two or three-hour counts do not need to be conducted consecutively. Multimodal users refer to individuals walking, rolling (e.g., using a skateboard, scooter, or other nonmotorized or motorized device), bicycling (whether pedal-powered or e-bikes), or utilizing wheelchairs or other mobility devices. This definition does not include golf carts.

Since elderly, young, and disabled pedestrians face greater challenges when crossing roadways such as difficulty judging traffic gaps and slower walking speeds these individuals count double (2x) towards the multimodal volume thresholds. Meaning a crossing used by 10 young pedestrians (e.g., elementary or middle school-aged children) would effectively meet the 20-crossing volume threshold due to this adjustment.

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Induced Pedestrian Demand

In lieu of the Minimum Multimodal Crossing Volumes mentioned above, a location may be considered for a marked crosswalk if it can be reasonably assumed the required crossing volume threshold would be met if a properly marked crosswalk were available. To qualify, the location must be at least 300 feet from the nearest existing crosswalk and within ½ mile of a recognized pedestrian attractor or generator, as outlined below. Additionally, a continuous and accessible sidewalk or multi-use trail must connect the proposed crossing location to the identified attractor or generator.

- Elementary/Middle/High Schools
- Community Civic Facility (i.e. library, senior citizens center, etc.)
- Park and Recreation Facilities
- Office and retail/restaurant developments

Crash History

Locations that have experienced at least one crash involving a multimodal user in the past three years shall be prioritized for crossing infrastructure improvements. Crashes that cannot be mitigated through engineering solutions, such as those caused by impaired driving, should be excluded from consideration.

Visibility

To ensure that multimodal users can be seen by oncoming vehicles, uncontrolled crosswalks shall only be marked if available SSD is equal to or greater than the minimum SSD required as specified in the latest edition of *AASHTO's A Policy on Geometric Design of Highways and Streets*. SSD shall be based on the posted speed limit or the 85th percentile speed as measured in a recent traffic study, whichever is higher.

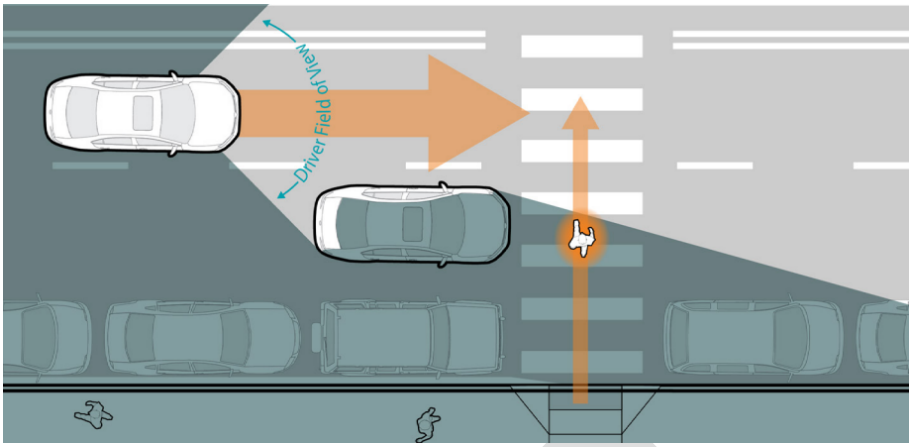
Distance to Nearest Marked or Controlled Crossing

The National Association of City Transportation Officials (NACTO) identifies a three-minute out-of-direction walk as a critical threshold beyond which multimodal users are more likely to engage in risk-taking behavior. While this behavior depends on the speed and volume of traffic, it is important to view crossings from the user's perspective. Multimodal users will typically seek the most direct and efficient crossing route, even if it compromises safety. Although no specific state or federal standards define exact distances between marked or enhanced crosswalks, factors like surrounding land use, network connectivity, and block length heavily influence spacing. A review of agency best practices in the United States showed that the typical spacing of a crosswalk range from 200 to 600 feet.

Using an assumed walking speed of 3.5 feet per second, a three-minute walk equates to approximately 600 feet in total distance, or 300 feet in either direction from a crossing. This aligns with the TMUTCD guidance which states that mid-block crosswalks shall not be signalized if they are located within 300 feet from the nearest traffic signal. Based on these findings, new marked crosswalks should generally only be considered if the proposed location is at least 300 feet from the nearest marked or controlled crossing. However, this minimum spacing may be reduced to 200 feet in central business districts due to higher pedestrian activity and shorter block lengths. At locations where pedestrian demand meets or exceeds twice the Minimum Multimodal Volume Threshold, crosswalk spacing may be further reduced to 150 feet. Such reductions should only be applied where pedestrian activity is not expected to significantly disrupt vehicular traffic operations or compromise safety.

Differential Vehicle Queueing

When pedestrians' cross roadways with two or more lanes in a single direction, they face the risk of "multiple threat" type accidents. A multiple threat accident occurs when one lane of traffic stops for a pedestrian and obscures the view of the crossing pedestrian to a driver in the adjacent travel lane. The result is that a pedestrian can step in front of a vehicle that is approaching too fast to stop. The likelihood of these accidents increases when vehicle queues extend into the crosswalk, especially if one lane has a significantly longer queue. In these situations, drivers may mistakenly assume the stopped traffic is caused by the queue, rather than by the presence of a pedestrian. If queue lengths cannot be effectively managed through measures like signal timing adjustments or improvements cannot be implemented to prevent multiple threat accidents the installation of a marked crosswalk should not be considered.



Prohibiting Parking

To improve visibility, parking restrictions should be implemented at marked crosswalks, especially on roads with multiple lanes in one direction. These measures help reduce the risk of accidents by ensuring clear sightlines for both pedestrians and drivers. Parking restrictions may be implemented by removing parking space markings, installing "No Parking" signs, or applying pavement markings to designate areas where parking is prohibited.

Exceptions to Criteria

In some instances, it may be reasonable to allow exceptions to the criteria previously described. Any exception requires review, consideration, and approval by town staff, and must be clearly documented including the reason why the exception was required. Examples could include a location that is identified for consideration of a crossing improvement but does not meet the criteria outlined in this document though it has other factors where crossing improvements would help improve safety.

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6.3-4 Further Analysis and Selection of Crossing Treatments

If a location is identified as appropriate for a marked crosswalk, the process described in this section should be followed to evaluate the need for additional infrastructure improvements. This step ensures that the most appropriate crosswalk treatments are identified and selected based on pedestrian needs, traffic conditions, and the specific characteristics of the crossing location.

Traffic Volume Review

The first step in this process is important, as the number and configuration of lanes are key factors used in the selection of crossing treatments. This step focuses on evaluating whether the roadway at the crossing

location is appropriately sized based on existing and projected traffic demands. Ensuring the roadway is properly sized is critical for minimizing crossing distances and reducing pedestrian exposure to hazards.

Evaluate the existing and projected traffic volumes for the roadway being crossed using the following capacity thresholds to determine if the design is appropriate.

Roadway Design	Capacity Range (vpd)	Capacity Range (vphpl)
2-lane undivided	7,000 – 8,000	425 - 500
3-lane (2-lane w/TWLTL)	12,000 – 14,000	500 - 525
4-lane undivided	17,000 – 18,000	500 - 550
4-lane divided	23,000 – 26,000	700 - 775
6-lane divided	44,000 – 49,000	880 - 990

- If the roadway design is appropriate proceed to the "Roadway Geometric Treatment Assessment" section and consider applying geometric treatments to further improve pedestrian safety.
- If the roadway design is not appropriate explore the possibility of lane reductions or turn lane removals to enhance safety and reduce crossing distances.

Roadway Geometric Treatment Assessment

Marking a crosswalk is just one of many tools that can be used to improve pedestrian safety. Before considering installing signage, markings, signals, or other treatments at a crossing, it is important to first assess the feasibility of roadway geometric improvements. Adjusting roadway geometry can significantly improve pedestrian safety by shortening crossing distances, enhancing visibility, and calming traffic. Below are recommended strategies for improving pedestrian safety through geometric improvements:

Lane Narrowing: Reducing lane width can slow traffic and create a safer pedestrian environment without causing adverse effects on traffic operation.

- Rural Roadways: 11 or 12-foot-wide lanes
- Urban Roadways: 10-foot-wide lanes (≤35 mph and turn lanes), 11-foot- wide lanes (suitable for all other roadway classifications), 12-foot-wide lanes (≥45 mph)

Reduce Conflict Points: Consider moving the crossing to a location with the least number of conflict points subject to engineering judgement. This could include an intersection leg with lower turning vehicles or overall traffic, as well as moving a crossing entirely out of an intersection and to a mid-block location.

Traffic Calming Measures: Consider installing traffic calming measures to slow down traffic and create safer crossings, such as:

- *Curb Extensions or Bulb-Outs*: Extend the sidewalk and curb into the roadway by narrowing the shoulder or parking lane. These treatments help reduce vehicle speeds, shorten crossing distances, and improve visibility for both pedestrians and drivers.
- *Pedestrian Refuge Islands***:** A raised median or island, at least six feet wide (preferably eight feet), located in the middle of a pedestrian crossing. It provides a safe space for pedestrians to

pause, allowing them to cross one direction of traffic at a time. By breaking the crossing into two stages, refuge islands increase the number of safe gaps in traffic, making it easier for pedestrians to navigate multi-lane roadways.

Additional traffic calming measures identified in best practice documents and guidance (e.g., NACTO, ITE, FHWA, etc.) may be considered based on engineering judgment and staff review.

Evaluate Crossing Infrastructure Improvements

Use the attached "Uncontrolled Crossing Treatment Matrix" to assess and select the most appropriate infrastructure improvements for the crossing location. The matrix organizes treatment options into five distinct categories based on roadway characteristics, traffic volumes, and pedestrian needs. Each category is described in detail below.

- ***Unmarked Crosswalk (Category A):*** This is the simplest form of a crossing treatment, where no visible pavement markings are used to define the pedestrian crossing. The only indication of the crossing is warning signs placed at or in advance of the crossing location. No additional signage or markings are used to encourage pedestrian use. This treatment is suitable for low-traffic roadways where pedestrians are already crossing, or where further improvements are not warranted.
- ***Marked Crosswalk (Category B):*** This is the most basic marked crosswalk treatment, consisting of only pavement markings to designate the crossing. It provides a clear visual cue for pedestrians and drivers but no additional safety features.
- ***Marked Crosswalk with Signs (Category C):*** This category builds upon the marked crosswalk treatment by adding crossing warning signs, such as Pedestrian (W11-2) or regulatory signs like "Stop Here for Pedestrians," (R1-5b) placed in advance of the crossing location to direct drivers where to stop when yielding to pedestrians.
- ***Heightened Awareness Crossing (Category D):*** This type of crossing features a marked crosswalk paired with pedestrian-activated RRFBs, which use high-frequency flashing LED lights to increase driver awareness of pedestrians. The RRFBs are used in conjunction with crossing warning signs and placed on each approach to the crosswalk, along with advanced "Stop Here for Pedestrian" signs and stop lines.

- ***Signalized Crossing (Category E):*** This treatment combines a marked crosswalk with PHBs or a traffic signal, supplemented with appropriate signage and pavement markings as specified in the TMUTCD. PHBs are activated by pedestrians and use flashing and solid lights to control traffic, signaling when drivers must stop and yield to pedestrians. PHBs are typically installed at multi-lane roadway crossings where a traffic signal is not warranted or desired.
- ***Grade-Separated Crossing (Category F):*** This is the most advanced form of a crossing treatment, where pedestrians are completely separated from vehicular traffic using an overpass (Bridge) or

underpass (tunnel). These types of crossings are typically implemented at roadway crossings with high pedestrian and vehicle volumes, or roads with high speeds, where the risk of vehicle-pedestrian conflict is significant.

6.4 Treatment Selection Guidance

The following guidelines should be used when selecting and installing crossing treatments at uncontrolled locations. To qualify for a crosswalk treatment, the crossing must meet the criteria outlined in this policy.

Unmarked Crosswalk (Category A)

The Installation of an unmarked crosswalk shall only be considered when the following criteria are met:

- The roadway being crossed is either a two-lane, one-way road; a two-lane, two-way road; a two-lane, two-way road with a dedicated turn lane; or a four-lane road with two through lanes in each direction with or without a raised median.
- The roadway has an ADT between 1,500–2,500 vehicles per day and a posted speed limit of 35 mph or lower.
- The crossing location is at least 300 feet from any existing marked or controlled crosswalk and meets AASHTO SSD requirements.
- Adequate street lighting is provided adjacent to the crossing.
- Existing curb ramps are available at both ends of the crossing; if not, curb ramps should be constructed; if immediate construction is not feasible, the crossing design must accommodate future curb ramp installation. Funding for the installation of the future curb ramps must be identified before proceeding.
- There is little potential to redirect multimodal users to a more defined crossing location.
- The crossing is not located adjacent to a school.
- A marked crosswalk is not warranted based on this policy.

Marked Crosswalk (Category B)

The Installation of a (marked crosswalk only) should be considered when the following criteria are met:

- The crosswalk is not a school crossing as defined in this policy.
- The combination of the ADT, number of lanes, and posted speed limit result in a “B” square when plotted in the Uncontrolled Crossing Treatment Matrix.

Marked Crosswalk with Signs (Category C)

The Installation of a (marked crosswalk supplemented with warning and regulatory signs) should be considered when the following criteria are met:

- The roadway being crossed is either a two-lane, one-way road; a two-lane, two-way road; a two-lane, two-way road with a dedicated turn lane; or a four-lane road with two through lanes in each direction with a raised median at least 6 feet wide; and
- The roadway has an ADT between 1,500–9,000 vehicles per day and a posted speed limit of 35 mph or lower; and
- The crosswalk is a school crossing; or
- The combination of the ADT, number of lanes, and posted speed limit result in a "C" square when plotted in the Uncontrolled Crossing Treatment Matrix.

Heightened Awareness Crossing (Category D)

The Installation of "Heightened Awareness" active signs (RRFB's) at an uncontrolled crossing should be considered when the following criteria are met:

- The roadway has an ADT between 3,000–9,000 vehicles per day and a posted speed limit of 40 mph or lower; and
- The crossing is a school crossing or connects to a multi-use trail; or
- The combination of the ADT, number of lanes, and posted speed limit result in a "D" when plotted in the Uncontrolled Crossing Treatment Matrix.

Signalized Crossings (Category E)

An uncontrolled marked crosswalk shall not be installed with this category. Strongly consider installation of a signalized pedestrian crossing on roadways when one of the following criteria are met:

- The roadway has three or more lanes in one direction for a pedestrian to cross and a posted speed limit of 45 mph or lower or
- The combination of the ADT, number of lanes, and posted speed limit result in a "E or E/F" square when plotted in the Uncontrolled Crossing Treatment Matrix

The TMUTCD provides comprehensive guidance and standards for determining when and where signalized pedestrian crossings (PHBs or traffic signals) should be installed and used in conjunction with signs and pavement markings to control traffic at locations where pedestrians enter or cross a roadway. A PHB or traffic signal should only be installed on a town roadway when warranted according to the TMUTCD.

Grade-Separated Crossing (Category F):

The installation of a grade separated crossing should be considered when one of the following criteria are met:

- The roadway has three or more lanes in one direction for a pedestrian to cross and a posted speed limit of 45 mph or greater; or
- The combination of the ADT, number of lanes, and posted speed limit result in a "E/F" square when plotted in the Uncontrolled Crossing Treatment Matrix.

While the criteria above provide a preliminary basis for considering a grade-separated pedestrian crossing, a more comprehensive engineering analysis beyond the scope of this policy should be performed to better understand the need for and feasibility of this treatment.

6.5 Additional Crossing Treatments

This section describes additional treatments that can be used to improve crossing safety for multimodal users. These treatments extend beyond standard crosswalk markings and warning signs, offering proven strategies to enhance crossing conditions. While not an exhaustive list, the treatments provided here represent effective options for addressing safety concerns at crossing locations.

Lane Reduction

A lane reduction, commonly known as a road diet, involves reconfiguring a four-lane (or more) undivided roadway into a three-lane roadway with two through lanes and a center two-way left-turn lane. This redesign creates additional space for various improvements, such as pedestrian refuge islands, landscaped medians, bike lanes, and other traffic-calming measures. Road diets are particularly suitable for undivided roads with wide travel lanes or multiple lanes that could be narrowed or repurposed. Roads with an ADT of 15,000 or less are typically an ideal candidate for a four-to-three lane conversion.

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Curb Extension

A curb extension, or bulb-out, is a design treatment that extends the sidewalk and curb line into the parking lane or shoulder, to reduce the effective width of the roadway. This treatment is typically used at intersections and mid-block crosswalks to improve pedestrian safety by shortening crossing distance, reducing pedestrian exposure to traffic, slowing vehicles speeds and improving visibility between pedestrians and drivers. At intersections, curb extensions prevent vehicles from parking too close to crosswalks and help reduce turning speeds. When placed at mid-block locations, curb extension's function as traffic-calming measure by physically narrowing the roadway and providing a visual cue that encourages drivers to slow down.

The installation of curb extensions in conjunction with other crosswalk treatments should be considered when the following criteria are met:

- The roadway is exceptionally wide or has two or more lanes for a pedestrian to cross; and
- The roadway has an ADT greater than 1500 vehicles per day and a posted speed limit of 35 mph or lower; or
- Pedestrians or drivers have limited visibility of each other due to factors such as parked vehicles, roadway curvature, or other obstructions.

Pedestrian Refuge Island

A pedestrian refuge Island is an effective tool for enhancing the safety and efficiency of pedestrian crossings. The presence (or not) of a median refuge can impact the type of crossing treatments that can be considered for a specific location. Typically located in the center of the roadway, a pedestrian refuge island is a raised area that separates opposing traffic lanes and provides a dedicated space for pedestrians to pause and wait for a safe gap in traffic before completing their crossing. By dividing the crossing into two distinct segments, this treatment allows pedestrians to focus on one direction of traffic at a time, greatly increasing the number of safe gaps available for crossing the roadway.

When designing a pedestrian refuge island, consideration should be given to creating a two-stage crossing that encourages pedestrians to cross one direction of traffic at a time and look towards oncoming traffic before completing the second part of the crossing. For a raised median to be considered a pedestrian refuge for an adjacent crosswalk, The raised median must be a minimum of 6 feet wide and include curb ramps or an at-grade walkway through the median. For multi-use trail crossings, a 10-foot width is ideal to better accommodate both bicycles and pedestrians. A painted center median or turn lane shall never be considered as pedestrian refuge.

The installation of a pedestrian refuge Island in conjunction with other crosswalk treatments should be considered when the following criteria are met:

- The roadway is exceptionally wide or has two or more lanes for a pedestrian to cross; and
- The roadway has an ADT greater than 1,500 vehicles per day and a posted speed limit of 35 mph or greater

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7. Supplemental Policies

This section provides supplemental policies to guide the installation of marked crosswalks and associated crossing treatments on town roadways. These polices ensure that crossings are strategically placed, designed, and implemented to effectively enhance pedestrian safety.

Avoid the overuse of Crossings and Treatments

The FHWA recommends that the overuse of crosswalk markings should be avoided to maximize their effectiveness. For this reason, crosswalks and crossing treatments should be used discriminately within the town so that the effectiveness of these treatments is not deteriorated by overuse. Although these treatments may be effective at individual locations, overuse of these treatments' town-wide may lead to a decrease in their value as drivers become desensitized to them. Minimum pedestrian and vehicular volume criteria have been established in this document with this in mind.

Accessible Crosswalks

To ensure that all users can safely and easily navigate the transportation network, any new crosswalk installed on a curbed roadway that connects to a sidewalk, trail, or other pedestrian pathway must include curb ramps at both ends. These curb ramps must be designed and constructed to comply with ADA Accessibility Guidelines (ADAAG), Public Right-of-Way Accessibility Guidelines (PROWAG), Texas Accessibility Standards (TAS), and TxDOT Construction Standards. For locations where existing curb ramps are non-compliant, the curb ramps shall be brought into compliance with the accessibility requirements outlined above.

Crosswalk Lighting

The FHWA recommends providing adequate lighting at crosswalks to improve pedestrian safety during nighttime crossings. Following this recommendation, adequate lighting shall be provided at all marked crosswalks located at traffic signals, PHBs, or RRFBs. For all other marked crosswalks lighting should be considered unless engineering judgment determines it is unnecessary. Crosswalk lighting should illuminate the entire crossing (curb ramp to curb ramp) following state and federal guidelines.

Textured and Colored Pavement Treatments

Textured, brick, and/or colored pavement treatments should typically not be used in lieu of a marked crosswalk. When such treatments are used, they are often aesthetic and not considered traffic control devices. Transverse white crosswalk marking (standard crosswalk pattern) are required at any location serving as a marked crosswalk.

Selecting Between PHBs and RRFBs

The choice between installing a PHB or a RRFB at a pedestrian crossing should be guided by engineering judgment and site-specific conditions. The TMUTCD provides warranting criteria for PHBs based on pedestrian and vehicle volumes, roadway speed, and crossing distance. In some cases, PHBs may be justified with as few as 20 pedestrians per hour, depending on traffic conditions at the crossing location.

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The Town has successfully utilized RRFBs at pedestrian crossings for several years, demonstrating their ability to significantly improve driver yield compliance and enhance pedestrian safety at uncontrolled crosswalks. However, the use of RRFBs may not always be appropriate especially at locations where there is a combination of both high traffic volumes and high pedestrian volumes. In these conditions, there may be an increase in traffic accidents and/or traffic delay that make the use of RRFBs inappropriate. In these cases, the use of a traffic signal or PHB may be more appropriate.

When selecting the most apocopate treatment, both PHBs and RRFBs are viable options in many situations. The final decision should be based on engineering judgment and take into consideration factors like vehicle, pedestrian, and bicycle volumes, roadway speed, crossing distances, median presence, the impact on corridor signal progression, proximity to intersections (both signalized and unsignalized), and vehicle queue formation. It is important to carefully consider all the above factors and analyze the characteristics of each crossing location to determine the most appropriate crossing treatment to implement.

Signal Progression and Traffic Operations

The installation of RRFBs and PHBs can have a significant impact on corridor traffic operations. When selecting the appropriate crossing treatment and determining its operation, key factors to consider include vehicle and pedestrian volumes, the spacing of nearby signalized intersections, and the specific characteristics of the pedestrian population (e.g., college students, young children, older adults, or a mix.) These considerations are crucial to balancing pedestrian safety with efficient traffic operations.

Whenever possible, PHB's should be coordinated with the signals in the corridor to minimize the impact on traffic flow. It is important to consider that coordinated signals may not be as responsive to pedestrian actuation, which could lead to delays in pedestrian service and even result in some pedestrians crossing against the signal rather than waiting. However, not coordinating PHBs may lead to unacceptable increases in traffic congestion and delay. As mentioned previously, RRFBs used at high volume pedestrian crossings on heavily traveled corridors can also have a significant impact on traffic congestion and compromise effective signal progression.

Prioritization

In situations where resources are limited, the Town may need to prioritize the installation of marked crosswalks and crossing treatments. For projects related to street rehabilitation, neighborhood improvements, or other town-initiated projects, crosswalk evaluations should be conducted during the planning phase to ensure they are integrated effectively into the overall project.

Citizen requests for crosswalks will be reviewed in the order they are received. For Town-initiated evaluations, locations will be prioritized based on crash history. Locations that meet installation guidelines will be further prioritized based on pedestrian activity, potential for vehicle-pedestrian conflicts, and construction costs.

Prohibiting Pedestrian Crossings

At most intersections, legal crosswalks exist regardless of whether they are marked or not. This means that if there are no signs indicating otherwise, an unmarked crosswalk can be used as a legal crossing. However, if a crosswalk has signs prohibiting pedestrian crossings, it is unlawful for pedestrians to cross at that crossing.

While crosswalk prohibition should only be implemented as a last resort, there may be situations where it is necessary due to safety concerns arising from site conditions or the infeasibility of interim improvements. If a crossing is prohibited, signs must be installed at the location directing that pedestrians shall not cross. Additional treatments, such as barricades or pedestrian fencing, may be considered as needed to reinforce the crossing prohibition.

Removal of Treatments

Conditions that contribute to the need for a crosswalk or crossing treatment may change over time, and an existing crosswalk or treatment may no longer be needed. When a roadway is impacted by reconstruction or resurfacing, a review of existing crosswalks should be performed to determine their use and need. If the use of a crosswalk is less than half of that which would be required for it to be warranted based on the criteria established in this polcy, the crosswalk should not be replaced when the construction or resurfacing is done, and any other treatments should be removed. Residents and property owners within 1,000 feet of the crosswalk must be notified, and notices must be visibly posted for 30 days at the crossing location to inform the public of the intent to remove them.

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City of Boulder

Pedestrian Crossing Treatment Installation Guidelines

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TABLE OF CONTENTS

Executive Summary iii

1.0 DEFINITIONS 5

2.0 CROSSING LOCATION EVALUATION PROCEDURES AND CONSIDERATIONS 4
2.1 Evaluation Steps 4
2.2 Additional Evaluation Considerations 7
2.2.1 Types of Crossing Treatments at Uncontrolled Locations 7
2.2.2 Minimum Vehicle Volume For Treatments 8
2.2.3 Minimum Pedestrian Volume for Treatments at Uncontrolled Crossing Locations 8
2.2.4 Definition of a Pedestrian Median Refuge and Minimum Median Refuge Width 9
2.2.5 Distance to Nearest Marked or Protected Crossing 10
2.2.6 Conditions That May Limit the Use of RRFBs at Pedestrian Crossings. 10
2.2.7 Selecting Between a Pedestrian Traffic Signal, HAWK Beacon, or RRFBs 11
2.2.8 Signal Progression and Traffic Operational Considerations 11
2.2.9 Differential Vehicle Queue Lengths and Pedestrian Safety 12
2.2.10 Unmarked Pedestrian Crossing Facilitation 12
2.2.11 Pedestrian Crossing Treatments at Higher Speed Roadways with Rural Character ... 13

3.0 SUPPLEMENTAL POLICIES 19
3.1 Crosswalk Lighting 19
3.2 Avoiding Overuse of Crossing Treatments 19
3.3 Multi-Use Path Crossings 19
3.4 Textured and Colored Pavement Treatments 19
3.5 Accessible Crosswalks 20
3.6 Raised Crossings at Right-Turn Bypass Islands 20
3.7 Removal of Treatments 20

4.0 NEXT STEPS 21

Appendix

LIST OF FIGURES AND TABLES

Crossing Location Evaluation Worksheet 14

Figure 1 – Pedestrian Crossing Treatment Flowchart 16

Table 1 – Criteria for Crossing Treatments at Uncontrolled Locations 17

Figure 2a - City of Boulder Guidelines for the Installation of Pedestrian Hybrid (HAWK) Beacons, Pedestrian Signals, or Rectangular Rapid Flash Beacon (RRFB) Signs on Low-Speed Roadways 17

Figure 2b - City of Boulder Guidelines for the Installation of Pedestrian Hybrid (HAWK) Beacons, Pedestrian Signals, or Rectangular Rapid Flash Beacon (RRFB) Signs on High-Speed Roadways.....17

APPENDIX

A1. Background
A1.1 Standards and Policies
A1.2 Pedestrian Crossing Enhancements
A1.3 Evaluation of Demonstration Devices Used in the City of Boulder
Bibliography

Executive Summary

Providing safe and efficient pedestrian facilities is a long-established goal of the City of Boulder. Pedestrian facilities are of particular importance as we try to reduce our dependency on the automobile. The decision to travel as a pedestrian is in part subject to the pedestrian's ability and perceived ability to safely and efficiently cross roadways along the travel route. With this in mind, the City of Boulder has established this document to provide a set of criteria, procedures, and policies to guide the installation of crossing treatments. This document, intended to replace the City of Boulder Pedestrian Crossing Treatment Warrants implemented in 1996, incorporates data collected both for the previous document and recently collected for this effort. Specifically, this document summarizes:

- Proposed pedestrian crossing criteria and procedures for evaluating the need for crossing treatments, including a "flowchart" approach
- Specific pedestrian crossing treatments that may be applicable for a particular set of pedestrian volumes, pedestrian types, vehicular volumes, vehicular speeds, and roadway geometry.

When Boulder's original Pedestrian Crossing Treatment Warrants were developed in 1996, there were relatively few studies available at the federal, state, and municipal levels with respect to the installation of crosswalks and other crossing treatments. Over the past few years more studies have been published which assist in the formulation of specific local policies. However, national standards still provide little guidance for the installation of marked crosswalks and treatments, particularly at mid-block locations. Crosswalks and other crossing treatments are typically installed based on engineering judgment. Key issues, such as the circumstances in which a crosswalk should be installed, how much safety benefit crosswalks provide, and the application of various crossing enhancements are still commonly debated topics.

Information recently published by the Federal Highways Administration (FHWA) (Zegeer et al)[1] suggests that on two-lane roadways, marked crosswalks alone at uncontrolled locations have no effect on pedestrian accident rates. The FHWA study goes on to suggest that, on higher volume, multi-lane roadways, marked crosswalks alone (without any other treatments) are associated with higher vehicle-pedestrian accidents rates compared to unmarked locations.

Over the past fourteen years, the City of Boulder has undertaken an extensive evaluation of the effectiveness and safety of various treatments being tested at crossing locations in the City. The City has installed demonstration devices at nearly 40 locations including two-lane and multi-lane crossings. These treatments have included enhanced crosswalk signing, pedestrian-actuated flashing signs, raised crossings on right-turn bypass islands, and other devices. This evaluation has shown that while these devices most often result in a significant increase in driver compliance (yielding to crossing pedestrians) at crosswalks, some of these devices may lead to higher vehicle-vehicle and vehicle-pedestrian accidents at multi-lane, high pedestrian/vehicle volume locations. The results of the data collection to date have been incorporated into these guidelines, though the City of Boulder will continue to evaluate these and other treatments and may make changes to the guidelines over time.

The Pedestrian Crossing Treatment Installation Guidelines are intended to provide a consistent procedure for considering the installation of crossing treatments where needed on a case-by-case basis in the City of Boulder. Implementation of crossing treatments will require funds that could potentially have been spent on other transportation system improvements, and, therefore, must be considered carefully in the funding allocation process.

1.0 DEFINITIONS

This section includes the definitions of some of the common technical terms used in this document.

Average Daily Traffic (ADT)
The amount of vehicular traffic that crosses an imaginary line across a roadway in a 24-hour period. ADT information typically includes both directions of vehicle travel (if on a two-way street).

Controlled Pedestrian Crossing
A pedestrian crossing where motorists are required to stop by either a stop sign or traffic signal (including a HAWK beacon)

Crosswalk Lighting
Street lighting applied at a pedestrian crossing to help approaching motorists see a crossing pedestrian. Crosswalk lighting is at a "vehicular scale" like normal street lighting rather than a "pedestrian scale" that is often used along a sidewalk.

Curb Extensions
A roadway edge treatment where a curbline is bulged out toward the middle of the roadway to narrow the width of the street. Curb extensions are sometimes call "neckdowns", and are often used at the location of a pedestrian crosswalk to minimize the distance and time that a crossing pedestrian must be in the roadway.

Differential Vehicle Queuing
See also Vehicle Queue. A condition on a roadway with two or more travel lanes in a single direction where the line of stopped traffic in one travel lane is significantly longer than the line of stopped traffic in the adjacent travel lane. Differential vehicle queuing across a pedestrian crosswalk can cause a significant safety concern as it increased the potential for "multiple threat" pedestrian accidents.

Gap in Traffic
A gap in traffic is the space between vehicles approaching the pedestrian crossing. Gaps are typically measured in seconds, not distance, as it is the length of the gap in time that a pedestrian must be able to cross in. A directional gap is the gap between vehicles approaching in a single direction. A directional gap can be measured between vehicles in a single lane, or between vehicles approaching in the same direction but in different lanes on a multi-lane approach. If there is no median refuge at the crossing, a pedestrian will need to find an acceptable gap in traffic approaching from two directions at once. This is much more challenging than finding a gap in each approach direction separately.

HAWK Beacon
A pedestrian hybrid beacon is a relatively new type of crossing treatment used to both warn and control traffic at a pedestrian crossing. It actuated by a pedestrian push button, and uses a combination of circular yellow and red traffic signal displays to first warn motorists of a

pedestrian that is about to cross the street, then require the motorist to stop for the pedestrian crossing, and then release the motorist to proceed once the pedestrian has cleared the crossing. The Beacon is a hybrid between a pedestrian traffic signal and a stop sign.

Lane
A portion of the roadway surface designated for motor vehicle travel, typically in a single directions, that is delineated by pavement marking stripes. Types of lanes include: "through lanes" for travel along the length of the roadway, often through intersections; "turn lanes" which are typically on intersection approaches and provide space for left or right turning motorists; "bike lanes" which are designated for bicycle travel in the same direction as the automobile travel, are typically narrower than vehicle lanes, and are usually located along the outside edges of the roadway.

Marked Crosswalk
A pedestrian crossing that is delineated by white crosswalk pavement markings. Marked crosswalks typically also are delineated by a variety of traffic signs. Marked crosswalks would also have curb ramps if there is curb and gutter in an area.

Median Refuge
An area in the middle of a roadway where a crossing pedestrian can take shelter from approaching traffic in either direction. In the context of these guidelines, the median refuge must include a raised median of some width (see Section 2.2.4 for a description of types of median refuges). A median refuge allows a pedestrian to cross each direction of approaching traffic in a separate step. By using the refuge, the pedestrian must only find an acceptable gap in traffic for one approach direction at a time.

Minimum Pedestrian Volume Threshold
The minimum amount of pedestrian crossing traffic (typically in a one hour period) that must be present to "warrant" the installation of a pedestrian crossing treatment. See Section 2.2.3.

Motorist Compliance Data
Observations made and recorded at a pedestrian crossing where it is determined if the approaching motorist complied with their legal requirement to yield to a crossing pedestrian who is in or about to enter the crosswalk.

Multiple Threat Accidents
A type of pedestrian accident that occurs on a roadway with two or more lanes in the same direction. A motorist that stops for a crossing pedestrian can obscure the view of the pedestrian from another motorist approaching in the adjacent travel lane. If the second motorist does not slow down it creates the potential for a crossing pedestrian to step out in front of a high speed approach vehicle with potentially dire consequences.

Multi-Use Path Crossing
A location where a sidewalk designated as a multi-use path intersects a roadway at-grade, and the path extends on both sides of the roadway.

Neckdowns
See Curb Extensions

Pedestrian Traffic Signal
A conventional traffic signal with circular red, yellow, and green displays for motorists and Walk/Don't Walk signals for pedestrians that is applied at a pedestrian crossing. Typically a pedestrian signal would be applied in a mid-block location since it would be considered a normal intersection related traffic signal if it were to be applied at an intersection.

Raised Median
An area in the middle of a roadway, commonly separating vehicles traveling in opposite directions, that is surrounded by curb and gutter and is physically raised above the surrounding pavement where vehicles travel. Raised medians often contain landscaped areas. See also Median Refuge.

Rectangular Rapid Flash Beacons (RRFBs)
RRFBs are small rectangular yellow flashing lights that are deployed with pedestrian crossing warning signs. They are typically actuated by a pedestrian push button and flash for a predetermined amount of time, to allow a pedestrian to cross the roadway, before going dark. RRFBs are warning devices and do not themselves create a legal requirement for a vehicle to stop when they are flashing. Boulder's pedestrian actuated flashing signs are an example of RRFBs.

School Crossing
School Crossing defined as a crossing location where ten or more student pedestrians per hour are crossing

Uncontrolled Pedestrian Crossing
An established pedestrian crossing that does not include a traffic signal, a HAWK beacon, or a stop sign that requires motor vehicles to stop before entering the crosswalk. For example, Boulder's crosswalks with signs and/or pedestrian actuated flashing yellow lights are considered "uncontrolled".

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

2.0 CROSSING LOCATION EVALUATION PROCEDURES AND CONSIDERATIONS

2.1 Evaluation Steps

Evaluation of an individual crossing location for potential crossing treatments in the City of Boulder should include the following four basic steps:

Step 1: Identification and Description of Crossing Location

Step 2: Physical Data Collection

Step 3: Traffic Data Collection and Operational Observations

Step 4: Apply Data to Figure 1, Table 1, and Figure 2 to Determine Appropriate Treatments

The Crossing Location Evaluation Worksheet is included on the following page which will guide staff through these steps. A detailed discussion of each of these procedures is provided in the following text.

Step 1: Identification and Description of Crossing Location

a) Identify the pedestrian crossing location including the major street and specific location of the crossing (i.e.: cross-street, street address, intersection path or trail, etc.).

b) Determine if the crossing location connects both ends of a multi-use path. If it does, the minimum pedestrian volume requirements are not required to be met to apply the treatments prescribed in Table 1 (see the policy discussion in Section 2.4 for more information).

c) Note the posted speed along the major street at the crossing location.

d) Identify the existing traffic control (if any) and any existing crossing treatments (signs, markings, or physical treatments), street lighting, and curb ramps.

Step 2: Physical Data Collection

a) Determine the existing roadway configuration including the number of lanes and the presence of painted or raised medians at the crossing location.

b) Identify the nearest marked or protected crossing and measure the distance to this crossing.

c) Measure the stopping sight distance (SSD) on all vehicular approaches to the crossing. If the SSD is less than eight times (8x) the posted speed limit (in feet), determine if

improvements (such as removal of obstructions) and/or lowering of the posted speed limit are feasible means to mitigate the inadequate SSD.

Step 3: Traffic Data Collection and Operational Observations

a) Gather or collect pedestrian crossing volumes during the peak hours of use. This will typically involve AM, mid-day, and PM peak hours. Locations near schools may only require two hours of data collection (AM and PM peak hours corresponding to school opening and closing times). All pedestrian volumes should include and differentiate between pedestrians and bicyclists and should note separately the number of young, elderly, and/or disabled pedestrians. For locations where school crossing traffic is anticipated, the volume of student pedestrians (school age pedestrians on their way to/from school) should also be separately noted.

   Whenever possible, pedestrian and bicycle volumes should be collected during warm-weather months (May through September) and during fair weather conditions to represent peak crossing activity (i.e.: no snow, rain, or high winds). Counts should be scheduled to coincide with events such as “walking Wednesdays” if appropriate, and at a time when nearby businesses are open. If school traffic is an issue, the counts should be scheduled on school days when classes are in session. Given the potential fluctuation in pedestrian traffic from day to day, it may be necessary to collect up to three days of data (use additional Crossing Location Evaluation Worksheets as needed) to determine if an enhanced pedestrian crossing treatment is warranted as follows:

   - Collect pedestrian data on day one. If the minimum pedestrian volume threshold (see Figure 1) is exceeded, no further pedestrian data collection is needed. If the threshold has not been exceeded, but at least 50% of the minimum pedestrian volume was observed, proceed to a second day of data collection.

   - Collect pedestrian data on day two. If the minimum pedestrian volume threshold is exceeded, no further pedestrian data collection is needed. If the threshold has not been met but again the volume is at least 50% of the minimum threshold, proceed to a third day of data collection.

   - Collect pedestrian data on day three. If the minimum pedestrian volume still has not been met, then no marked pedestrian crossing treatment is warranted by pedestrian crossing volume.

b) Gather or collect hourly and average daily traffic (ADT) volumes for automobile traffic along the major roadway at the crossing location. A one day sample should be adequate, with hourly volumes collected during the same hour as the pedestrian crossing volumes. [Note: City Staff is currently evaluating the benefit of including vehicle gap and/or pedestrian delay data collection to this step]

c) Due to the potential for vehicular traffic queues to impact safety at the crossings, the presence of queues extending from downstream signals or intersections back into the crossing location should be observed, as well as any "differential" queuing that may occur on a lane to lane basis. While collecting automobile traffic data, the formation of

vehicle queues from adjacent intersections should be noted. If one or both directional queues reaches back to the crossing location, the number of times per hour that it reaches the crossing location should be noted and the maximum queue length should also be recorded. If there is more than one through lane in each direction, it should be noted if the queues reaching back to the crossing are approximately the same length in each lane, or is there a significant differences in the length of the queues in each lane. If the queues are routinely of different length as they extend beyond the crossing location, notes should be made as to the potential cause of the differential queuing.

Step 4: Apply Data to Figure 1, Table 1, and Figure 2 to Determine Appropriate Treatments

a) Using the available data, utilize *Figure 1 – Pedestrian Crossing Treatment Flowchart* and *Table 1 – Criteria for Crossing Treatments at Uncontrolled Locations* (if applicable) to determine appropriate treatment(s) for signalized, stop-controlled, or uncontrolled locations. Also consider and incorporate the information in Section 2.2 and in Figure 2 as appropriate.

2.2 Additional Evaluation Considerations

The following information should be considered by the user of these guidelines when determining the appropriate pedestrian crossing treatment:

2.2.1 Types of Crossing Treatments at Uncontrolled Locations

(See also Table 1)

Table 1 identifies six primary types of uncontrolled crossing treatments for consideration depending on the physical roadway conditions, vehicle volume, pedestrian volume at the potential crossing location, etc. The crossing types are as follows:

Crossing Type A:

- Marked crosswalk
- "State Law – Yield to Pedestrians" signs mounted on the side of the roadway at the crossing, with diagonal down arrow placards (W16-7P)
- standard advance pedestrian warning signs (W11-2) mounted in advance of the crossing
- If the location is a school crossing then standard S1-1 signs should be used

Crossing Type B:

- Same as Type A above, plus
- "State Law – Yield to Pedestrians – Within Crosswalk" signs (R1-6) mounted on flexible bollards on the centerline (if no median present) or mounted on sign posts in the median, if median is present

Crossing Type C:

- Same as Type B above plus
- Add neckdowns (curb extensions) and median refuge island to shorten the pedestrian crossing distance and increase the visibility of pedestrians to approaching motorists

Crossing Type D:

- Marked crosswalk
- Median refuge island [Note: If a median refuge can not be constructed on a 2-way street then go to Crossing Type F]
- "State Law – Yield to Pedestrians" signs mounted on the side of the roadway and in the median at the crossing, with diagonal down arrow placards (W16-7P)
- Pedestrian actuated Rectangular Rapid Flash Beacons (RRFBs) mounted with the "State Law…." Signs
- standard advance pedestrian warning signs (W11-2) mounted in advance of the crossing
- If there are 2 approach lanes in a single direction install advance yield lines and "Yield Here To Pedestrians" (R1-5) signs
- If the location is a school crossing then standard S1-1 signs should be used
- Consider adding curb extensions if on-street parking exists and storm drainage can be accommodated
- [Note: If pedestrian volume falls above the RRFB limit line on Figure 2, go to Crossing Type F]

Crossing Type E:

- Where speed limit is initially greater than or equal to 45 miles per hour
- Determine if the speed limit can be effectively reduced to 40 mph AND a raised median refuge island can be installed
- If so, go to Crossing Type D
- If not, go to Crossing Type F

Crossing Type F:

- Crossing has 3 or more through lanes in a given direction or is otherwise not suitable for an uncontrolled marked crosswalk
- Consider HAWK beacon, pedestrian traffic signal, or grade-separated pedestrian crossing
- Refer to Figure 2 when considering crossing treatment type
- Must consider corridor signal progression, grades, physical constraints, and other engineering factors

In Table 1 there are two columns that list:

- # or lanes crossed to reach a refuge
- # of "multiple threat" lanes per crossing

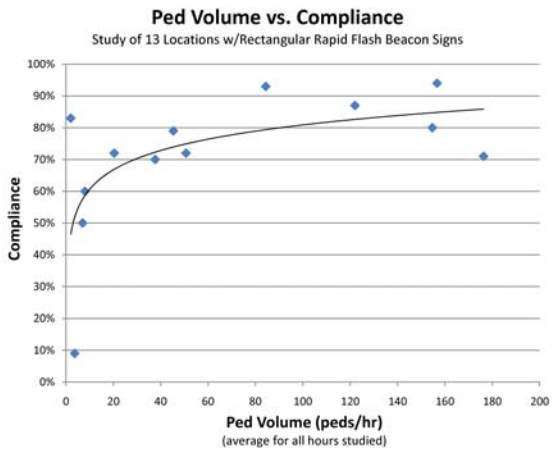
This information does not directly play in to the use of Table 1, but they do provide important context for the user as they help distinguish the crossing types and support the difference in recommended crossing treatments. These topics are discussed in more detail below.

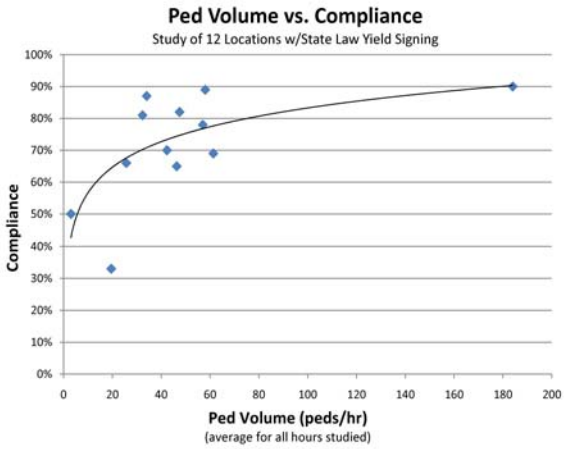
2.2.2 Minimum Vehicle Volume For Treatments

Recognizing the limited availability of resources to implement crossing treatments within the City, crossing treatments should generally not be installed at locations where the ADT is lower than 1,500 vehicles per day. Exceptions may be made at school crossing locations where the peak hour vehicle traffic exceeds 10% of the ADT. School crossings are defined as locations where 10 or more student pedestrians are crossing per hour. Treatments for roadways with greater than 1,500 vehicles per day should be installed based on the criteria in Figure 1, Table 1, and the information in Figure 2 (a or b depending on the speed limit).

2.2.3 Minimum Pedestrian Volume for Treatments at Uncontrolled Crossing Locations

The City of Boulder has evaluated crosswalk enhancements at uncontrolled crossing locations over the years and has determined that there is a clear relationship between driver compliance (yielding) and the pedestrian and/or bicycle crossing volume. Data collected at Boulder crosswalks where rectangular rapid flash beacon signs (RRFB) or State Law-Yield signs were installed shows that driver compliance typically increases with higher crossing volumes. It is theorized that the primary reason for this relationship is that drivers tend to ignore enhanced crossing treatments over time at locations where they infrequently see pedestrians crossing. The following graphs illustrate this relationship:





The above data also illustrates that, below roughly 20 pedestrians per hour, driver compliance decreases significantly. Thus, the base threshold for consideration of an enhanced crossing treatment at an uncontrolled location is 20 pedestrians per hour. This threshold is consistent with recent national guidance and policies adopted by other states and cities, as determined through literature research.

The Minimum Pedestrian Volume Thresholds are as follows:

- 20 peds per hour* in any one hour, or
- 18 peds per hour* in any two hours, or
- 15 peds per hour* in any three hours
- 10 school aged pedestrians traveling to/from school in any one hour

* Young, elderly, and disabled pedestrians count 2x towards volume thresholds
** School Crossing defined as a crossing location where ten or more student pedestrians per hour are crossing

2.2.4 Definition of a Pedestrian Median Refuge and Minimum Median Refuge Width

A pedestrian refuge median is a useful tool in increasing the safety and efficiency of a pedestrian crossing, and the presence (or not) of a median refuge will influence the type of pedestrian crossing treatment that can be considered (see Table 1). In this context a pedestrian refuge median is defined as a location in the middle of a pedestrian crossing where a pedestrian can take refuge, thereby separating their crossing into two steps, across each direction of approaching traffic separately. Separating the crossing into two directional crossings greatly increases the number of acceptable gaps for pedestrians to safely cross a roadway. A pedestrian refuge must include some type of raised median as described below:

- A painted center median or a painted turn lane can never be considered a pedestrian refuge.

- A raised median nose at an intersection (next to a left turn bay for example) can only be considered a pedestrian refuge for the adjacent crosswalk if the median is at least 4 feet wide AND the left turn volume is less than 20 vehicles per hour. This low left turn volume means that during most pedestrian crossings there will not be a vehicle in the left turn lane and the pedestrian will be "shadowed" by the width of the median and the adjacent turn lane as they cross the street.

- A raised median at a mid-block pedestrian crossing can only be considered as a refuge if it is at least 6 feet wide (preferably 8 feet wide) and includes curb ramps or a walkway at grade through the median. A median of this width will allow over two feet on each side for splash protection; it will store a group of pedestrians; and it will accommodate the storage of a bicycle without it overhanging into the traffic lanes. For multi-use path crossing locations, a 10' median refuge width is desirable to better accommodate bicycles with child trailers, recumbent bicycles, and tandem bicycles.

2.2.5 Distance to Nearest Marked or Protected Crossing

The Pedestrian Crossing Treatment Flowchart in Figure 1 includes consideration of spacing criteria for an uncontrolled crossing to the nearest marked or projected crossing. The flowchart requires that a new uncontrolled mid-block crossing be at least 300 feet from the nearest crossing. However, the flowchart allows this spacing criteria to be waived if the proposed crossing serves a multi-use path, or the pedestrian crossing volume exceeds twice the minimum threshold.

As with this entire PCTIG, this criteria is also subject to engineering judgment. In urban conditions where Boulder's typical block length is 400 feet, the engineer may want to consider allowing a minimum spacing of 200 feet, provided that the resultant pedestrian crossing:

- does not cross any auxiliary lanes (left or right turn lanes or their transitions) where it is anticipated that vehicles will be changing lanes and may be distracted from observing pedestrians in the crosswalk
- is not in an intersection influence area where it will create undue restriction to vehicular traffic operations.

2.2.6 Conditions That May Limit the Use of Rectangular Rapid Flash Beacons at Pedestrian Crossings

The City of Boulder has been using pedestrian actuated rectangular rapid flash beacons (RRFBs) at pedestrian crossings on four lane roadways for many years, and these "flashing signs" have greatly increased motorist yielding to pedestrians at these unsignalized crosswalks. However, the City has also learned that the use of RRFBs may not be appropriate in locations where there is a combination of both high traffic volumes and high pedestrian volumes. In these extreme conditions there may be an increase in traffic accidents and/or traffic delay that make

the use of RRFBs inappropriate. In these cases, the use of conventional pedestrian traffic signals or the HAWK signals may be more appropriate.

While the decision not to use RRFBs at a pedestrian crossing should be based on engineering judgment, the limit line in Figure 2 has been prepared to aid in this determination.

2.2.7 Selecting Between a Pedestrian Traffic Signal, HAWK Beacon, or RRFBs

Pedestrian traffic signals may be considered for application at high volume pedestrian crossings based on engineering judgment. The MUTCD contains warranting procedures for conventional pedestrian traffic signals based on automobile and vehicle traffic volumes to help determine if a pedestrian signal is appropriate. These signals are typically considered when there are over 130 pedestrians an hour crossing a roadway.

Hybrid Beacons (HAWK beacons) may also be considered and the MUTCD contains warranting guidelines that utilize automobile traffic, pedestrian traffic, automobile speeds, and pedestrian crossing distance. HAWK beacons may be installed where the crossing volume is as low as 20 pedestrians per hour, depending on the crossing distance, automobile traffic volume, and engineering judgment.

As noted above, the City of Boulder has been successful in using RRFBs to increase motorist yielding to pedestrians at unsignalized crossings, typically where there are two travel lanes in each direction. A minimum crossing volume of 20 pedestrians per hour is typically required, as discussed in Section 2.1.3. However, also as noted in Section 2.1.6, there may be cases where the combination of high pedestrian and traffic volumes may make application of RRFBs inappropriate. Figure 2a and Figure 2b illustrate City of Boulder recommendations for the use of RRFBs overlain on the MUTCD Hawk beacon and Pedestrian Traffic Signal warrant guidelines. The City of Boulder recommendations are based on safety and operational evaluations performed over the years at high volume RRFB locations.

In many cases, either HAWK beacons or RRFBs could be considered for application, and the final decision should be based on engineering judgment. Factors that should be considered include: automobile, bicycle and pedestrian volumes, vehicular speeds, crossing distances, the presence of a median or not, potential impact to corridor signal progression, proximity to signalized intersection, and vehicle queue formation.

2.2.8 Signal Progression and Traffic Operational Considerations

The installation of RRFBs, HAWK beacons, or pedestrian traffic signals can all have a significant impact on the automobile traffic operation in a corridor. The automobile and pedestrian crossing volumes, the spacing to the adjacent signalized intersections, the type of pedestrian population (college students, elementary students, elderly, a mix) should all be considered when selecting the crossing treatment type and how it will be operated. Where practical, HAWK beacons and pedestrian traffic signals should be coordinated with the signal progression in the corridor to minimize the impact of the new traffic signal on corridor traffic flow. However, coordinated signals may be less responsive to pedestrian actuation, and the delay in

pedestrian service may result in some pedestrians crossing against the signal rather than waiting. Not coordinating the pedestrian crossing signals may result in unacceptable increases in automobile congestion and delay.

RRFBs used at high volume pedestrian crossings in congested roadway corridors can also have a significant impact on automobile congestion and compromise effective signal progression. The RRFB limit line in Figure 2 can help minimize this problem.

Once again, engineering judgment will need to be applied to reach the best compromise for all involved.

2.2.9 Differential Vehicle Queue Lengths and Pedestrian Safety

A pedestrian crossing of a roadway with two or more lanes in a single direction has the potential for "multiple threat" type accidents. A multiple threat accident is when one lane of traffic stops for a pedestrian and obscures the view of the crossing pedestrian to a motorist in the adjacent travel lane. The result is that a pedestrian can step in front of a vehicle that is approaching too fast to stop. This condition is exacerbated when there are vehicle queues that back across the pedestrian crossing. If the queue in one lane backs into the crossing and is much longer than the queue in the adjacent lane, a motorist would commonly assume that the stopped traffic in one lane is the result of the queuing (which may usually be the case). Now if a vehicle in one lane stops for a pedestrian, instead of the queue, there is an even greater chance for a multiple threat accident.

Therefore it is important for the engineer to be aware of the formation of queues to and across the pedestrian crossing from a downstream intersection. It is even more important for the engineer to be aware of routine occurrence of one queue longer than the other across the pedestrian crossing. The Operational Observations section of the Crossing Location Evaluation Worksheet has a place to note this occurrence.

When deciding to install an uncontrolled crossing treatment (or not), the engineer should consider if differential vehicle queue lengths is an issue, and if so, can they be mitigated (say by signal timing adjustments at the downstream intersection). If differential queues can not be minimized, it may be reason to not install an unprotected crossing treatment (such as Type A, B, or C).

2.2.10 Unmarked Pedestrian Crossing Facilitation

Staff is aware of the fact that there are locations where pedestrians regularly cross arterial roadways yet the crossing does not serve a multi-use path or a school, and the pedestrian volume is below the minimum thresholds in Figure 1 for installing the types of marked and signed treatments detailed in Table 1. These locations typically occur on 4-lane roadways (such as at the intersection of 23rd/Canyon) or 6-lane roadways (such as at the intersection of Broadway/Ash), and often serve transit stops in the area. In some cases, subject to engineering judgment, it may be appropriate to install treatments that facilitate pedestrian or bicycle

crossings but stop short of the signed and marked crossing treatments defined in Table 1. This type of treatment or pedestrian facilitation may include curb ramps and/or a raised median refuge, but no effort is made to attract pedestrians to this crossing. The treatments simply acknowledge the low volume, but regular pedestrian crossing that occurs at a location. Installing these treatments does not endorse the use of the crossing nor attempt to attract new users to the crossing. They simply acknowledge that the crossing is occurring, will not likely go away, and some level of facilitation can make it safer for the pedestrians or bicyclists that are using the crossing already. The only other option would be to ignore the crossing, but staff does not believe this is an appropriate response. These treatments will only be considered if the location is more than 300 feet from the nearest signed and marked pedestrian crossing (whether it is controlled or uncontrolled), and it is believed that there is little potential to redirect pedestrians to a more defined crossing location.

2.2.11 Pedestrian Crossing Treatments at Higher Speed Roadways with Rural Character

Even though most Boulder streets have speed limits of 35 mph or less, there are some locations, particularly on the edges of the city, where speed limits are 40 or 45 miles per hour and roadways are transitioning between City and Boulder County jurisdiction. County roads may increase to 50 miles per hour just beyond City limits. In this context, there may be conditions that necessitate the installation of pedestrian crossings where speeds are higher and special consideration is warranted. Boulder County Transportation staff also encountered these situations (ex. 75th St. from Jay to Lookout). For reference, Boulder County staff has utilized Boulder's PCTIGs as a starting point and modified them to address this type of higher speed roadway where pedestrian crossings may be needed. The County's approach is to require there to be a refuge median and enhanced signing at any crossing where the speed limit is 40 or 45 (although they currently do not use RRFBs). Where speed limits are greater than 45, the County considers if the speed limit can reasonably be lowered to effect a slower travel speed before declining to install an at grade crossing.

In this context, it is recommended that engineering judgment be applied and consideration be given to providing an uncontrolled at-grade crossing treatment only if the speed limit can be effectively reduced to 40 mph and a raised refuge median is constructed has part of the crossing treatment (See Treatment Type E).

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

STEP 3a - TRAFFIC DATA

Pedestrian Crossing Volumes / Bicycle Crossing Volumes:

	AM	**Mid-Day**	**PM**	**Other**
Time:	to	to	to	to
Date/Day of Week:	/	/	/	/
Major Street Vehicular Volume (**Hourly**):				
# of Transit Boardings (if applicable)				
# of Young Peds / Bicyclists	/	/	/	/
# of Elderly Peds				
# of Disabled Peds				
# of Non-Y/E/D Peds / Bicyclists	/	/	/	/
TOTAL PEDS (Actual) (Include All Bicyclists in Total Sum)				
TOTAL PEDS (**Adjusted** for 2x Y/E/D				

Major Street Vehicular Volume (**Daily**): ADT = _____ veh/day

Crossing Location Evaluation Worksheet *(Continued)*

STEP 3b - OPERATIONAL OBSERVATIONS

Nearest Intersection (Direction #1): Cross Street Name: _____

Located _____ ft to the ☐N ☐S ☐E ☐W of crossing location

Signalized? ☐Y ☐N Distance from Crossing _____ ft

	AM	Mid-Day	PM	Other
How many times per hour did the downstream vehicle queue back up into pedestrian crossing?				
If multiple lanes per direction, are queue lengths approximately equal?	Y N	Y N	Y N	Y N
If NO (above),which lane is longer (inside, outside, middle) and by how much (feet)?				

Nearest Intersection (Direction #2): Cross Street Name: _____

Located _____ ft to the ☐N ☐S ☐E ☐W of crossing location

Signalized? ☐Y ☐N Distance from Crossing _____ ft

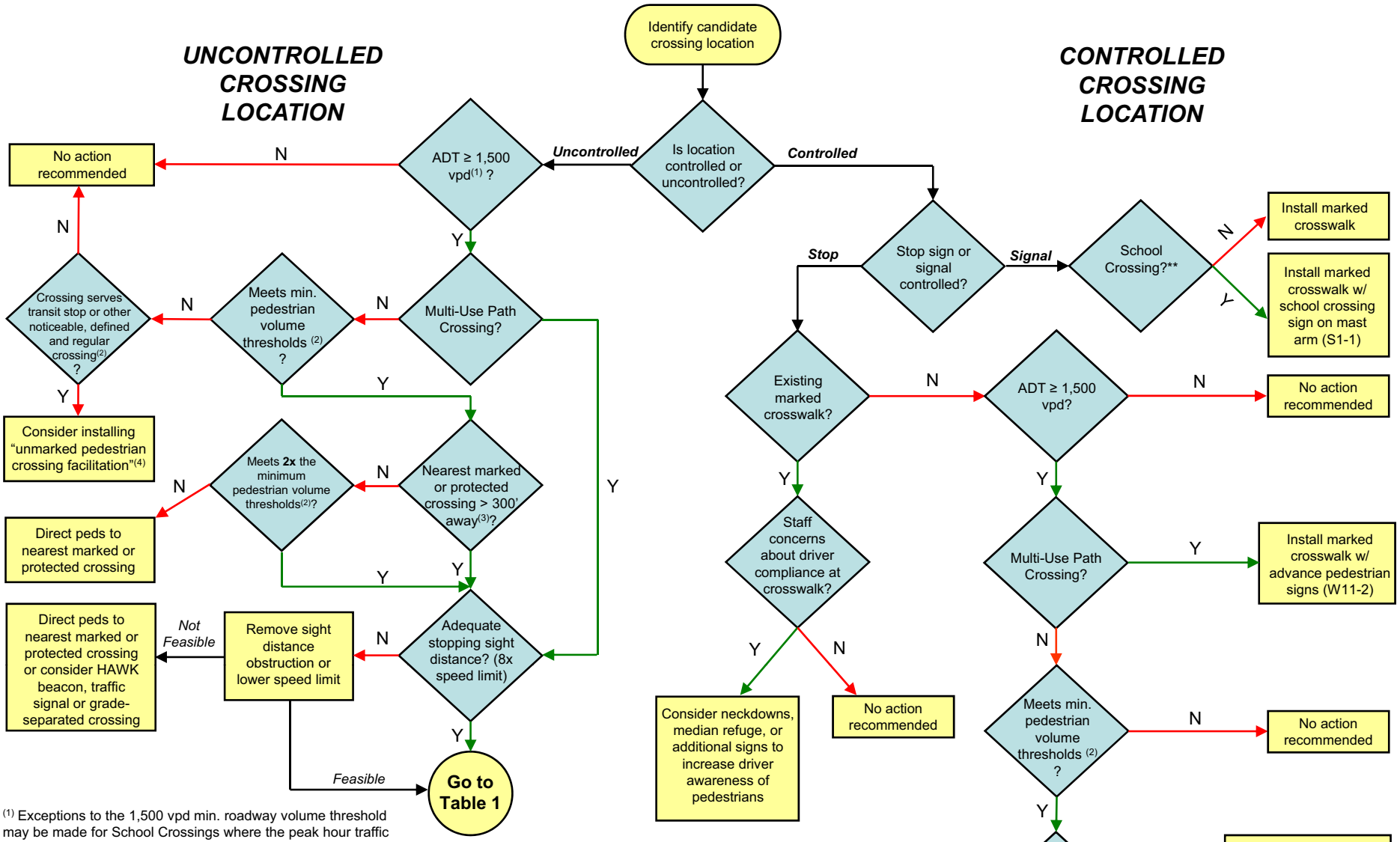
	AM	Mid-Day	PM	Other
How many times per hour did the downstream vehicle queue back up into pedestrian crossing?				
If multiple lanes per direction, are queue lengths approximately equal?	Y N	Y N	Y N	Y N
If NO (above),which lane is longer (inside, outside, middle) and by how much (feet)?				

STEP 4 - APPLY DATA TO FIGURE 1 and TABLE 1

Recommended Treatment(s): _____

_____

_____



(1) Exceptions to the 1,500 vpd min. roadway volume threshold may be made for School Crossings where the peak hour traffic exceeds 10% of the daily traffic

(2) **Minimum Pedestrian Volume Thresholds**:

- 20 peds per hour* in any one hour, or
- 18 peds per hour* in any two hours, or
- 15 peds per hour* in any three hours

* Young, elderly, and disabled pedestrians count 2x towards volume thresholds

** School Crossing defined as a crossing location where ten or more student pedestrians per hour are crossing.

(3) Distance to nearest marked or protected crossing may be reduced to 200' in urban conditions, subject to engineering judgment, where 1) the crosswalk does cross any auxiliary lanes, and 2) crossing treatments and crossing activity would not create undue restriction to vehicular traffic operations.

(4) An "unmarked pedestrian crossing facilitation" is any treatment that improves a pedestrian's ability to cross a roadway, short of the marked, signed and enhanced crossings detailed in Table 1. Installation of this type of pedestrian facilitation is subject to engineering judgment and may include curb ramps and/or a raised median refuge. However, no effort is made to attract pedestrians or recommend that pedestrians cross at this location. The treatments simply provide an improvement for a low volume pedestrian crossing where pedestrians are already crossing and will like continue to cross.

Figure 1 – Pedestrian Crossing Treatment Flowchart

Table 1 - Criteria for Crossing Treatments at Uncontrolled Locations

Roadway Configuration	# of lanes crossed to reach a refuge[1]	# of multiple threat lanes[2] per crossing	Roadway ADT and Posted Speed															
			1,500-9,000 vpd				9,000-12,000 vpd				12,000-15,000 vpd				> 15,000 vpd			
			≤ 30 mph	35 mph	40 mph	≥ 45 mph	≤ 30 mph	35 mph	40 mph	≥ 45 mph	≤ 30 mph	35 mph	40 mph	≥ 45 mph	≤ 30 mph	35 mph	40 mph	≥ 45 mph
2 Lanes (one way street)	2	1	A	B	C	E	A	B	C	E	B	B	C	E	B	C	C	E
2 Lanes (two way street with no median)	2	0	A	B	C	E	A	B	C	E	B	B	C	E	B	C	C	E
3 Lanes w/Raised Median	1 or 2	0 or 1	A	B	D	E	A	C	D	E	B	D	D	E	C	D	D	E
3 Lanes w//Striped Median	3	0 or 1	C	C	D	E	C	C	D	E	C	C	D	E	C	D	D	E
4 Lanes (two way street with no median)	4	2	A	D	D	E	B	D	D	E	B	D	D	E	D	D	D	E
5 Lanes w/Raised Median	2 or 3	2	A	B	D	E	B	C	D	E	B	C	D	E	C	C	D	E
5 Lanes w/Striped Median	5	2	D	D	D	E	D	D	D	E	D	D	D	E	D	D	D	E
6 Lanes (two way street with or without median)	3 to 6	4	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F

Notes:

1. Painted medians can never be considered a refuge for a crossing pedestrian. Similarly, a 4 foot wide raised median next to a left turn lane can only be considered a refuge for pedestrians if the left turning volume is less than 20 vehicles per hour (meaning that in most cases the left turn lane is not occupied while the pedestrian is crossing).
2. A multiple threat lane is defined as a through lane where it is possible for a pedestrian to step out from in front of a stopped vehicle in the adjacent travel lane (either through or turn lane).

Treatment Descriptions:

A ***Install marked crosswalk with enhanced road-side signs***

Specific Guidance : Install marked crosswalk with "State Law - Yield to Pedestrian" signs mounted on the side of the roadway with standard (W11-2) advance pedestrian warning signs; use S1-1 signs for School Crossing locations.

B ***Install marked crosswalk with enhanced road-side and in-roadway (bollard mounted) signs***

Specific Guidance : Install marked crosswalk with "State Law - Yield to Pedestrian" signs mounted on the side of the roadway and on in-roadway bollards; use standard (W11-2) advance pedestrian warning signs; use S1-1 signs for School Crossing locations.

C ***Install marked crosswalk with enhanced signs and geometric improvements to increase pedestrian visibility and reduce exposure***

Specific Guidance : For 2 or 3-lane roadways, install marked crosswalk with "State Law - Yield to Pedestrian" signs mounted on the side of the roadway and on in-roadway bollards or median mounted signs; use standard (W11-2) advance pedestrian warning signs; use S1-1 signs for School Crossing locations. Add neckdowns or median refuge islands to shorten the pedestrian crossing distance and increase pedestrian visibility to motorists.

D ***Install marked crosswalk with enhanced signs, pedestrian activated RRFBs, and geometric improvements to increase pedestrian visibility and reduce exposure***

Specific Guidance : Install raised median refuge island (unless it is a one-way street or one already exists) to shorten the pedestrian crossing distance and increase pedestrian visibility to motorists. [If a median refuge can not be constructed on a two-way street, Go To Scenario F]. *Install marked crosswalk with "State Law - Yield to Pedestrian" signs WITH pedestrian activated RRFBs mounted on the side of the roadway and on median mounted signs; use standard (W11-2) advance pedestrian warning signs; use S1-1 signs for School Crossing locations. Consider adding neckdowns at the crossing if on-street parking exists on the roadway and storm drain considerations will allow. [Note: If pedestrian volume falls above the RRFB limit line on Figure 2, consider Hawk beacon, pedestrian traffic signal, or grade-separated crossing.]*

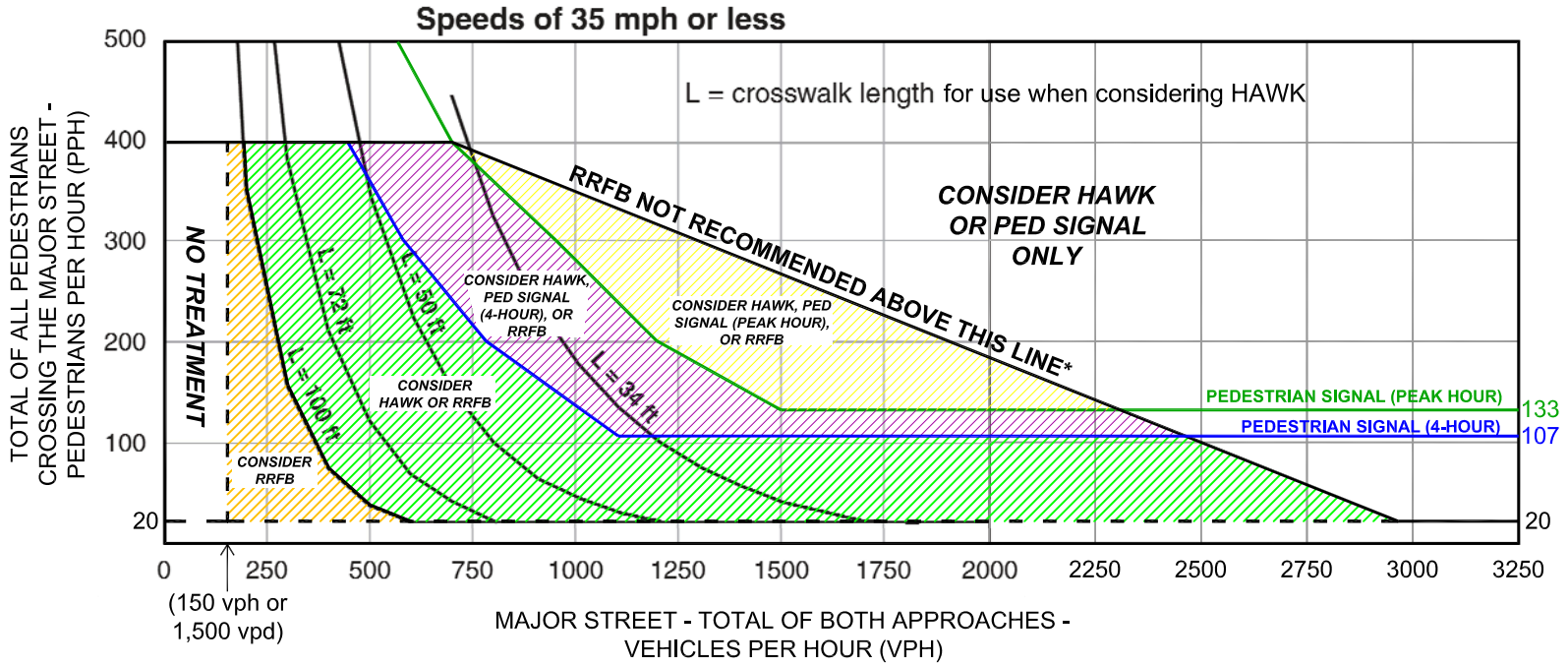
E ***Do not install marked crosswalk at uncontrolled crossing. Determine if the speed limit can be effectively reduced to 40 mph AND a raised refuge median can be installed. If so, utliize Scenario D criteria above. If this is not possible, or if pedestrian volume falls above the RRFB limit line on Figure 2, consider HAWK beacon, pedestrian traffic signal, or grade-separated crossing.***

Specific Guidance : Consider HAWK beacon, pedestrian traffic signal or grade-separated crossing; application of these treatments will consider corridor signal progression, existing grades, phyiscal contraints, and other engieering factors

F ***Do not install marked crosswalk at uncontrolled crossing with 3 or more THROUGH lanes per direction or where the speed limit is ≥ 45 mph and/or there is not a median refuge on a 5-lane crossing. Consider HAWK beacon, pedestrian traffic signal, or grade-separated crossing.***

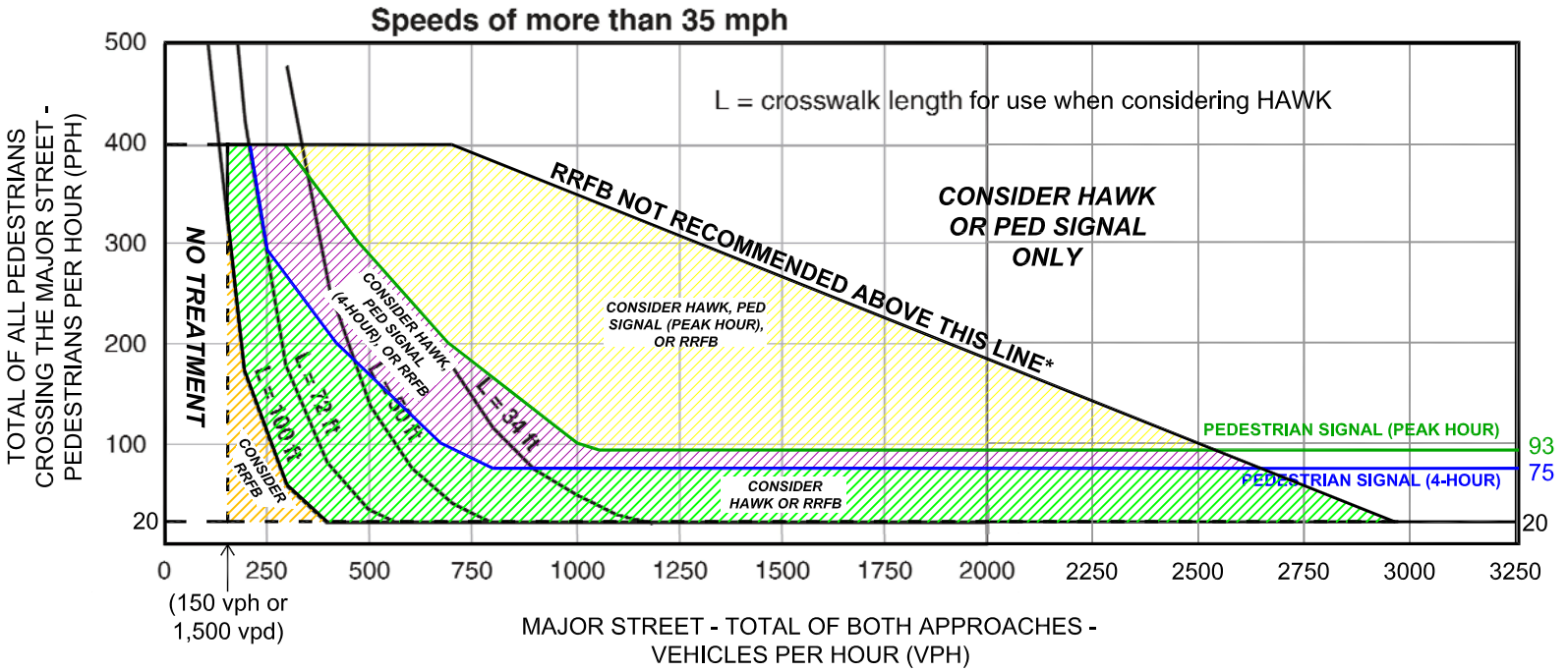
Specific Guidance : Consider HAWK beacon, pedestrian traffic signal or grade-separated crossing; application of these treatments will consider corridor signal progression, existing grades, phyiscal contraints, and other engieering factors

Figure 2a. City of Boulder Guidelines for the Installation of Pedestrian Hybrid (HAWK) Beacons, Pedestrian Signals, or Rectangular Rapid Flash Beacon (RRFB) Signs on Low-Speed Roadways



* RECOMMENDATION BASED ON CITY OF BOULDER SAFETY EVALUATIONS AT EXISTING RRFB SITES AND OBSERVED IMPACTS TO VEHICULAR TRAFFIC OPERATIONS

Figure 2b. City of Boulder Guidelines for the Installation of Pedestrian Hybrid (HAWK) Beacons, Pedestrian Signals, or Rectangular Rapid Flash Beacon (RRFB) Signs on High-Speed Roadways



* RECOMMENDATION BASED ON CITY OF BOULDER SAFETY EVALUATIONS AT EXISTING RRFB SITES AND OBSERVED IMPACTS TO VEHICULAR TRAFFIC OPERATIONS

3.0 SUPPLEMENTAL POLICIES

This section contains discussion of supplemental policies to guide the installation of crossing treatments in the City of Boulder.

3.1 Crosswalk Lighting

Research provided by the FHWA recommends that adequate nighttime lighting should be provided at marked crosswalks to enhance the safety of pedestrians crossing at night. Crosswalk lighting will be provided at all crosswalks utilizing traffic signals, HAWK beacons and RRFBs. Crosswalk lighting will be provided at all other marked crosswalks, unless engineering judgement suggests crosswalk lighting is not needed. The placement and level of crosswalk lighting will be determined by engineering judgement at all crossing treatments.

3.2 Avoiding Overuse of Crossing Treatments

The FHWA recommends that overuse of crosswalk markings should be avoided to maximize their effectiveness. Crosswalks and sign treatments (such as the "State Law – Yield to Pedestrians" and rectangular rapid flash beacon signs) should be used discriminately within the City of Boulder so that the effectiveness of these treatments is not deteriorated by overuse. Although these treatments may be effective at individual locations, overuse of these treatments city-wide may lead to a decrease in their value as drivers become desensitized to them. Minimum pedestrian and vehicular volume criteria have been established in this document with this in mind.

3.3 Multi-Use Path Crossings

Crossing locations where a multi-use path crosses a roadway should include a marked and signed crosswalk at a minimum, regardless of pedestrian crossing volumes, as long as the minimum vehicular volume criteria in Section 2.1.2 is satisfied. This policy is to promote the use of multi-use paths recognizing that roadway crossings often create barriers for pedestrians and bicyclists and may contribute to a lack of use.

3.4 Textured and Colored Pavement Treatments

Textured, brick, and/or colored pavement treatments should typically not be used in lieu of a marked crosswalk. When such treatments are used they are often aesthetic and not considered traffic control devices. Retroreflective pavement markings are required at any location serving as a marked crosswalk. Exceptions are granted for signalized intersection crossings, right-turn bypass (raised) crossings, and for multi-use path crossings at driveways and unsignalized intersections where the City has developed other treatments designed to call attention to the crossings.

3.5 Accessible Crosswalks

It is the goal of the City of Boulder that all crosswalks installed will comply with the Americans with Disabilities Act (ADA) to maximize mobility for all users. Where a new crosswalk is installed in a curbed roadway, curb ramps will include a detectable warning surface. The City intends to retrofit existing non-ADA compliant curb ramps with detectable warning surfaces as part of its on-going sidewalk maintenance program.

3.6 Raised Crossings at Right-Turn Bypass Islands

Raised pedestrian crossings at right-turn bypass islands meet the goals of these guidelines by improving visibility for pedestrians, improving accessibility, and helping to mitigate the speed of right-turning vehicle traffic. City staff will review all new or proposed right-turn bypass movements to determine if a raised crossing should be installed. If deemed feasible, a raised crossing will be incorporated into the design.

3.7 Removal of Treatments

Conditions that contribute to the need for a crosswalk or crossing treatments may change over time, and an existing crosswalk or treatment may no longer be needed. When a roadway surface is to be impacted by reconstruction or resurfacing, a review of any unprotected crosswalks should be performed to determine their use and need. If the use of a crosswalk is less than half of that which would be required for it to be warranted based on the criteria established in these guidelines for a new installation, the crosswalk should not be replaced when the construction or resurfacing is done and any other treatments will be removed. In such cases, residents and property owners within 1000' of walking distance to the crosswalk in question will be notified via mail. In addition, notices will be visibly posted for 30 days prior at the crossing location to inform the public of the intent to remove them. City contact information will be provided on these mailings and notices. Should concerns arise from the public as a result of that mailing or from the notification sign at the crosswalk, staff may then begin a more substantial public process with concerned parties.

4.0 NEXT STEPS

The City of Boulder is committed to providing safe and effective pedestrian crossing treatments and will continue to evaluate the criteria and treatments being used to implement treatments throughout the City. Specifically, City staff will carry out the following "Next Steps" to ensure that the pedestrian crossing treatment program meets the goals defined in this document:

- Continue testing and evaluation of new multi-lane crossing treatments. These treatments may include variations and/or combinations of the existing RRFB signs to increase both driver and pedestrian awareness at crosswalks. As newer technologies continue to develop into more viable options, passive detection devices such as microwave or video detection may also be tested. As performed for existing devices in the City, evaluation of new devices will include both the effectiveness of devices and a safety (accident history) analysis. Although operational impacts can be evaluated within months of installation of a treatment, it should be noted that safety analysis will require years of accident data to provide relevant results.
- As Federal signing standards continue to become more progressive with respect to enhanced pedestrian signing, strive to become compliant with the standards. This can be accomplished through a combination of bringing Boulder's policies/standards more in line with Federal standards as well as utilizing Boulder's significant experience to help shape future changes to Federal standards.
- Continue to evaluate the City's policy towards provision of curb ramps and median breaks at crossing locations where crosswalks are not provided due to speed, volume, or other consideration.
- Stay current with the latest pedestrian crossing research being performed at the federal, state, and municipal level. As more communities strive to increase the viability of pedestrian mode use additional studies and new findings are being made available. The City of Boulder will look to utilize this research to improve its own use of pedestrian crossing treatments.
- Continue to receive feedback from City of Boulder citizens with respect to various crossing treatments and the criteria established in this document to implement these treatments.
- Continue to work with the Transportation Advisory Board and City Council to implement policies, including these guidelines and any future amendments to this document, to promote the use of pedestrian facilities and the safety of people using them.
- Coordinate with the State of Colorado to modify current state law to include the curb ramp area the definition of a legal crosswalk so that it is clear that a motorist should yield to a pedestrian waiting to cross at a crosswalk.
- Develop an implementation plan to upgrade existing, qualifying crossing locations with "State Law – Yield to Pedestrians" signs as prescribed in this document.
- Continue to evaluate the effectiveness of raised crossings at right-turn bypass islands and work to develop a city-wide policy for application of these treatments.
- Collect data at crossing locations where treatments have been requested (or as defined in the Transportation Master Plan) and apply the criteria in this document to create a list

of projects for implementation. Staff will then prioritize the list of projects and perform crossing treatment installations based on funding availability.

APPENDIX

A1.0 Background

Roadway crossings can be barriers to pedestrian travel. The decision to travel as a pedestrian is in part dependent upon the actual and perceived ability to safely and efficiently cross roadways along the pedestrian's intended travel route. The City of Boulder wants to encourage pedestrian travel by providing safe and efficient roadway crossing opportunities. There are a variety of methods available to help facilitate pedestrian crossings on busy roadways, including marked crosswalks, enhanced crosswalks, and traffic signals. Crosswalk enhancements may include alternative signing, pedestrian-activated warning devices that draw attention to the pedestrian and alert motorists to their presence at a crosswalk, and physical enhancements intended to increase pedestrian visibility and/or reduce exposure such as neckdowns, raised crosswalks, and median refuges.

Signalized traffic control measures to reduce pedestrian-vehicle conflicts typically increase delays for both pedestrian and vehicular traffic. This creates a conflict between providing safety and generating operational efficiency for all modes of travel. These guidelines are tailored to meet the needs of the City of Boulder for optimizing safety and minimizing delay. The Pedestrian Crossing Treatment Installation Guidelines will provide a framework for identifying locations where pedestrian crossing treatments are appropriate and should be implemented by the City.

Application of these guidelines should accomplish the following project goals:

- Promote pedestrian travel by providing safe, efficient, and effective roadway crossing opportunities
- Reflect the needs of our diverse range of pedestrian age and ability groups
- Provide for a balance between the demand for treatments and resources to implement them
- Achieve a reasonable balance of impacts to all modes of travel

A1.1 Standards and Policies

Upon beginning the process of determining pedestrian crossing installation criteria, an extensive review of the latest available technical literature was conducted. This current effort was intended to build upon the research conducted during the previous (1996 and 2006 efforts.

The Manual on Uniform Traffic Control Devices (MUTCD) is the national standard for establishing traffic control on roadways throughout the United States and has been adopted by the City of Boulder as the City standard. Although the MUTCD does provide pedestrian crossing warrant criteria for the installation of pedestrian traffic signals, these warrants have been controversial in that signals are typically very hard to justify. According to the Federal Highway Administration's report on pedestrian signalization alternatives (July 1985), "The existing [1978] MUTCD Minimum Pedestrian Volume Warrant is highly impractical for most real-world conditions and is largely ignored by the traffic engineering community." The MUTCD also offers little guidance with respect to the installation of marked crosswalks, stating that

"crosswalks should be marked at all intersections where there is a substantial conflict between vehicular and pedestrian movements" and that an "engineering study should be performed before they are installed at (uncontrolled) locations."

In response to the controversial MUTCD pedestrian volume and school crossing traffic signal warrants, and lack of guidance by the MUTCD with respect to the installation of marked crosswalks, some agencies have developed their own unique policies and procedures. Generally, these documents supplement the basic provisions of the MUTCD with more detailed criteria based on their own research and field studies.

In 1997, the Institute of Transportation Engineers (ITE) adopted the "Design and Safety of Pedestrian Facilities"[2] as a Recommended Practice. This document built on MUTCD policies and guidelines and provided thresholds for the installation of marked crosswalks at uncontrolled locations based on those developed by Steven A Smith and Richard L. Knoblauch[3]. These guidelines provide recommended thresholds for marked crosswalks based on minimum hourly pedestrian volume, average daily traffic volumes, roadway configuration (laneage and presence of median refuges).

In 2002 the FHWA published a report titled, "Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines"[1]. Based on a five-year safety analysis at 1,000 marked crosswalks and 1,000 unmarked crossing locations, this report provides recommendations for installing marked crosswalks and enhancements based on roadway volume, speed, and laneage. The report suggests that on two-lane roadways, marked crosswalks alone at uncontrolled locations have no effect on pedestrian accident rates. The report also suggests that, on multi-lane roadways with a traffic volume greater than 12,000 vehicles per day, marked crosswalks alone (without any other treatments) are associated with higher vehicle-pedestrian accidents rates compared to unmarked locations.

Several years ago the Virginia Department of Transportation adopted a set of guidelines[4] for the installation of marked crosswalks that built upon the FHWA recommendations and provided more detailed guidance with respect to what types of crosswalk enhancements may be appropriate for a given set of roadway. These guidelines provided five basic levels of devices given the conditions present.

Level 1: standard crosswalk, raised crossing, rumble strips
Level 2: high-visibility crosswalks (retroreflective white markings and textured pavements)
Level 3: refuge islands, split-pedestrian crossover, neckdowns
Level 4: overhead signs and flashing beacons, in-roadway warning lights
Level 5: pedestrian-actuated traffic signals, grade-separated crossings

During the research review, it was noted that the City of Boulder's existing minimum pedestrian volume thresholds (based on the 1996 document) for basic crossing treatments were typically higher than those adopted by the agencies researched. The Virginia guidelines[4], for instance, state a minimum requirement of 20 pedestrians per hour (15 elderly and/or children) or 60 in four hours crossing at the location in question. The City of San Jose, CA[5] have adopted guidelines that require at least 15 pedestrians crossing the street during the highest one-hour period or 25 pedestrians crossing during the highest consecutive two-hour period. This is in comparison to the previously adopted City of Boulder thresholds of 100 pedestrians per hour or 50 pedestrians per hour during the peak four hours. It is believed that this downward trend in

pedestrian volume necessary to warrant treatments is both a result of increased efforts by agencies to accommodate pedestrians and provide safer and more efficient pedestrian facilities.

A1.2 Pedestrian Crossing Enhancements

A wide range of crossing enhancements (treatments used to increase the effectiveness of marked crosswalks) are being used in other communities in the United States and elsewhere which have been considered for use in the City of Boulder. The most comprehensive resource for information relative to these devices, including pros and cons, costs, and effectiveness, is the Alternative Treatments for At-Grade Pedestrian Crossings[6]. Enhancements being used elsewhere include:

- Automated detection
- Curb extensions
- In-pavement lighting
- Flags
- Flashing beacons
- In-roadway signs
- Lane reductions
- Rumble strips
- Markings and legends
- Overhead signs
- Pedestrian railings
- Raised markers (with LEDs)
- Refuge islands
- Street lighting
- Raised crossings
- Pavement treatments

Many of these treatments are being used and/or have been tested as “demonstration” devices in the City of Boulder, with varying degrees of success. Devices used in the City of Boulder have included most of the physical devices shown above, in addition to demonstration devices such as in-pavement lighting, rumble strips, flashing signs, in-roadway signs, and alternative signs and markings (such as the “State Law Yield-to-Pedestrians” signs and advance yield markings).

In 2000, city staff began demonstrating two new enhanced pedestrian crossing treatments. The purpose of these treatments was to draw attention to high volume pedestrian crossing locations and to encourage vehicles to have better compliance with their legal requirement to yield to pedestrians in these locations.

The first demonstration was a new, multi-colored sign which stated “State Law - YIELD to Pedestrians in Crosswalk." The signs were placed on an orange barrel or bollard in the street and mounted on a standard assembly at the side of the street. The other demonstration was pedestrian actuated flashing lights imbedded in a standard pedestrian warning sign, mounted at the side of the road and on medians in the center of the road. These lights flash when a pedestrian pushes a button. Over the past 11 years, staff has been expanding the use of these demonstration devices to other locations within the city.

The City of Boulder will continue to stay abreast of the latest crossing enhancement technologies and research and will continue to test and modify its own applications to maximize the safety and efficiency of these treatments. A discussion of the “Next Steps” involved in this process is included in Section 4.0

A1.3 Evaluation of Demonstration Devices Used in the City of Boulder

Over the past 14 years, the City of Boulder has evaluated driver compliance at crosswalks both before and after the installation of "demonstration devices". The devices evaluated included:

- "State Law–Yield to Pedestrians" Signs and Bollards (used at 2 or 3-lane crossings)
- Pedestrian Activated Flashing (or RRFB) Signs (used primarily at multi-lane crossings)
- Rumble strips

In addition to evaluating the effectiveness of these devices in terms of driver compliance, accident histories were compiled to compare the safety effects of the demonstration devices both before and after installation.

The evaluations have showed that the "State Law -Yield" and RRFB devices are effective at getting more vehicles to comply with state law and yield to pedestrians in crosswalks than if not installed. They accomplish this with a relatively minor impact to vehicle delay. In addition, the evaluation showed that at locations with "State Law – Yield to Pedestrians" signs, there were very few examples of increased accident frequency for either rear-end collisions or accidents involving pedestrians or bicyclists being hit by a motor vehicle. The majority of accident frequencies either stayed the same or was reduced at locations studied.

At locations using the pedestrian-actuated flashing signs, there were increases in rear-end collision frequencies at some locations and increases in the frequency of pedestrians or bicycles being hit in the crosswalk at several locations. Injury accident frequencies also increased at many locations. It should be noted that, since these devices were installed primarily at multi-lane crossing locations, the effectiveness of these devices cannot be directly compared to the "State-Law" signs.

While the pedestrian-actuated flashing signs do not change the rules of the roadway, the effectiveness of encouraging vehicles to yield to pedestrians has resulted in more vehicles stopping for pedestrians, which has further resulted in more rear-end collisions (this same phenomenon exists when new traffic signals are installed in the roadway). It is possible that the increased compliance of motor vehicles yielding to pedestrians is also resulting in some pedestrians and bicyclists using less caution when they cross which in turn results in an increase in vehicle-pedestrian and vehicle-bicycle accidents.

Further analysis of the safety effects of these devices is recommended so that a larger sample of data may be obtained and accident trends related to physical and environmental variables may be identified.

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November
2018





CLARK COUNTY, WA

Clark County Pedestrian Crossing Treatment Policy

Prepared Jointly with HDR

INTEROFFICE MEMORANDUM

Transportation Division

Clark County, Washington

Department of Public Works

TO: Ahmad Qayoumi, P.E., County Engineer

CC: Matt Griswold, P.E., Traffic Engineering Manager

FROM: Ejaz Khan, P.E., Traffic Engineer
Courtney Furman, P.E., Traffic Engineer

DATE: November 19, 2018

SUBJECT Pedestrian Crossing Treatment Policy

Clark County is committed to enhancing mobility and safety for all modes of transportation including bicycles and pedestrians. In line with the mission statement of the Clark County Traffic Engineering Section, the county has prepared this *Pedestrian Crossing Treatment Policy*. The purpose of this policy is to recommend appropriate pedestrian crossing treatments to enhance pedestrian safety and to ensure continued pedestrian mobility.

In accordance with the *Washington State Department of Transportation's Design Manual*, the indiscriminate marking of pedestrian crossings is discouraged because the overuse of marked crosswalks leads to unsafe pedestrian crossing conditions and non-compliance of traffic control by drivers. The policy utilizes objective criteria to recommend pedestrian crossing treatments under varying sets of roadway geometrics, traffic operations and pedestrian crossing demand.

With a focus on uniformity of application, this policy follows a three-step process to guide the consideration and selection of pedestrian crossing treatments.



The methodology was primarily based upon pedestrian delay from the *Highway Capacity Manual*. The delay analysis evaluated a set of typical pedestrian crossings to determine appropriate crossing treatments based on established delay thresholds. The hierarchy of treatment options recommended in this policy is based on the latest research regarding drivers yielding to pedestrians.

The guidance provided in this document must be followed up with an engineering evaluation including a field assessment prior to finalizing a decision regarding a pedestrian crossing treatment. Pedestrian treatment options listed in this document may be modified to include a combination of treatment options or alternate treatment options may be provided for unique cases.

TABLE OF CONTENTS

LIST OF FIGURES ii

LIST OF TABLES ii

CHAPTER 1: INTRODUCTION 1

1.1 Pedestrian Crossing Treatment Policy Background 1

1.2 Pedestrian Crossing Treatment Decision Process 1

CHAPTER 2: CROSSWALK BASICS 3

2.1 Definitions 3

2.2 Laws and Rules about Pedestrian Crossings 4

CHAPTER 3: PEDESTRIAN CROSSING TREATMENTS 9

3.1 Pedestrian Crossing Treatment Decision Trees 9

3.2 Enhanced Crossing Treatment Selection Table 13

3.3 Pedestrian Crossing Toolbox Cut Sheets 13

Appendix

Appendix A: Enhanced Pedestrian Crossing Treatment Decision Tool Memo

Appendix B: Crossing Evaluation Worksheets

Appendix C: HCM Pedestrian Delay Analysis Results

LIST OF FIGURES

Figure 1. Pedestrian Crossing Treatment Decision Process 2
Figure 2. Sources for Pedestrian Crossing Laws and Rules..... 4
Figure 3. Uncontrolled Crossing Decision Tree..... 10
Figure 4. Controlled Crossing Decision Tree..... 11
Figure 5. School Crosswalk Decision Tree 12
Figure 6. Enhanced Crossing Treatment Selection Table 14
Figure 7. Marked Crosswalk Cut Sheet..... 15
Figure 8. Flashing Beacon Cut Sheet..... 16
Figure 9. Pedestrian Hybrid Beacon Cut Sheet..... 17

LIST OF TABLES

Table 1. RCWs pertaining to pedestrian crossings 6
Table 2.WACs pertaining to pedestrian crossings..... 7

ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
FHWA	Federal Highway Administration
HCM	Highway Capacity Manual
MUTCD	Manual on Uniform Traffic Control Devices
MPH	Miles per Hour
NCHRP	National Cooperative Highway Research Program
PHB	Pedestrian Hybrid Beacon
RCW	Revised Code of Washington
SSD	Stopping Sight Distance
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation

CHAPTER 1: INTRODUCTION

1.1 Pedestrian Crossing Treatment Policy Background

Clark County, Washington has been experiencing an increased demand to provide enhanced pedestrian facilities. As demand for pedestrian mode of travel continues to increase, the County is committed to provide infrastructure for a seamless network and efficient movement of pedestrians, including a variety of pedestrian crossing treatments. The Clark County Pedestrian Crossing Treatment Policy has developed decision-making guidelines to help recommend the appropriate pedestrian crossing treatment, best suited for each potential location. This policy is intended to inform and guide developers and County staff about triggers, considerations, and requirements associated with the implementation of enhanced crossing treatments within Clark County.

The purpose of this policy is to define trigger points for pedestrian crossing treatments and recommend appropriate pedestrian crossing treatments to enhance pedestrian safety and to ensure continued pedestrian mobility.

The guidelines provided in this policy cover the suitability of marked crosswalks, flashing beacons and pedestrian hybrid beacons, and standards for traffic control devices including signing, striping, pavement markings, and illumination to ensure consistent and uniform applications. The crossing treatment applications contained in this document are not the only treatments that may be used. Variations of the above mentioned treatments or other pedestrian crossing treatments as prescribed in the Federal Highway Administration's Pedestrian Crossing Treatment Toolbox[1] may be used to address unique situations.

1.2 Pedestrian Crossing Treatment Decision Process

This policy introduces the Pedestrian Crossing Treatment Decision Process, which includes three steps that guide the consideration and selection of pedestrian crossing treatments. The three-step process, outlined below in Figure 1, includes Pedestrian Crossing Treatment Decision Trees for controlled crossings at intersections, uncontrolled crossings at intersections or mid-block locations and school crossing locations; an Enhanced Crossing Treatment Selection Table; and conceptual Pedestrian Crossing Toolbox Cut Sheets to guide facility implementation.

[1] https://www.fhwa.dot.gov/publications/research/safety/01102/01102.pdf

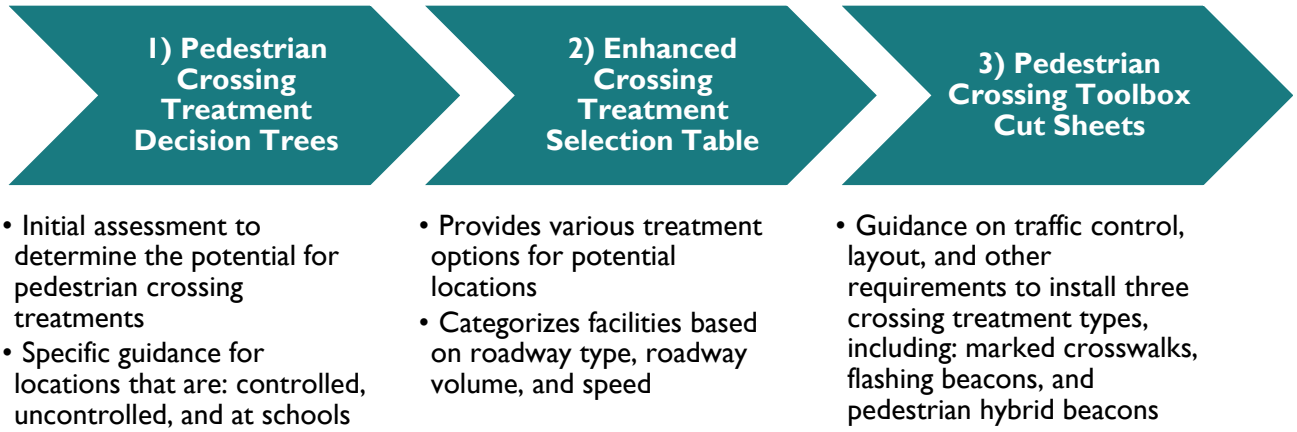


Figure 1. Pedestrian Crossing Treatment Decision Process

The following describes the pedestrian crossing treatment decision process in further detail:

1. ***Pedestrian Crossing Treatment Decision Trees***
   The decision trees are an initial assessment to assist in determining the suitability of pedestrian crossing treatments at an existing or proposed pedestrian crossing location based on a series of criteria. This includes specific guidance on locations that are uncontrolled, controlled (for both signals and stop signs), or near schools, and includes criteria that considers shared-use path locations, roadway volumes, pedestrian volumes, and proximity to existing crosswalks. To prevent proliferation of unwarranted marked crosswalks, the use of traffic engineering guidelines such as the Washington State Department of Transportation's *Design Manual* discourages the indiscriminate use of marked crosswalks. An engineering evaluation including a field assessment should always be conducted prior to finalizing a decision regarding a pedestrian crossing treatment. In addition, a pedestrian crossing treatment may be provided to channelize pedestrians at a certain location.
2. ***Enhanced Crossing Treatment Selection Table***
   The selection table provides appropriate treatment options for potential locations under various sets of pedestrian, vehicle, and roadway conditions. The table categorizes facilities based on roadway type, roadway volume, and speed at specific crossing locations under consideration.
3. ***Pedestrian Crossing Toolbox Cut Sheets***
   The cut sheets provide implementation guidance on traffic control, general layout, and other requirements to install three crossing treatment types, including marked crosswalks, flashing beacons, and pedestrian hybrid beacons (PHB).

CHAPTER 2: CROSSWALK BASICS

2.1 Definitions

An **unmarked crosswalk** is a legal crossing, at a public road intersection, without any pavement marking feature delineating the crossing. Unmarked crosswalks include the portion of the roadway behind a prolongation of the curb or edge of the through traffic lane and a prolongation of the farthest sidewalk connection.[2]

A **marked crosswalk** is a legal crossing with the traffic control feature of pavement markings delineating the crossing. Marked crosswalks can be used at intersections or mid-block locations. Crosswalks are not to be marked indiscriminately. When crosswalks are marked, they shall follow Clark County Standard Detail T3.0.

Controlled crossings are legal crosswalks across a roadway approach that is controlled by a positive regulatory traffic control device such as a stop sign, traffic signal or pedestrian hybrid beacon.

Uncontrolled crossings are legal crosswalks across a roadway approach not controlled by a positive regulatory traffic control device. Uncontrolled crossings can occur at intersections or mid-block locations. Uncontrolled crossings may need to be enhanced with additional warning devices in various forms such as static signs or flashing beacons.

Public road intersections are legal crossings for pedestrians even without the pavement marking. Because drivers do not expect pedestrians to cross at mid-block locations, it is preferable to install pedestrian crossing treatments at public road intersections. There are situations where a mid-block pedestrian crossing can be considered, however engineering judgment should be used and the decision to recommend a mid-block pedestrian crossing should be documented. Factors to include regarding the use of mid-block pedestrian crossings include the following:

- On roadways with very high pedestrian crossing traffic caused by nearby pedestrian generators.
- Modal interchange points where high volumes of crossing pedestrians occur (e.g., transit stop to an apartment complex).
- High pedestrian crossing volumes present with long block spacing and the out-of-direction travel to the nearest controlled crossing exceeds 600 feet.
- Crash history at mid-block locations.
- Realistic opportunity to channel multiple pedestrian crossings to a single location.
- Sight lines that enable sufficient eye contact between motorists and pedestrians.
- Community commitment for a successful outcome.
- Ability to mitigate risks associated with the location using proven countermeasures such as, but not limited to, refuge islands, flashing beacons, and/or pedestrian hybrid beacons. [3]

Care should be taken to ensure that all signing, striping, and pavement markings intended to warn the drivers of the approaching mid-block pedestrian crossing locations are conspicuous to the maximum extent possible.

School crossings are uncontrolled crossings, and Clark County requires the protection of an adult crossing guard. See the Clark County School Zone Traffic Control Policy for further detail.

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[2] WSDOT Design Manual Section 1510.10(2)(a)
[3] WSDOT Design Manual Section 1510.10

2.2 Laws and Rules about Pedestrian Crossings

Laws and rules about pedestrian crossings are set at both the national, state, and county levels. Several national, state, and county manuals provide guidance on the implementation of pedestrian crossing traffic control devices that are compliant with the laws. National guidance should be used unless there is a Washington State or Clark County modification in place. Figure 2 shows the sources for laws and rules that were used to develop this policy regarding pedestrian crossings grouped at the national, state and county levels.

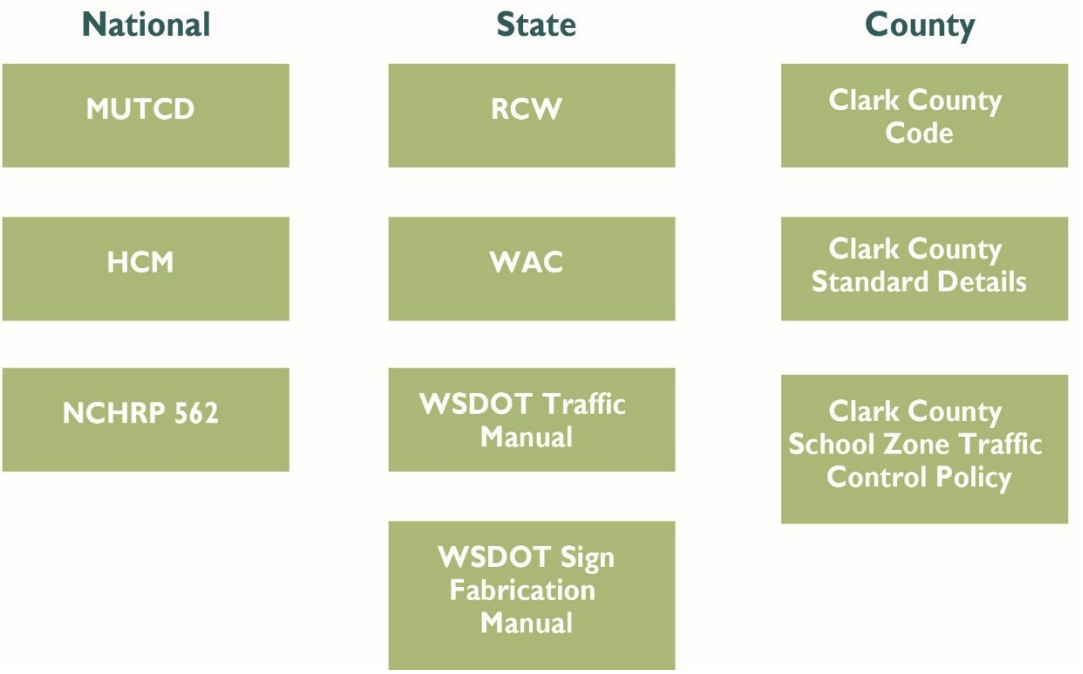


Figure 2. Sources for Pedestrian Crossing Laws and Rules

Manual on Uniform Traffic Control Devices (MUTCD)

The MUTCD, published by the Federal Highway Administration (FHWA), sets national standards and guidelines for traffic control devices along facilities open to public travel (see Appendix A for more details).

Traffic control devices for pedestrian crossings are covered in various parts of the manual (Parts 2, 3, and 4). The MUTCD provides guidance on the following items related to pedestrian crossings:

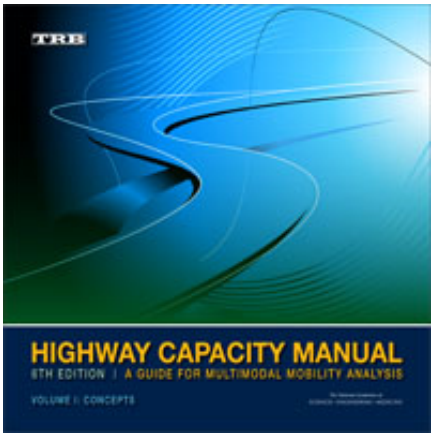
- Pedestrian crossing signs and pavement markings
- Warrants for traffic signals based on pedestrian volume
- Warrants for pedestrian hybrid beacons
- Provisions for pedestrians at signalized locations

Uniform application of traffic control devices is a proven method of improving safety at pedestrian crossings. Uniformity avoids confusion among road users and promotes consistent behavior and expectations.

The MUTCD emphasizes the importance of uniformity by providing standards and guidance on many aspects of signing and pavement markings, such as sign sizes, color, location, mounting height, and retro-reflectivity.

Highway Capacity Manual (HCM)

The HCM provides methods to quantify highway capacity and quality of service. The HCM is published by the Transportation Research Board and is the national standard.



It consists of four dimensions:

- Quantity of travel, the magnitude of use of a transportation facility or service;
- Quality of travel, users' perceptions of travel on a transportation facility or service with respect to their expectations;
- Accessibility, the ease with which travelers can engage in desired activities; and
- Capacity, the ability of a transportation facility or service to meet the quantity of travel demanded of it.

Quality of service for uncontrolled pedestrian crossings is covered in Chapter 20, which is based on pedestrian delay and is linked to a pedestrian's likelihood of risk taking behavior.

National Cooperative Highway Research Program (NCHRP) 562 – Improving Pedestrian Safety at Unsignalized Crossings

NCHRP 562 provides guidelines that can be used to select pedestrian crossing treatments for unsignalized intersections and mid-block locations based on data collected and analyzed through the research study. The guidelines are based on pedestrian volume, street crossing width, speed and traffic volume. The recommendations include a marked crosswalk, enhanced/high-visibility/"active when present" traffic control device, red signal or beacon device and a conventional traffic control signal. The report also provides a spreadsheet that can be used to determine the appropriate pedestrian crossing treatment per their recommendations. In addition to the guidance on pedestrian crossing treatments, NCHRP 562 also provides modifications to the MUTCD signal warrants for pedestrian volume, which are difficult to meet in many cases.

NCHRP 562 was developed with two main objectives:

- Identify pedestrian crossing treatments to improve safety for pedestrians crossing high-volume and high-speed roadways at unsignalized locations.
- Recommend modifications to the MUTCD pedestrian traffic signal warrant guidance.

Revised Code of Washington (RCW)

The Revised Code of Washington (RCW) is a compilation of the current laws in the state of Washington. Title 46 relates to motor vehicle laws and Title 61 is specific to rules of the road. Several RCWs apply to pedestrian crossings, as described in Table 1.

Table 1. RCWs pertaining to pedestrian crossings

RCW Number	Name	Description
46.61.065	Flashing signals	Whenever an illuminated flashing red or yellow signal is used in a traffic sign or signal it shall require obedience by vehicular traffic as follows: ■ FLASHING RED (STOP SIGNAL) – vehicles shall stop at a clearly marked stop line, but if none, before entering a marked crosswalk on the near side of the intersection, or, if none, then at the point nearest the intersecting roadway where the driver has a view of approaching traffic on the intersecting roadway before entering the intersection, and the right to proceed shall be subject to the rules applicable after making a stop at a stop sign. ■ FLASHING YELLOW (CAUTION SIGNAL) – vehicles may proceed through the intersection with caution.
46.61.230	Pedestrians subject to traffic regulations	Pedestrians shall be subject to traffic-control signals at intersections
46.61.235	Crosswalks	■ Vehicles shall stop and remain stopped to allow a pedestrian or bicycle to cross the roadway within an unmarked or marked crosswalk when the pedestrian or bicycle is upon or within one lane of the half of the roadway upon which the vehicle is traveling or onto which it is turning. For purposes of this section "half of the roadway" means all traffic lanes carrying traffic in one direction of travel, and includes the entire width of a one-way roadway. ■ Pedestrians and bicyclists shall not suddenly leave a curb or other place of safety and move into the path of a vehicle which is so close that it is impossible for the driver to stop. ■ Vehicles are not allowed to pass when a vehicle is stopped at a crosswalk for a pedestrian or bicyclist to cross the roadway
46.61.240	Crossing at other than crosswalks	■ Pedestrians crossing a roadway at any point other than within a marked crosswalk or within an unmarked crosswalk at an intersection shall yield the right-of-way to vehicles. ■ Where curb ramps exist at or adjacent to intersections or at marked crosswalks, disabled persons may enter the roadway from the curb ramps and cross the roadway within or as closely as practicable to the crosswalk. ■ Pedestrians shall not cross at any place between adjacent signalized intersections except for a marked crosswalk. ■ Pedestrians shall not cross a roadway intersection diagonally unless authorized by official traffic-control devices. ■ Pedestrians shall not cross a roadway at an unmarked crosswalk where an official sign prohibits such crossing.

RCW Number	Name	Description
46.61.245	Drivers to exercise care	Drivers shall exercise due care to avoid colliding with any pedestrian upon any roadway
46.61.261	Sidewalks, crosswalks – Pedestrians, bicycles	Bicyclists shall yield right-of-way to a pedestrian on a crosswalk

Washington Administrative Code (WAC)

The Washington Administrative Code (WAC) amends the MUTCD to comply with laws and policies specific to the Revised Code of Washington (the RCWs). These amendments for pedestrian crossings are listed in Table 2.

Table 2.WACs pertaining to pedestrian crossings

WAC Number	Name	Description
468-95-033	In-street pedestrian crossing sign (R1-6a)	MUTCD Section 2B.12 Amends the MUTCD regarding in-street pedestrian crossing signs to remove the 'yield to pedestrians' option and keeps the 'stop for pedestrians' option. Deletes signs R1-5, R1-5a, R1-6, and R1-9 from Figure 2B-2.
468-95-230	Crosswalk markings	MUTCD Section 3B.18 Amends the MUTCD regarding the crosswalk marking patterns.
468-95-360	Crosswalk markings	MUTCD Section 7C.02 Amends the MUTCD regarding the crosswalk marking patterns.

Washington State Department of Transportation (WSDOT) Traffic Manual and Sign Fabrication Manual

The WSDOT Traffic Manual provides guidance on pedestrian crossings, crosswalk specifications and standard details for crosswalks and stop lines (see Chapter 3). The WSDOT Sign Fabrication Manual provides fabrication details to maintain uniformity in appearance of signs.

Clark County Code

The Clark County Code is a codification of the general ordinances of Clark County, Washington. Title 10, vehicles and traffic, Title 12, streets and roads, and Title 40, unified development code, all include information regarding pedestrian crossings.

Clark County Standard Details

The Clark County Standard Details are provided for constructing various projects within the county. The details include roadway, drainage, sidewalk, and development and have been grouped according to specific construction categories. There are Clark County Standard Details for signing and striping.

Clark County School Zone Traffic Control Policy

The Clark County School Zone Traffic Control Policy, approved in 2016, provides clear guidance on the implementation of school zone traffic control under various sets of conditions. The policy provides assessments for when school crossings, reduced school speed zones, school areas, and school zone flashers should be implemented. Additionally, the policy includes details regarding signing, striping and illumination requirements.

CHAPTER 3: PEDESTRIAN CROSSING TREATMENTS

This policy is intended to inform and guide developers, and County staff the triggers, considerations, and requirements associated with implementing pedestrian crossing treatments within Clark County. The following three-step decision process guides the consideration and selection of pedestrian crossing treatments:

1. **Pedestrian Crossing Treatment Decision Trees:** The first decision point determines the potential for pedestrian crossing treatments, depending upon if the location is currently uncontrolled, controlled, or near a school.
2. **Enhanced Crossing Treatment Selection Table:** The outcome of the applicable decision tree may direct the user to the Enhanced Crossing Treatment Selection Table. The selection table determines an appropriate crossing treatment, including a marked crosswalk only, flashing beacons, a raised pedestrian refuge island, a pedestrian hybrid beacon, traffic signal or a combination of the above.
3. **Pedestrian Crossing Toolbox Cut Sheets**: The toolbox includes signing, striping, and design considerations for various pedestrian crossing treatments to assist in facility implementation.

3.1 Pedestrian Crossing Treatment Decision Trees

The first decision point assists in determining the potential need for pedestrian crossing treatments at an existing crosswalk or a proposed pedestrian crossing location based on a series of criteria. The existing traffic control at the crossing location and proximity to a school (e.g., uncontrolled, controlled, or near a school) determines which decision tree to use. An uncontrolled location can be at an intersection or mid-block. A controlled location can be a signal, roundabout, or at a stop sign. A school crosswalk can be adjacent to school grounds or shown on a school route plan.

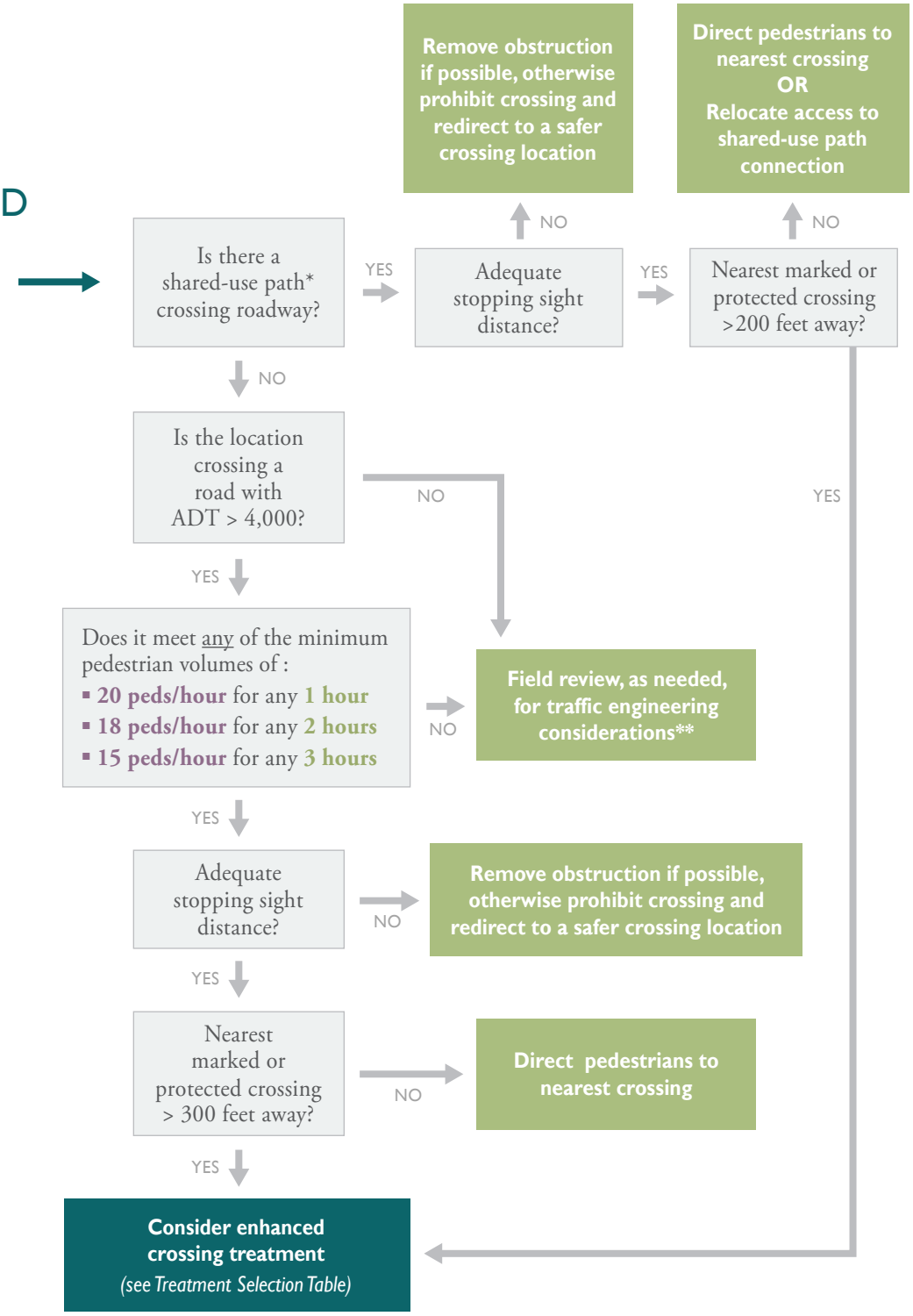
There are three decision trees: uncontrolled crossings, controlled crossings, and school crosswalks:

- Uncontrolled locations – see Figure 3
- Controlled locations – see Figure 4
- Locations near a school – see Figure 5

An evaluation worksheet for each type of crossing location is provided in Appendix B to help collect field data to identify what type of crossing treatment is appropriate based on the evaluation criteria. One outcome from the decision trees is to move on to Step 2 of the decision process, to see the Enhanced Crossing Treatment Selection Table (Figure 6).

UNCONTROLLED CROSSING DECISION TREE - Figure 3

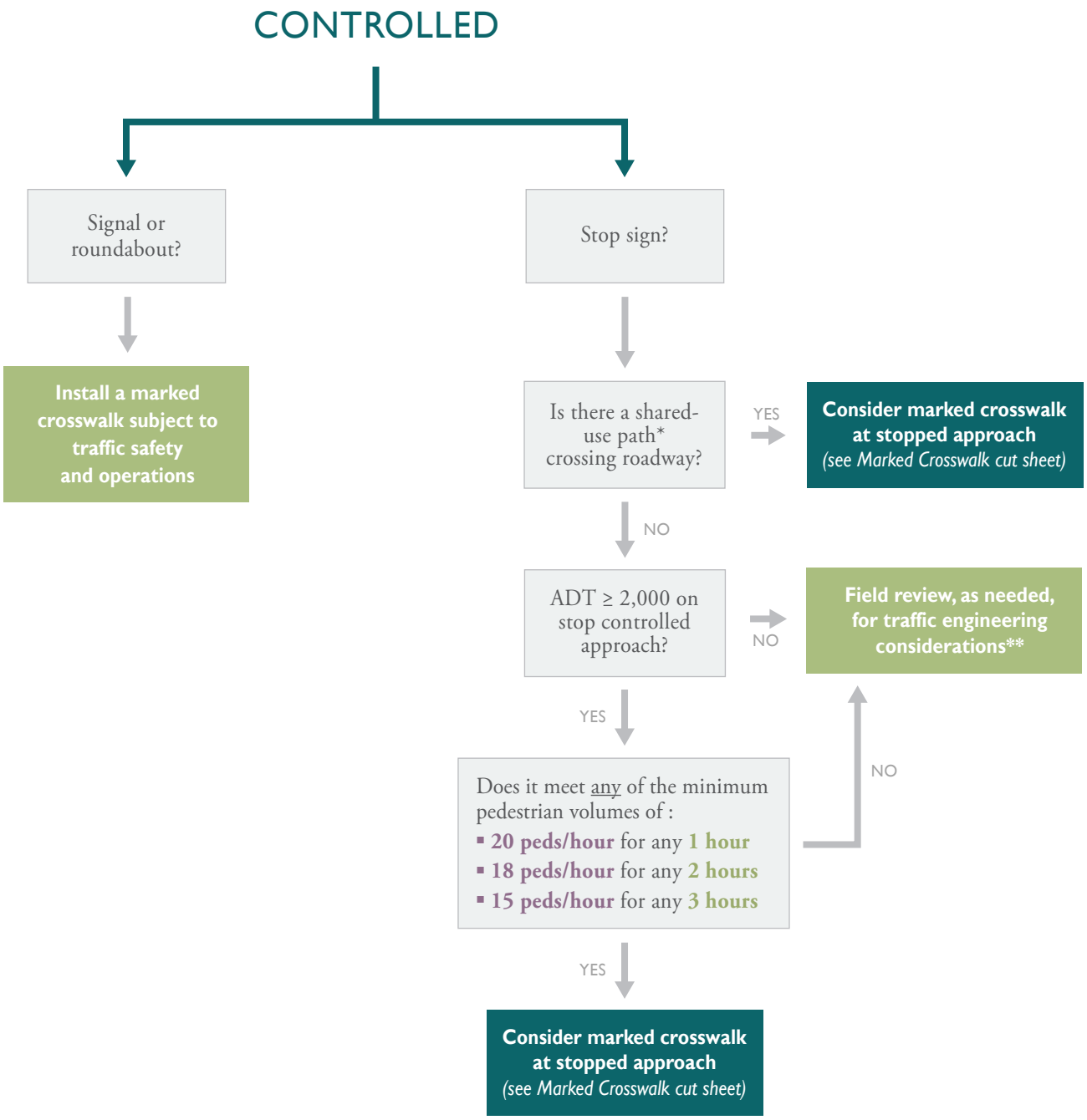
UNCONTROLLED (INTERSECTION/ MIDBLOCK)



* Shared-use path defined as a public facility separated from motorized vehicular traffic for bicyclists and pedestrians.

** Traffic engineering considerations include, but are not limited to the following: pedestrian activity, vehicle turning movements, speed, crossing distance, and crash history.

CONTROLLED CROSSING DECISION TREE - Figure 4

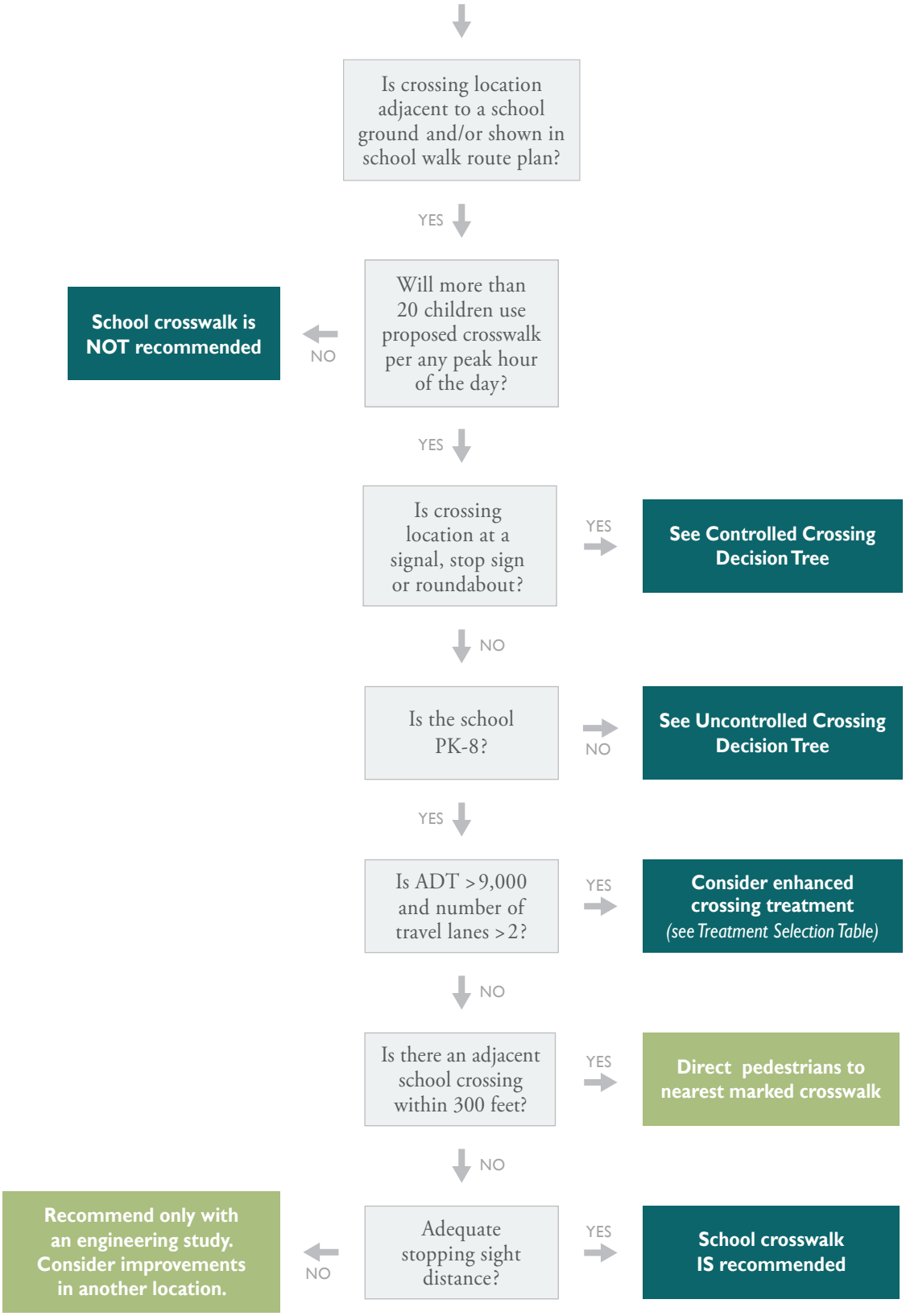


* Shared-use path defined as a public facility separated from motorized vehicular traffic for bicyclists and pedestrians.

** Traffic engineering considerations include, but are not limited to the following: pedestrian activity, vehicle turning movements, speed on stop controlled, approach, and crash history.

SCHOOL CROSSWALK DECISION TREE - Figure 5

CRITERIA PER CLARK COUNTY SCHOOL ZONE TRAFFIC CONTROL POLICY



3.2 Enhanced Crossing Treatment Selection Table

The Enhanced Crossing Treatment Selection Table (Figure 6) was developed based upon peer cities, the Zeeger table, and delay analysis from the Highway Capacity Manual.[4] The HCM pedestrian delay was the primary influence on the selection table recommendations, the results of which are shown in Appendix C. The delay analysis evaluated a set of typical pedestrian crossings to determine delay thresholds to assist in the selection of the appropriate crossing treatment. A delay threshold of 30 seconds was used where only a marked crosswalk at an existing unmarked location would be sufficient.

The outcomes from the selection table include a marked crosswalk, flashing beacons, a raised pedestrian refuge island, a pedestrian hybrid beacon, or traffic signals. For each of those facilities, see the Pedestrian Crossing Toolbox Cut Sheets for further details on implementation.

The selection table shown in Figure 6 provides a preliminary recommendation, but requires a follow-up engineering study for the final treatment selection. The engineering study needs to account for factors such as sight distance, traffic safety, traffic operations, pedestrian population, and other field conditions. Additionally, a site-specific delay analysis using the HCM and field observation of gaps in traffic stream is required before a final treatment is selected.

3.3 Pedestrian Crossing Toolbox Cut Sheets

The following Pedestrian Crossing Cut Sheets provide implementation guidance on each of the different potential enhanced pedestrian crossing treatments. The Pedestrian Crossing Toolbox includes details about signing, striping, and design considerations for the following pedestrian crossing treatments:

- Marked Crosswalks (with and without an island) – see Figure 7
- Flashing Beacons (with and without an island) – see Figure 8
- Pedestrian Hybrid Beacons (with and without an island) – see Figure 9

[4] Highway Capacity Manual, 6th Edition, Chapter 20 Two-Way Stop Controlled Intersections: Pedestrian Mode, 2016

ENHANCED CROSSING TREATMENT SELECTION TABLE - Figure 6

IF THE DECISION TREE OUTCOME WAS **CONSIDER ENHANCED CROSSING TREATMENT** **THEN REFER TO THIS SELECTION TABLE**

RECOMMENDATIONS FOR MARKED CROSSWALKS AND ENHANCED PEDESTRIAN CROSSING TREATMENTS AT UNCONTROLLED LOCATIONS

ROADWAY TYPE (NUMBER OF TRAVEL LANES)	VEHICLE ADT **> 4,000 TO 6,000**			VEHICLE ADT **> 6,000 TO 9,000**			VEHICLE ADT **> 9,000 TO 12,000**			VEHICLE ADT **> 12,000 TO 15,000**			VEHICLE ADT **>15,000**		
	SPEED LIMIT														
	≤ 30 MPH	35 MPH	≥ 40 MPH	≤ 30 MPH	35 MPH	≥ 40 MPH	≤ 30 MPH	35 MPH	≥ 40 MPH	≤ 30 MPH	35 MPH	≥ 40 MPH	≤ 30 MPH	35 MPH	≥ 40 MPH
2 Lanes	**A**	**A**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**E**	**B**	**B**	**E**
3 Lanes	**A**	**A**	**B**	**C**	**C**	**D**	**C**	**D**	**D**	**C**	**D**	**E**	**D**	**D**	**E**
Multi-Lane (4 or more Lanes)	**C**	**C**	**C**	**C**	**C**	**D**	**C**	**D**	**E**	**D**	**D**	**E**	**D**	**D**	**E**

NOTES:

- *Shared-use path crossing locations with ADT less than 4,000 ADT may qualify for marked crosswalks and/or enhanced pedestrian crossing treatments as shown in the column for "Vehicle ADT >4,000 to 6,000."*
- *Installation of marked crosswalk or enhanced crossing treatment, at any location, subject to engineering study and judgement that accounts for factors such as sight distance, traffic safety, traffic operations, other field conditions and pedestrian population. The engineering study must include a site-specific delay analysis, using the HCM.*

LEGEND

- **A** Marked Crosswalk
- **B** Marked Crosswalk with Flashing Beacon
- **C** Marked Crosswalk with Median Island
- **D** Marked Crosswalk with Flashing Beacon and Median Island
- **E** Marked Crosswalk with Pedestrian Hybrid Beacon (PHB) or Traffic Signal

REFERENCES:

- *Zegeer, Steward, Huang, "Safety Effects of Marked vs Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines", FHWA, 2002.*
- *Manual on Uniform Traffic Control Devices (MUTCD), 2009 Edition, published by FHWA.*
- *Highway Capacity Manual (HCM), 2016 sixth edition, published by TRB.*

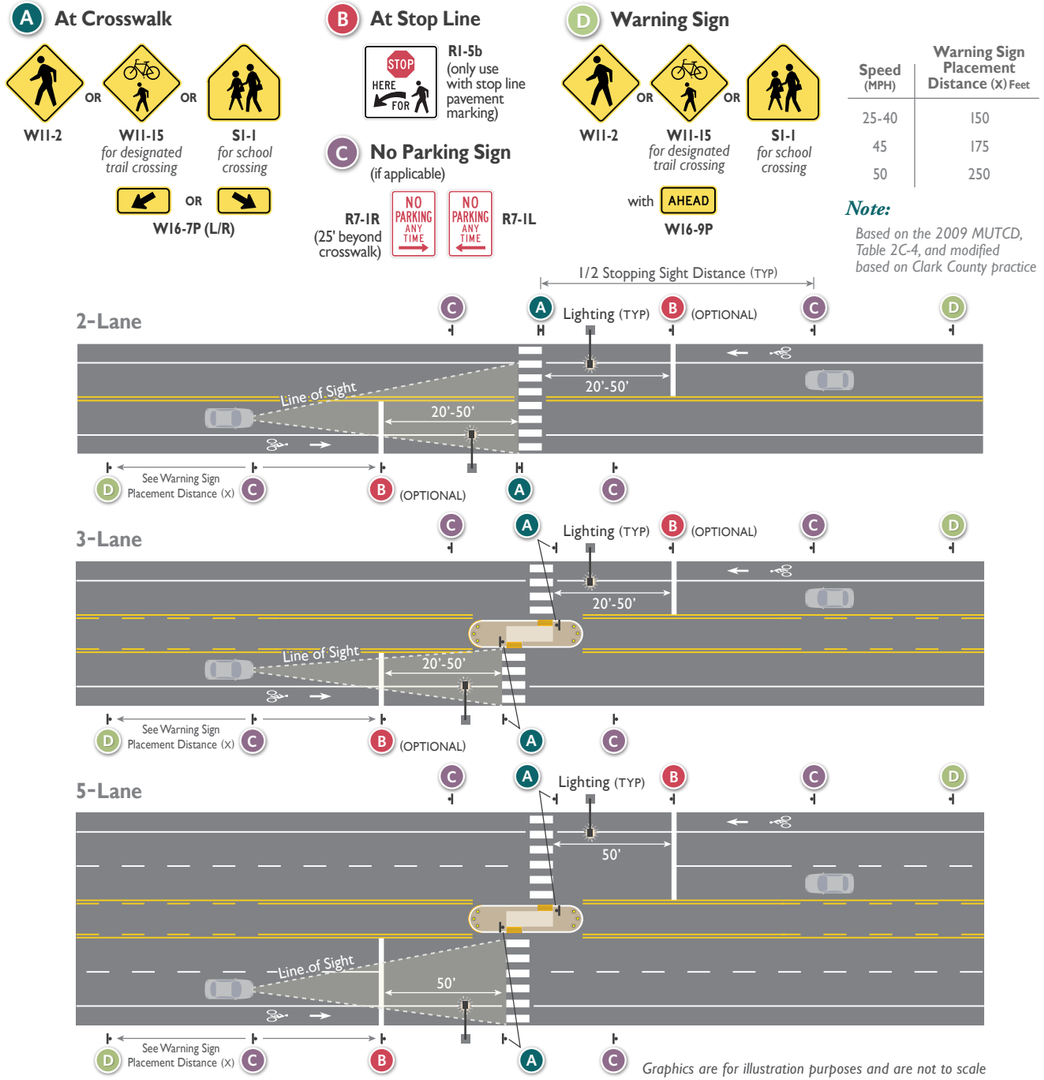
Clark County Pedestrian Crossings

MARKED CROSSWALK - Figure 7

MARKED CROSSWALKS

Marked crosswalks direct pedestrians to cross the street at a designated location either at intersections or midblock locations. Crosswalk markings are typically 8 feet wide, ladder-style, and are clearly marked and signed *(see Clark County Standard Detail T3.0)*. They can be installed on either two-lane or multi-lane roadways, as justified by an engineering study. Conceptual road sections with typical marked crosswalk signage and striping are shown below.

SIGNING + STRIPING



Speed (MPH)	Warning Sign Placement Distance (X) Feet
25-40	150
45	175
50	250

Note:

Based on the 2009 MUTCD, Table 2C-4, and modified based on Clark County practice

Graphics are for illustration purposes and are not to scale

STOPPING SIGHT DISTANCE

The available stopping sight distance should be sufficiently long to enable a vehicle traveling at the posted speed listed to stop before reaching the stop line or prior to the crosswalk. A pedestrian crossing shall only be installed if the minimum sight distance to the stopping location is achieved. On-street parking or sight obstructions should be removed in stopping line of sight.

Posted Speed (mph)	Stopping Sight Distance (SSD)[1]
25	210 ft
30	265 ft
35	325 ft
40	390 ft
45	460 ft
50	535 ft

1. *Typical condition is the warning of a potential stop situation. The distances are based on the 2011 AASHTO "Green Book," Table 3-1, Stopping Sight Distance, with a modified brake reaction time of 4.0 seconds, to account for longer detection time.*

LIGHTING

Illuminate the entire midblock pedestrian crossing, including any refuge area in the roadway, and the sidewalks or shoulders adjacent to the crosswalk per the current WSDOT Design Manual, Chapter 1040. Lighting analysis should be performed to confirm that light levels will meet the standards listed below. Emphasis should be placed on positive lighting of the pedestrians in the crosswalk and on the adjacent sidewalks.

FROM WSDOT DESIGN MANUAL EXHIBIT 1040-22: LIGHT LEVELS AND UNIFORMITY RATIOS

Minimum Average Maintained Horizontal Light Level — Pedestrian/Area Classification *(footcandles)*			Maximum Uniformity Ratio [2]	Maximum Veiling Luminance Ratio [3]
High	Medium	Low		
Midblock pedestrian crossing				
2.0	2.0	2.0	4:1	0.3:1
Highways without full access control – intersections				
1.2	0.9	0.9	4:1	0.3:1

2. *Minimum Average Maintained Light Level / Minimum Light Level = Maximum Uniformity Ratio*

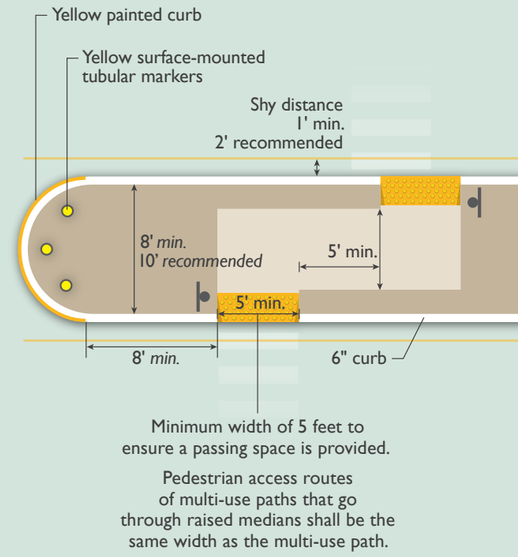
3. *Maximum Veiling Luminance / Average Luminance = Veiling Luminance Ratio*

Note:

Both midblock and intersection – different areas covered (see Exhibit 1040-B for intersection)

MEDIAN ISLAND WITH PEDESTRIAN REFUGE DETAIL

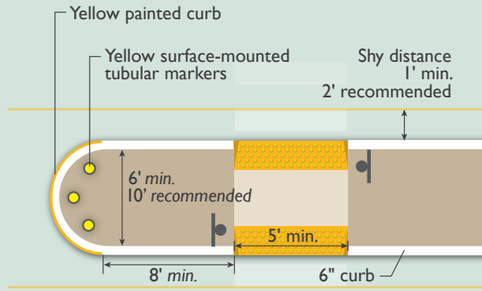
Preferred Option



Minimum width of 5 feet to ensure a passing space is provided.

Pedestrian access routes of multi-use paths that go through raised medians shall be the same width as the multi-use path.

Alternate Option



REFERENCE

WSDOT Design Manual, *Exhibit 1510-22*

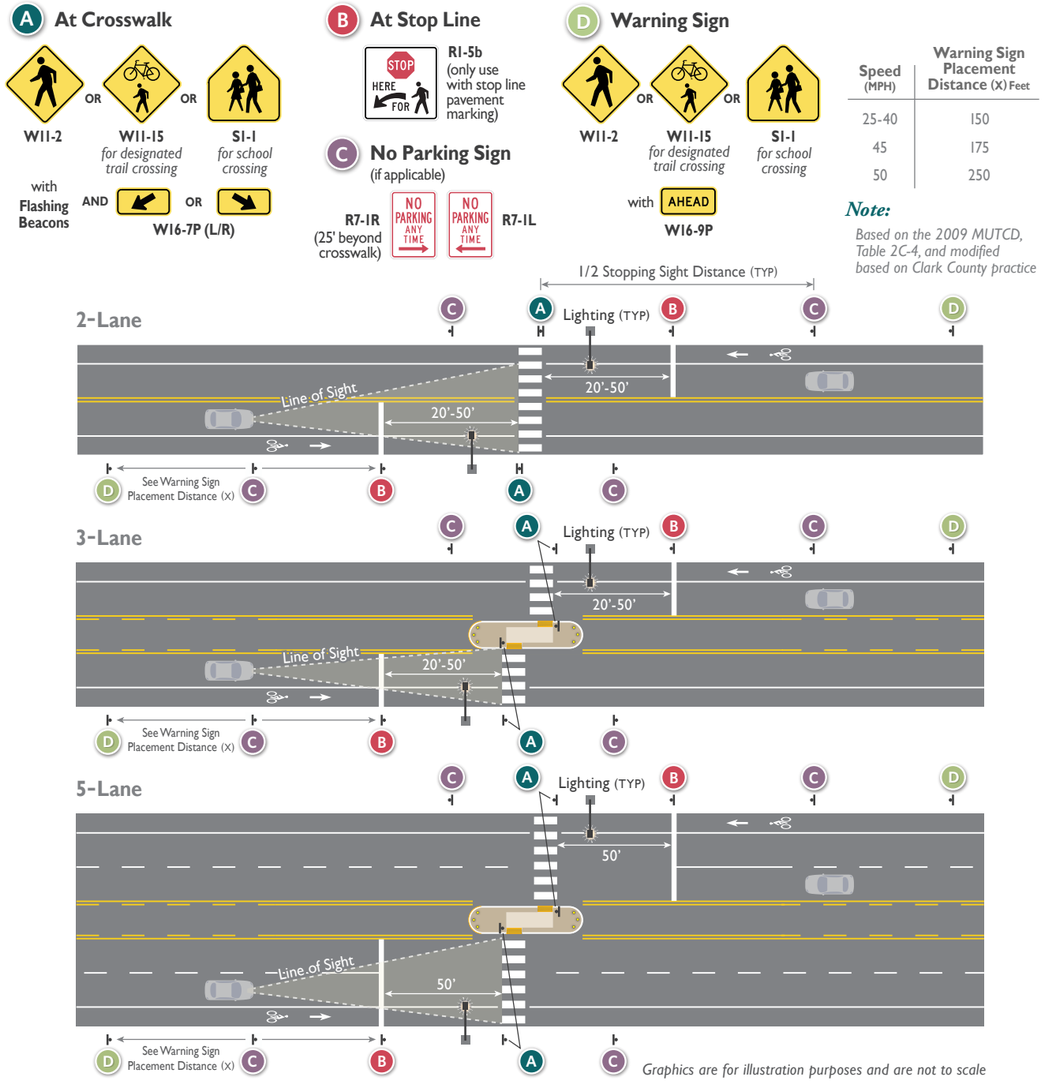
Clark County Pedestrian Crossings

FLASHING BEACON - Figure 8

FLASHING BEACONS

Flashing beacons are user-actuated amber LEDs that accentuate warning signs at uncontrolled pedestrian crossings. They are manually activated by pedestrians pushing a button. Flashing beacons comply with the MUTCD. WSDOT provides a standard detail (IS-22) for flashing beacon configuration. Conceptual road sections with typical marked crosswalk signage and striping are shown below.

SIGNING + STRIPING



Speed (MPH)	Warning Sign Placement Distance (X) Feet
25-40	150
45	175
50	250

Note:

Based on the 2009 MUTCD, Table 2C-4, and modified based on Clark County practice

Graphics are for illustration purposes and are not to scale

STOPPING SIGHT DISTANCE

The available stopping sight distance should be sufficiently long to enable a vehicle traveling at the posted speed listed to stop before reaching the stop line. A midblock pedestrian crossing shall only be installed if the minimum sight distance to the stopping location is achieved. On-street parking or sight obstructions should be removed in stopping line of sight.

Posted Speed (mph)	Stopping Sight Distance (SSD)[1]
25	155 ft
30	200 ft
35	250 ft
40	305 ft
45	360 ft
50	425 ft

1. *Typical condition is the warning of a potential stop situation. The distances are based on the 2011 AASHTO "Green Book," Table 3-1, Stopping Sight Distance.*

LIGHTING

Illuminate the entire midblock pedestrian crossing, including any refuge area in the roadway, and the sidewalks or shoulders adjacent to the crosswalk per the current WSDOT Design Manual, Chapter 1040. Lighting analysis should be performed to confirm that light levels will meet the standards listed below. Emphasis should be placed on positive lighting of the pedestrians in the crosswalk and on the adjacent sidewalks.

FROM WSDOT DESIGN MANUAL EXHIBIT 1040-22: LIGHT LEVELS AND UNIFORMITY RATIOS

Minimum Average Maintained Horizontal Light Level — Pedestrian/Area Classification (footcandles)			Maximum Uniformity Ratio [2]	Maximum Veiling Luminance Ratio [3]
High	Medium	Low		
Midblock pedestrian crossing				
2.0	2.0	2.0	4:1	0.3:1
Highways without full access control – intersections				
1.2	0.9	0.9	4:1	0.3:1

2. *Minimum Average Maintained Light Level / Minimum Light Level = Maximum Uniformity Ratio*

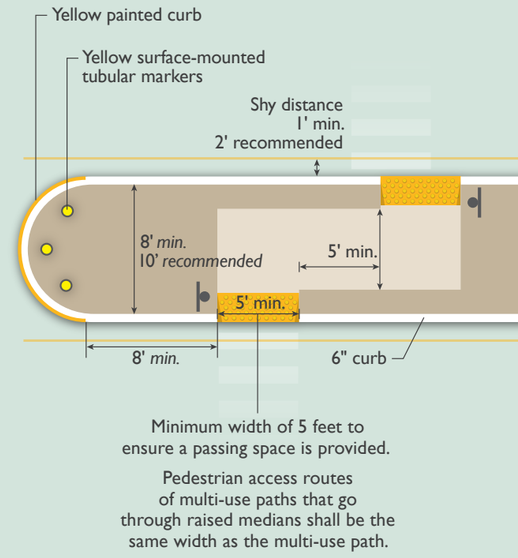
3. *Maximum Veiling Luminance / Average Luminance = Veiling Luminance Ratio*

Note:

Both midblock and intersection – different areas covered (see Exhibit 1040-B for intersection)

MEDIAN ISLAND WITH PEDESTRIAN REFUGE DETAIL

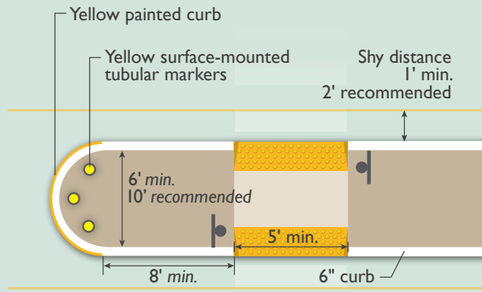
Preferred Option



Minimum width of 5 feet to ensure a passing space is provided.

Pedestrian access routes of multi-use paths that go through raised medians shall be the same width as the multi-use path.

Alternate Option



REFERENCE

WSDOT Design Manual, *Exhibit 1510-22*

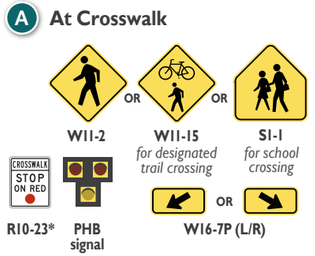
Clark County Pedestrian Crossings

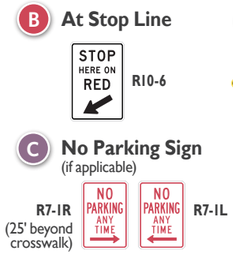
PEDESTRIAN HYBRID BEACON (PHB) - Figure 9

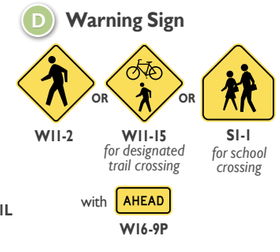
PEDESTRIAN HYBRID BEACONS

PHBs are user-actuated LEDs that illuminate when a pedestrian manually pushes a button. Upon activation, the LED illuminates a flashing yellow beacon then changes to solid yellow to communicate to drivers to prepare to stop. The beacon changes to a steady red once it is safe for a pedestrian to cross, followed by a flashing red during the pedestrian clearance interval. PHBs have FHWA official approval and can be installed on either a two-lane or multi-lane roadway, as long as they are installed 100 feet from a side street, and are justified by an engineering study. Conceptual road sections with typical marked crosswalk signage and striping are shown below.

SIGNING + STRIPING



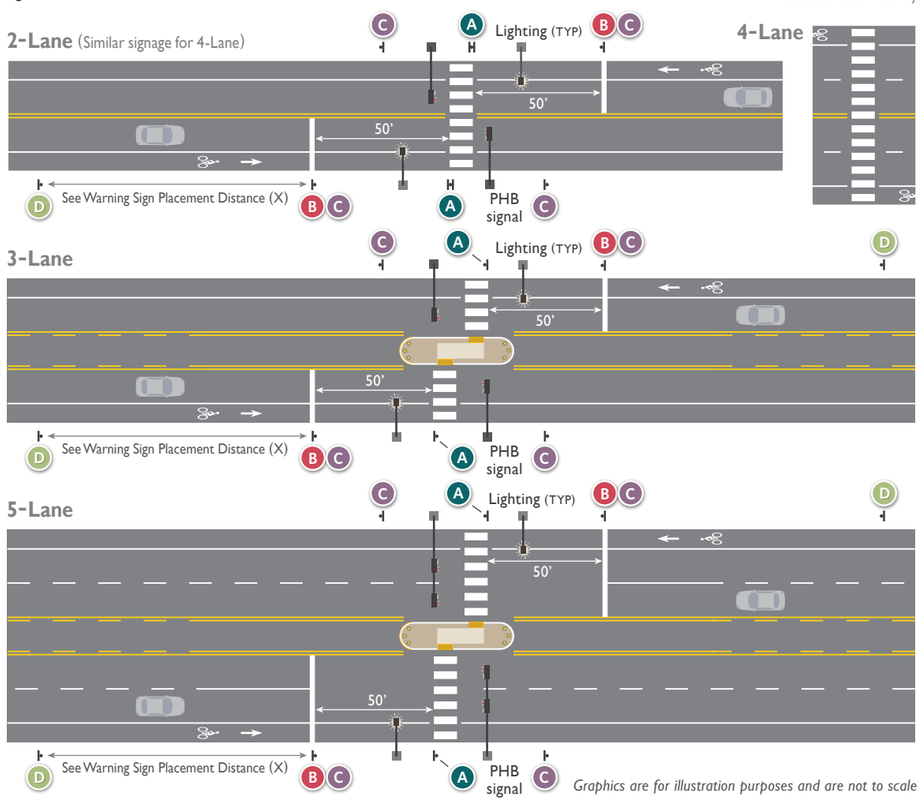




Speed (MPH)	Warning Sign Placement Distance (X) Feet
25-40	150
45	175
50	250

Note:

Based on the 2009 MUTCD, Table 2C-4, and modified based on Clark County practice



Graphics are for illustration purposes and are not to scale

SIGNAL VISIBILITY SIGHT DISTANCE

The sight distance for visibility of signal indications to approaching traffic should be sufficiently long to enable a vehicle traveling to stop before reaching the stop line. The minimum sight distance for signal visibility is the sum of stopping sight distance plus an assumed queue length.

Posted Speed (mph)	Minimal Sight Distance for Signal Visibility[1]
25	215 ft
30	270 ft
35	325 ft
40	390 ft
45	460 ft
50	540 ft

1. *Distances are based on the 2009 MUTCD, Table 4D-2.*

LIGHTING

Illuminate the entire midblock pedestrian crossing, including any refuge area in the roadway, and the sidewalks or shoulders adjacent to the crosswalk per the current WSDOT Design Manual, Chapter 1040. Lighting analysis should be performed to confirm that light levels will meet the standards listed below. Emphasis should be placed on positive lighting of the pedestrians in the crosswalk and on the adjacent sidewalks.

FROM WSDOT DESIGN MANUAL EXHIBIT 1040-22: LIGHT LEVELS AND UNIFORMITY RATIOS

Minimum Average Maintained Horizontal Light Level — Pedestrian/Area Classification (footcandles)			Maximum Uniformity Ratio [2]	Maximum Veiling Luminance Ratio [3]
High	Medium	Low		
Midblock pedestrian crossing				
2.0	2.0	2.0	4:1	0.3:1
Highways without full access control – intersections				
1.2	0.9	0.9	4:1	0.3:1

2. *Minimum Average Maintained Light Level / Minimum Light Level = Maximum Uniformity Ratio*

3. *Maximum Veiling Luminance / Average Luminance = Veiling Luminance Ratio*

Note:

Both midblock and intersection – different areas covered (see Exhibit 1040-B for intersection)

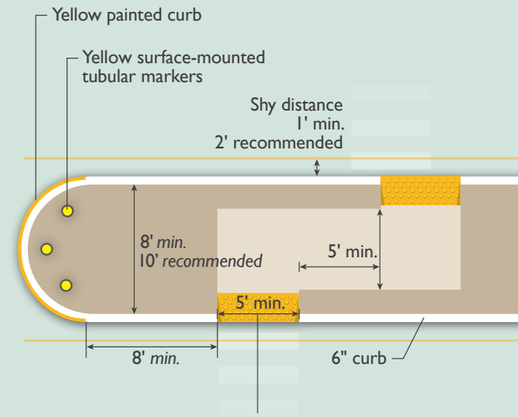
PHB SIGNAL



*** This sign can be used in place of R10-23 for educational purposes** for the first 3 years after installation

MEDIAN ISLAND WITH PEDESTRIAN REFUGE DETAIL

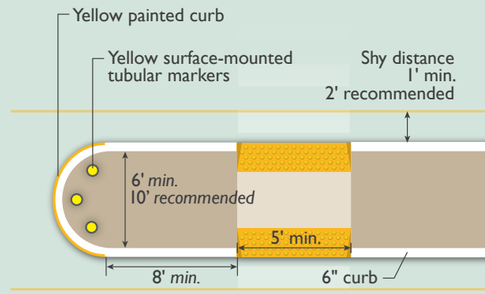
Preferred Option



Minimum width of 5 feet to ensure a passing space is provided.

Pedestrian access routes of multi-use paths that go through raised medians shall be the same width as the multi-use path.

Alternate Option



REFERENCE

WSDOT Design Manual, *Exhibit 1510-22*

Appendix A: Enhanced Pedestrian Crossing Treatment Decision Tool Memo

Memo

Date:	Friday, September 29, 2017
Project:	Clark County Pedestrian Crossing Treatment Guidelines
To:	Courtney Furman & Ejaz Khan, Clark County
From:	Tom Shook, HDR
Subject:	Revised Draft Enhanced Pedestrian Crossing Treatment Decision Tool Memo

Introduction and Purpose

Clark County, Washington has been experiencing an increased demand for pedestrian facilities. As demand for pedestrian mode of travel continues to increase, the County is committed to provide infrastructure for seamless network and efficient movement of pedestrians, including a variety of pedestrian crossing treatments. Pedestrian crossings that safely connect pedestrian facilities to various origins and destinations are a key component in providing pedestrian infrastructure.

Clark County wishes to develop decision-making guidelines to determine appropriate pedestrian crossing treatments best suited for each location. The purpose of this memo is to provide background in the development of the ***enhanced pedestrian crossing treatment decision tool*** for Clark County. The guidelines consider a series of national best practices and peer agency review to provide background and influence into the development to the County's tool. This memo includes the following:

- Review of three national best practice guidelines pertaining to pedestrian crossing treatment warrants, including the MUTCD, NCHRP 562, and the "Zegeer Table" that includes specific criteria for selection of different types of pedestrian crossing treatments.
- Summaries of three peer agencies with adopted pedestrian crosswalk decision tools to provide background for the development of Clark County's decision tool, including City of Portland, OR Bureau of Transportation (PBOT), City of Boulder, CO, and Virginia Department of Transportation (VDOT).
- A draft enhanced pedestrian crossing decision tool catered to Clark County conditions utilizing research gathered from peer agencies and national best practices that provides objective guidelines through a two-step process using:
    1. A ***pedestrian crossing treatment decision flow chart*** to identify the need for an enhanced crosswalk at an existing unmarked location; and
    2. An ***enhanced crossing treatment selection table*** providing various treatment options if enhanced pedestrian treatments are appropriate at a location under consideration, using a set of evaluation criteria.

Best Practice Review

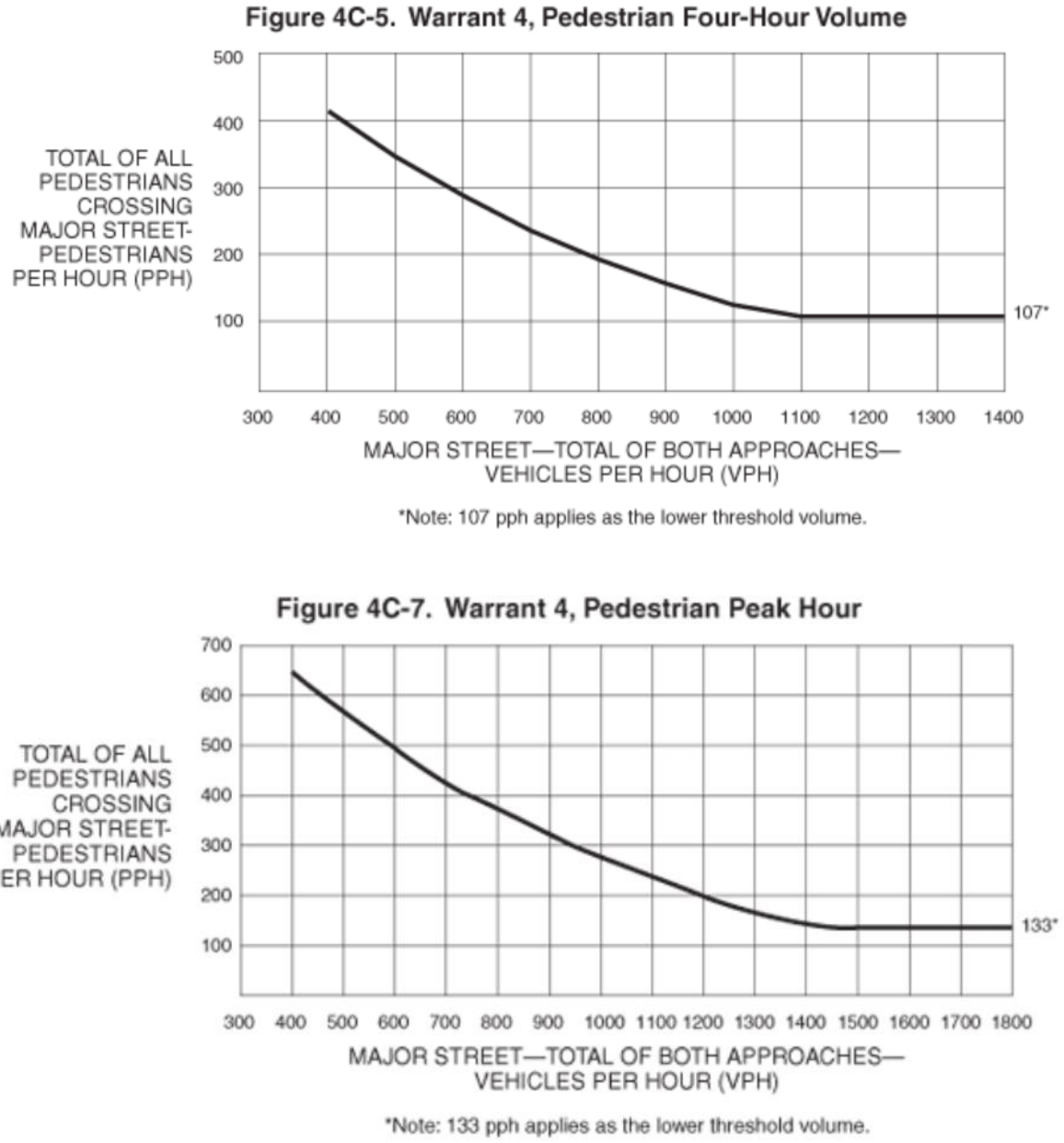
Manual on Uniform Traffic Control Devices (MUTCD)

The MUTCD sets standards and provides guidance on a variety of traffic control devices to ensure uniformity among traffic control throughout the United States. The MUTCD provides specific guidance on pedestrian control features and pedestrian signal warrants.

Pedestrian control features included in the MUTCD are standard markings, signage, and pedestrian signal control features (e.g., pedestrian signal heads, pedestrian interval timing, and pedestrian detectors) for use in providing safe and uniform treatment for pedestrians to cross roadways. The MUTCD provides a series of pedestrian signal warrants for use when considering installing a full signal for safe pedestrian crossing.

- **Traffic signal using pedestrian volumes (Warrant 4)**: A full traffic signal may be warranted at a location depending on pedestrian crossing volumes and major street approach volumes where pedestrians experience excessive delay crossing the major street (for either 4-hour or peak hour volumes). This criteria should not be applied where the distance to the nearest traffic signal or stop sign is less than 300 feet. Figure 1 illustrates the 4-hour and peak hour pedestrian volume traffic signal warrant graphs. There is a 70% reduction that can be used if the speed limit or the 85th-percentile speed on the major street exceeds 35 miles per hour, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000.

Figure 1. MUTCD Traffic Signal Warrant using Pedestrian Volumes



Source: MUTCD, FHWA, 2009.

- **Pedestrian hybrid beacon**: Should be examined at locations that do not meet full traffic signal warrants or a traffic signal installation is not feasible. Considers crosswalk length, pedestrian crossing volumes, and major street vehicle volumes for both low-speed roads (35 mph or less) and high-speed roads (greater than 35 mph). Figure 2

illustrates the peak hour hybrid beacon signal warrants for low- and high-speed roadways.

Figure 2. MUTCD Pedestrian Hybrid Beacon Warrants for Low- and High-Speed Roadways

Figure 4F-1. Guidelines for the Installation of Pedestrian Hybrid Beacons on Low-Speed Roadways

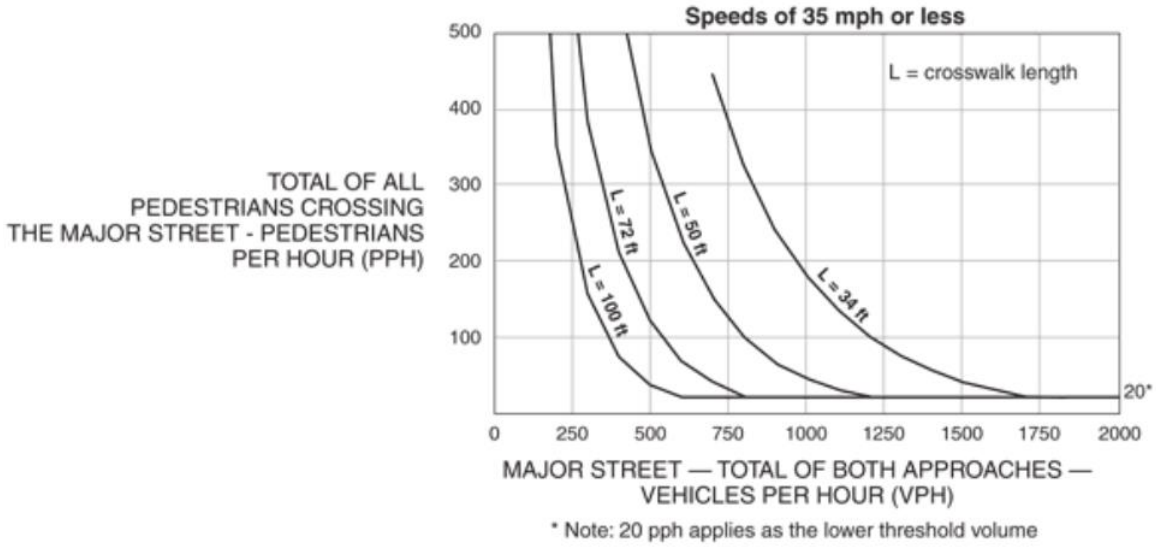
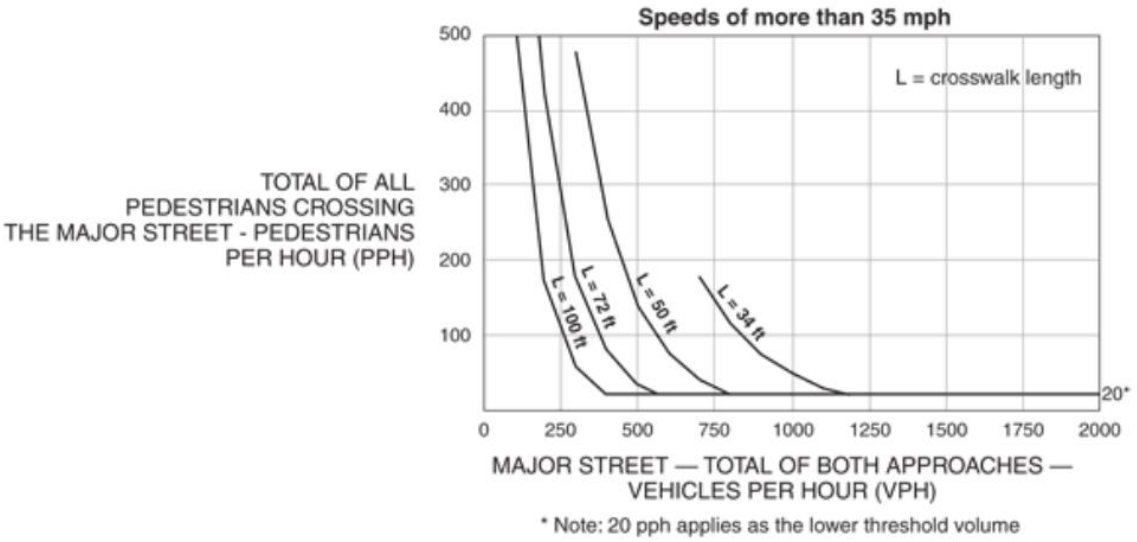


Figure 4F-2. Guidelines for the Installation of Pedestrian Hybrid Beacons on High-Speed Roadways



Source: MUTCD, FHWA, 2009.

NCHRP 562

NCHRP 562 - Improving Pedestrian Safety at Unsignalized Crossings was developed with two main objectives:

- Identify pedestrian crossing treatments to improve safety for pedestrians crossing high-volume, high-speed roadways at unsignalized locations.
- Recommend modifications to the MUTCD pedestrian traffic signal warrant guidance discussed above.

Pedestrian Crossing Treatments

NCHRP 562 provides a series of enhanced pedestrian crossing treatments in addition to what is included in the MUTCD. Table 1 summarizes the list of treatment options recommended for enhanced pedestrian crossings. These types of treatments have been documented as successful in encouraging motorists to yield to pedestrians, especially on high volume streets.

Table 1. NCHRP 562 Pedestrian Crossing Treatments

Advance Signing	In-Roadway Warning Lights
Advance Stop Line and Sign	Pedestrian Crossing Flags
Median Refuge Island	Overhead Flashing Amber Beacons
Raised Crosswalk	Pedestrian Crosswalk Signal
Curb Extension	Half Signal
Roadway Narrowing	HAWK Beacon Signal
Marking and Crossing Signs	Pedestrian Beacon
In-Street Pedestrian Crossing Signs	Traffic Signal
High-Visibility Signs and Markings	

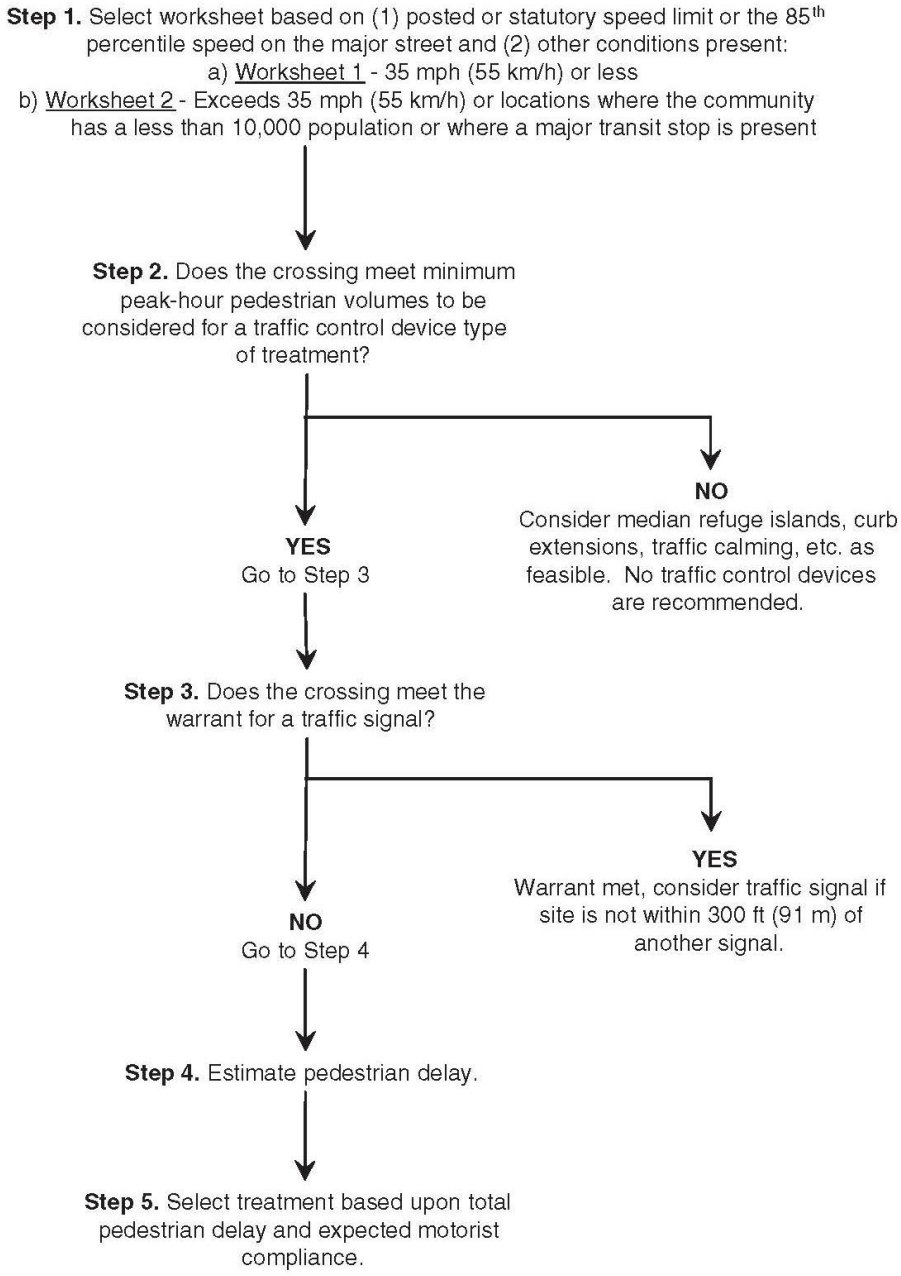
Source: NCHRP 562, Improving Pedestrian Safety at Unsignalized Crossings, 2006.

Refined Pedestrian Signal Warrant

NCHRP 562 provides modifications to MUTCD pedestrian signal warrants described above, including a more robust evaluation process, and guidance on additional enhanced pedestrian crossing treatments beyond what is included in the MUTCD. The NCHRP 562 Signal warrant process is described below and graphically represented in Figure 3:

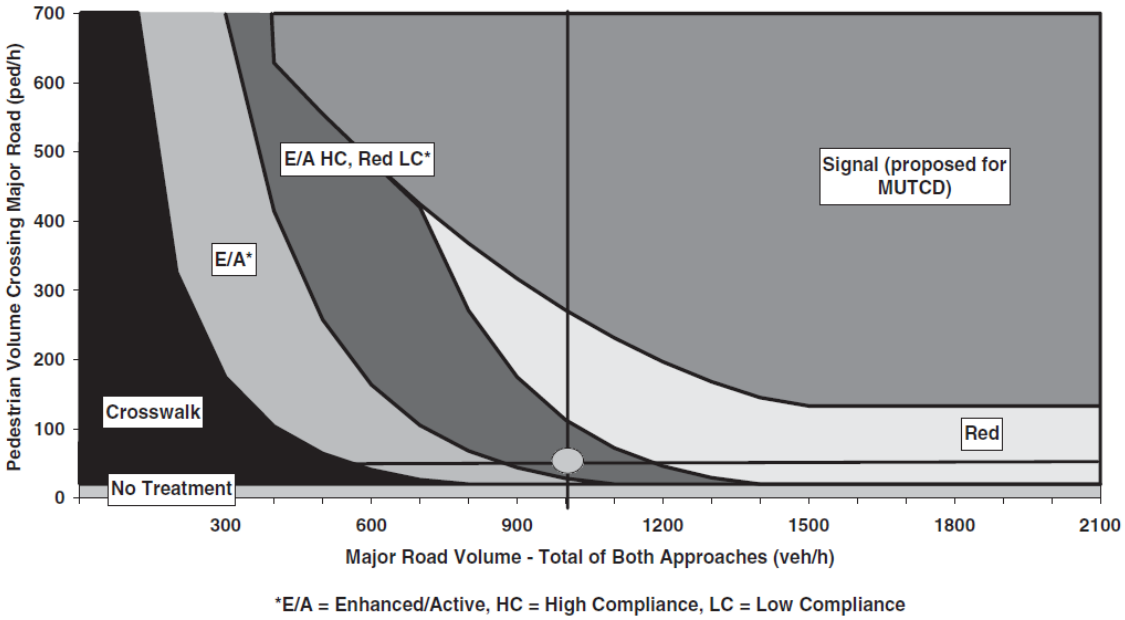
1. Select Worksheet, either low-speed (35 mph or less) or high-speed (over 35 mph)
2. Check minimum pedestrian volume, using peak-hour pedestrian counts and a minimum of 20 pedestrians per hour in both directions
3. Check MUTCD Signal Warrant
4. Estimate approach pedestrian delay, using the 2010 Highway Capacity Manual (HCM) methodology
5. Select appropriate treatment, using the total pedestrian delay and the results of the crossing warrant plot shown in Figure 4, using the following category guidance:
    - **No treatment**: no pedestrian treatment recommended
    - **Crosswalk**: Standard crosswalk using MUTCD striping guidance
    - **Enhanced**: Permanent warning signs, markings, and/or beacons to enhance the visibility of the crossing location and pedestrians using the crossing
    - **Active**: “Active when present” devices that display a warning only when a pedestrian is present
    - **Red**: Devices that display a circular red indicator at pedestrian locations
    - **Signal**: traffic control signal

Figure 3. NCHRP Pedestrian Crossing Treatment Guidelines Flowchart



Source: NCHRP 562, Improving Pedestrian Safety at Unsignalized Crossings, 2006.

Figure 4. NCHRP Pedestrian Crossing Warrant Plot



Source: NCHRP 562, Improving Pedestrian Safety at Unsignalized Crossings, 2006.

"ZEGEER TABLE"

Many of the agencies that have developed enhanced pedestrian facility selection tables adapted their criteria and structure on the "Zegeer Table" included in the *Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations* sponsored by FHWA in 2002. Figure 5 details the "Zegeer Table", which highlights enhanced pedestrian crossing actions using speed and traffic volume thresholds for various roadway types.

Figure 5. "Zegeer Table"

Roadway Type (Number of Travel Lanes and Median Type)	Vehicle ADT ≤ 9,000			Vehicle ADT >9000 to 12,000			Vehicle ADT >12,000 - 15,000			Vehicle ADT > 15,000		
	Speed Limit**											
	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h
2 Lanes	C	C	P	C	C	P	C	C	N	C	P	N
3 Lanes	C	C	P	C	P	P	P	P	N	P	N	N
Multi-Lane (4 or More Lanes) With Raised Median***	C	C	P	C	P	N	P	P	N	N	N	N
Multi-Lane (4 or More Lanes) Without Raised Median	C	P	N	P	P	N	N	N	N	N	N	N

* These guidelines include intersection and midblock locations with no traffic signals or stop signs on the approach to the crossing. They do not apply to school crossings. A two-way center turn lane is not considered a median. Crosswalks should not be installed at locations that could present an increased safety risk to pedestrians, such as where there is poor sight distance, complex or confusing designs, a substantial volume of heavy trucks, or other dangers, without first providing adequate design features and/or traffic control devices. Adding crosswalks alone **will not** make crossings safer, nor will they necessarily result in more vehicles stopping for pedestrians. Whether or not marked crosswalks are installed, it is important to consider other pedestrian facility enhancements (e.g., raised median, traffic signal, roadway narrowing, enhanced overhead lighting, traffic-calming measures, curb extensions), as needed, to improve the safety of the crossing. **These are general recommendations; good engineering judgment should be used in individual cases for deciding where to install crosswalks.**

** Where the speed limit exceeds 40 mi/h (64.4 km/h) marked crosswalks alone should not be used at unsignalized locations.

C = **Candidate sites for marked crosswalks**. Marked crosswalks must be installed carefully and selectively. Before installing new marked crosswalks, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review may be sufficient at some locations, while a more in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, etc. may be needed at other sites. It is recommended that a minimum of 20 pedestrian crossings per peak hour (or 15 or more elderly and/or child pedestrians) exist at a location before placing a high priority on the installation of a marked crosswalk alone.

P = **Possible increase in pedestrian crash risk may occur if crosswalks are added without other pedestrian facility enhancements.** These locations should be closely monitored and enhanced with other pedestrian crossing improvements, if necessary, before adding a marked crosswalk.

N = **Marked crosswalks alone are insufficient, since pedestrian crash risk may be increased due to providing marked crosswalks alone. Consider using other treatments, such as traffic-calming treatments, traffic signals with pedestrian signals where warranted, or other substantial crossing improvement to improve crossing safety for pedestrians.**

*** The raised median or crossing island must be at least 4 ft (1.2 m) wide and 6 ft (1.8 m) long to adequately serve as a refuge area for pedestrians in accordance with MUTCD and American Association of State Highway and Transportation Officials (AASHTO) guidelines.

Source: Zegeer, et. al., FHWA, 2002.

Peer Agency Review

The development of Clark County's ***enhanced pedestrian crossing treatment decision tool*** relies on information gathered from peer agencies with adopted pedestrian crossing decision making processes. PBOT, the City of Boulder, and VDOT each follow unique decision making steps when considering an enhanced pedestrian crossing at specific locations. Each agency's process is summarized below.

City of Portland, OR Bureau of Transportation (PBOT)

PBOT developed a simple and effective tool to assess the need for various types of pedestrian crossing facilities at certain locations on city-owned streets. PBOT's tool includes a decision tree to assist in justifying the need for a pedestrian crossing facility, and if warranted, the type of facility that should be installed at locations under consideration. PBOT adopted a crosswalk assessment tool to tailor crosswalk treatments at specific locations, using the following two-step process:

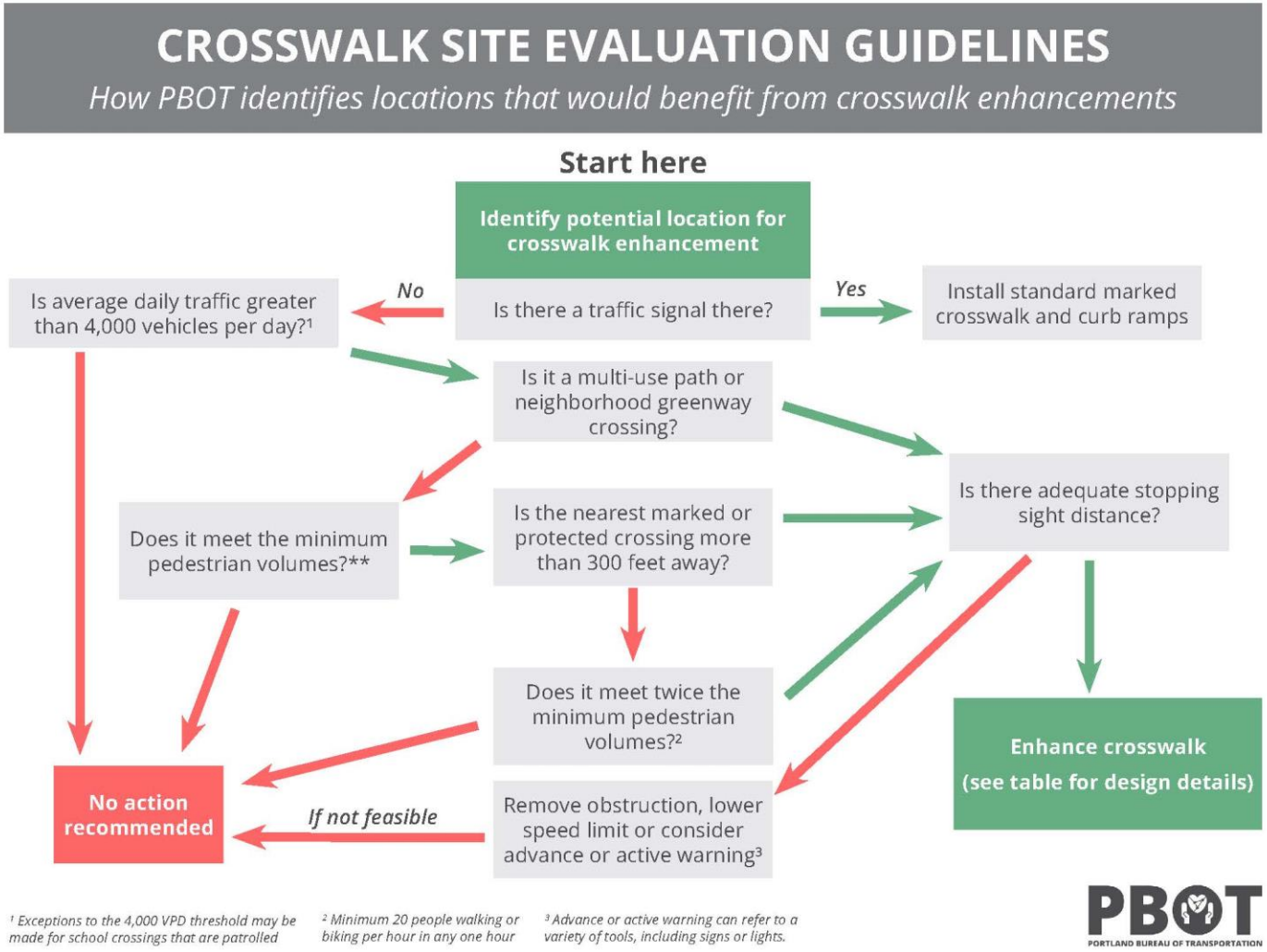
1. A flow chart that determines the need for enhanced crosswalk treatments at specific locations (See Figure 6 below).
2. If the flow chart determines that a location warrants an enhanced crosswalk, an evaluation table that provides guidance in determining the recommended crossing treatment type depending on the number of roadway lanes, Average Daily Traffic (ADT), and speed at the location under consideration (See Figure 7 below). The table includes four unique enhanced crossing facilities types for consideration. PBOT provides public data on traffic counts, speeds, and roadway types for use in considering the need and type of pedestrian crossing facility.

PBOT's decision tool includes several unique factors that were considered when developing Clark County's decision tool, as described in Table 2.

Table 2. PBOT's Pedestrian Crossing Treatment Tool Features

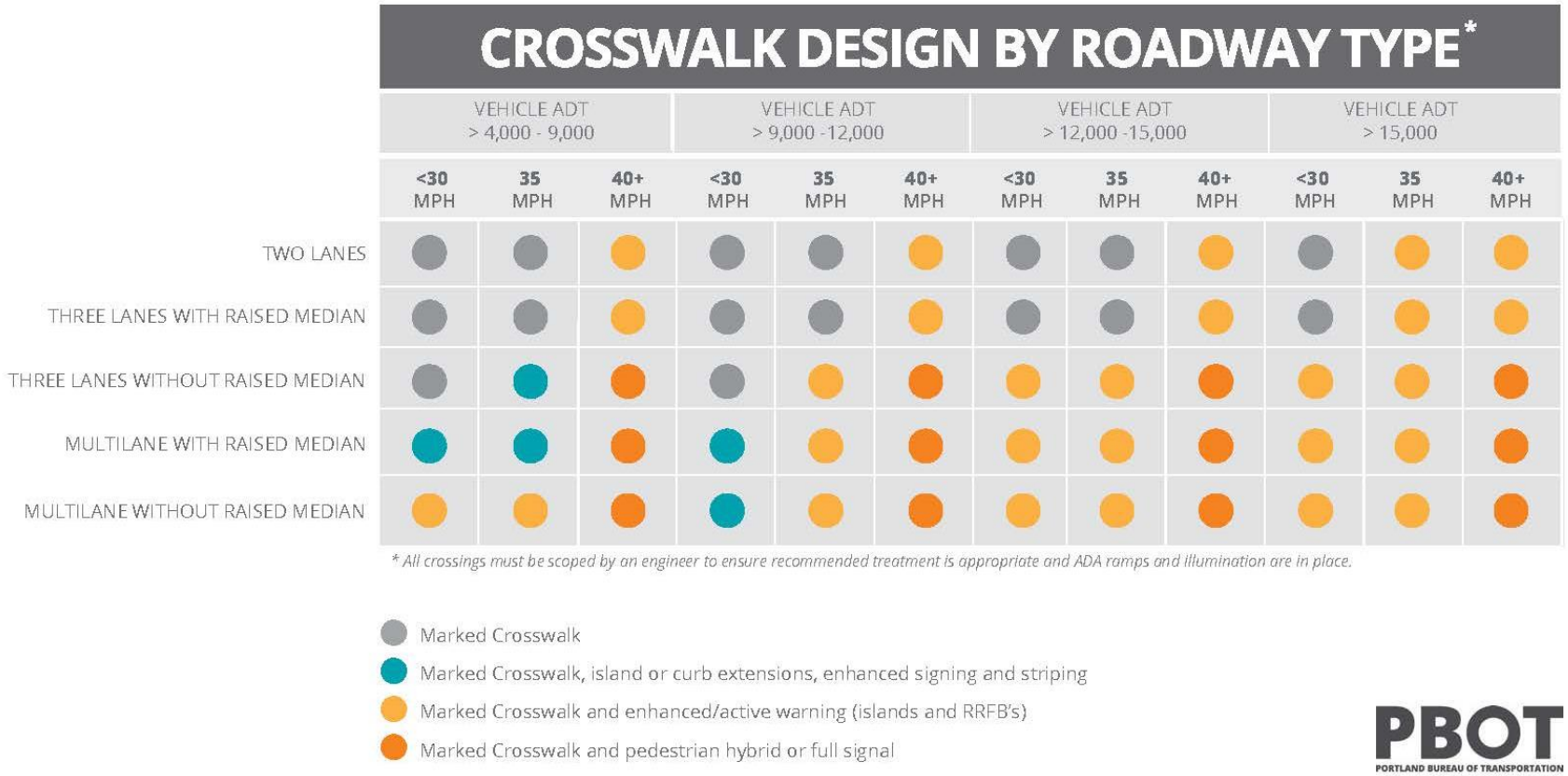
The flow chart (Figure 6):
• Does not consider specific guidance on a location with an existing stop sign
• Does not consider specific guidance on school crossing locations
• Eliminates any location that crosses a roadway with under 4,000 ADT, limiting the possibility of installing any type of crosswalk on lower volume facilities
• Considers a minimum pedestrian volume trigger of 20 pedestrians or cyclists per hour
• Considers crossing treatment at a location within 300 feet of an existing marked or protected crossing if it meets twice the minimum pedestrian volumes
• Does not consider distance to nearest marked or protected crossing if an unsignalized multi-use path or neighborhood greenway warrants a crossing, which may result in closely spaced crossing locations
The evaluation table (Figure 7):
• Categorizes facility selection for 2-lane, 3-lane (with and without raised median), and multi-lane (4+, with and without raised median) roadway facilities
• Categorizes facility selection into three speed groups: 30 mph or under, 35 mph, and 40 mph and over, limiting the need for guidance on higher speed (45+) roadway facilities
• Includes four enhanced crossing treatment categories, including a specific facility category that includes a marked crosswalk, island or curb extension, and enhanced signing and striping

Figure 6. PBOT Crosswalk Guideline Flow Chart



Source: Portland Bureau of Transportation

Figure 7. PBOT Crosswalk Options Table



Source: Portland Bureau of Transportation

City of Boulder, Colorado

The City of Boulder established a long-term goal of providing safe and efficient pedestrian facilities to reduce the dependency on the personal automobile. Boulder originally developed pedestrian crossing treatment warrants in 1996, but has since refined the decision process to guide the implementation of enhanced crossing facilities. The City uses the following 4-step evaluation process in coordination with an evaluation worksheet when considering and evaluating enhanced pedestrian crossing improvements:

1. **Identification and description of crossing locations**, including connections to a multi-use path, speed limits, and existing traffic control.
2. **Physical data collection**, including roadway configuration (number of lanes, presence of a painted/raised median), distance to nearest marked or protected crossing, and stopping sight distance for all approaches.
3. **Traffic data collection and operational observations**, including pedestrian crossing volumes during peak hours of use (and in some cases up to three consecutive days to determine pedestrian volume fluctuation), vehicle ADT along the major roadway at the crossing location, and vehicle queues from adjacent intersections.
4. **Applying data to the:**
    - *Pedestrian Crossing Treatment Flowchart* (Figure 8)
    - *Criteria for Crossing Treatment at Uncontrolled Locations* (Figure 9)
    - *City of Boulder Guidelines for the Installation of HAWK Beacons, Pedestrian Signals, or RRFB Signs on Low- and High-Speed Roadways* (Figure 10), which tailors the pedestrian signal warrant methodology developed in NCHRP 562 to City of Boulder conditions

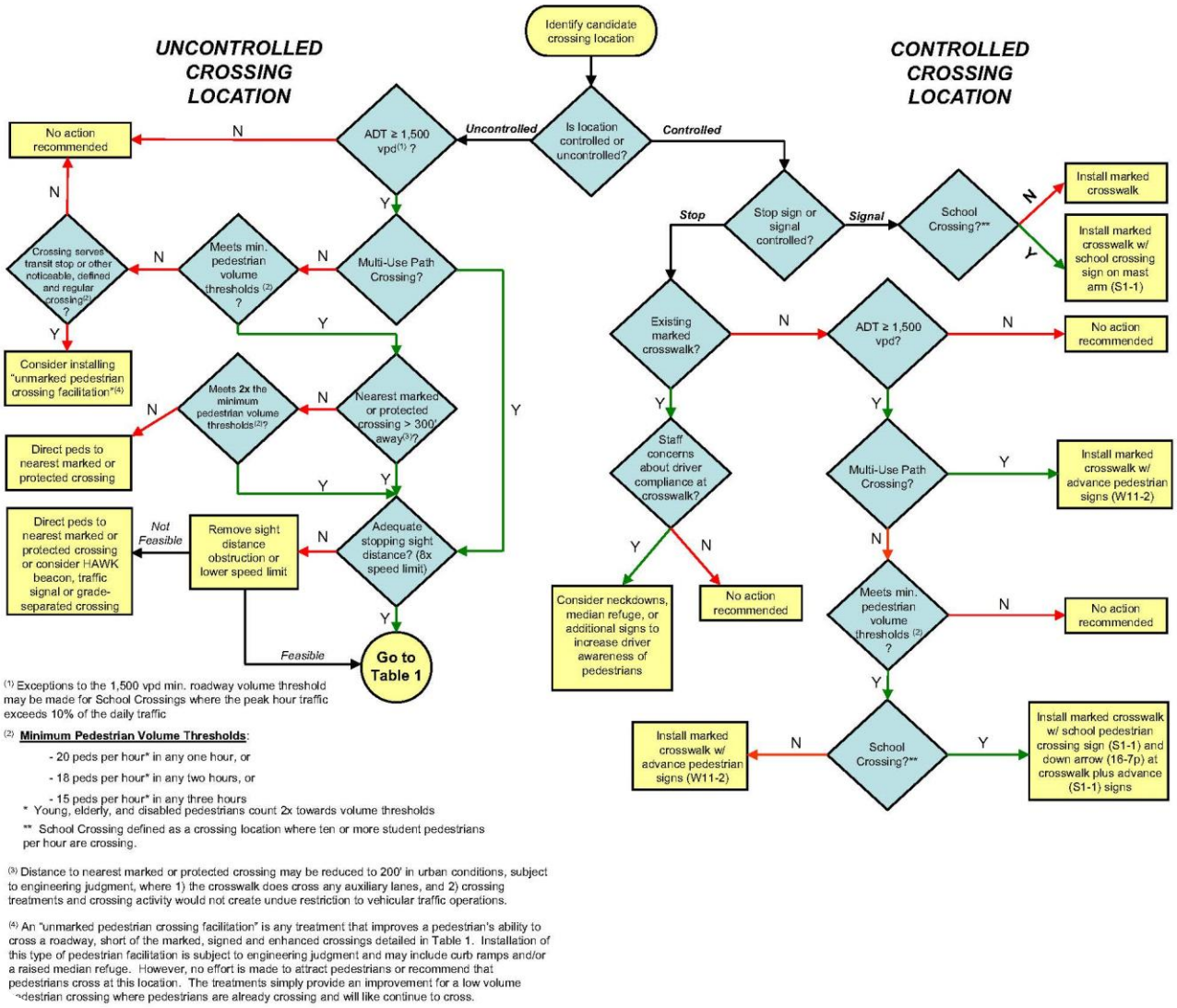
Boulder's guidelines also include several supplemental policies to guide the installation of crossing treatments in the City, including crosswalk lighting, avoiding overuse of crossing treatments, multi-use path crossings, textured and colored pavement treatments, accessible crosswalks, raised crossings at right-turn bypass islands, and removal of treatments.

Boulder's decision tool includes several unique factors that were considered when developing Clark County's decision tool, as described in Table 3.

Table 3. Boulder's Pedestrian Crossing Treatment Tool Features

The flow chart (Figure 8):
• Considers specific guidance on locations that are uncontrolled and controlled, including stop signs
• Considers specific guidance on school crossing locations
• Eliminates any location that crosses a roadway with under 1,500 ADT, increasing the possibility of installing a crosswalk on lower volume facilities
• Considers a variety of minimum pedestrian volume triggers depending on the time period (20 pedestrians per hour for any one hour; 18 pedestrians per hour for any two hours, 15 pedestrians per hour for any three hours)
• Counts young, elderly, and disabled pedestrians as double toward volume thresholds
• Considers crossing treatment at a location within 300 feet of an existing marked or protected crossing if it meets twice the minimum pedestrian volumes
• Considers crossing treatment for locations that do not meet minimum pedestrian volume triggers but serves a transit stop
• Does not consider distance to nearest marked or protected crossing if an uncontrolled multi-use path warrants a crossing, which may result in closely spaced crossing locations
The criteria table (Figure 9):
• Categorizes facility selection for 2-lane (one-way or two-way), 3-lane (with raised or striped median), 4-lane (without median), 5-lane (with raised or striped median), and 6-lane (with or without median) roadway facilities
• Categorizes facility selection into three speed groups: 30 mph or under 35 mph, 40 mph, and 45 mph or greater, improving guidance on higher speed (45+) roadway facilities
• Includes six enhanced crossing treatment categories, each with specific guidance pertaining to signing and striping suggestions
• Includes suggestions on determining the possibility of reducing speed limits to trigger different treatment options
• Suggests conducting additional evaluation for signalized crossing treatments for low- and high-speed roadways using Figure 10 below

Figure 8. Boulder's Pedestrian Crossing Treatment Flowchart



(1) Exceptions to the 1,500 vpd min. roadway volume threshold may be made for School Crossings where the peak hour traffic exceeds 10% of the daily traffic

(2) **Minimum Pedestrian Volume Thresholds**:

- 20 peds per hour* in any one hour, or
- 18 peds per hour* in any two hours, or
- 15 peds per hour* in any three hours

* Young, elderly, and disabled pedestrians count 2x towards volume thresholds

** School Crossing defined as a crossing location where ten or more student pedestrians per hour are crossing.

(3) Distance to nearest marked or protected crossing may be reduced to 200' in urban conditions, subject to engineering judgment, where 1) the crosswalk does cross any auxiliary lanes, and 2) crossing treatments and crossing activity would not create undue restriction to vehicular traffic operations.

(4) An "unmarked pedestrian crossing facilitation" is any treatment that improves a pedestrian's ability to cross a roadway, short of the marked, signed and enhanced crossings detailed in Table 1. Installation of this type of pedestrian facilitation is subject to engineering judgment and may include curb ramps and/or a raised median refuge. However, no effort is made to attract pedestrians or recommend that pedestrians cross at this location. The treatments simply provide an improvement for a low volume pedestrian crossing where pedestrians are already crossing and will like continue to cross.

Source: City of Boulder, CO, 2011.

Figure 9. Boulder's Criteria for Crossing Treatment at Uncontrolled Locations

Roadway Configuration	# of lanes crossed to reach a refuge[1]	# of multiple threat lanes[2] per crossing	Roadway ADT and Posted Speed															
			1,500-9,000 vpd				9,000-12,000 vpd				12,000-15,000 vpd				> 15,000 vpd			
			≤ 30 mph	35 mph	40 mph	≥ 45 mph	≤ 30 mph	35 mph	40 mph	≥ 45 mph	≤ 30 mph	35 mph	40 mph	≥ 45 mph	≤ 30 mph	35 mph	40 mph	≥ 45 mph
2 Lanes (one way street)	2	1	A	B	C	E	A	B	C	E	B	B	C	E	B	C	C	E
2 Lanes (two way street with no median)	2	0	A	B	C	E	A	B	C	E	B	B	C	E	B	C	C	E
3 Lanes w/Raised Median	1 or 2	0 or 1	A	B	D	E	A	C	D	E	B	D	D	E	C	D	D	E
3 Lanes w//Striped Median	3	0 or 1	C	C	D	E	C	C	D	E	C	C	D	E	C	D	D	E
4 Lanes (two way street with no median)	4	2	A	D	D	E	B	D	D	E	B	D	D	E	D	D	D	E
5 Lanes w/Raised Median	2 or 3	2	A	B	D	E	B	C	D	E	B	C	D	E	C	C	D	E
5 Lanes w/Striped Median	5	2	D	D	D	E	D	D	D	E	D	D	D	E	D	D	D	E
6 Lanes (two way street with or without median)	3 to 6	4	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F

Notes:

1. Painted medians can never be considered a refuge for a crossing pedestrian. Similarly, a 4 foot wide raised median next to a left turn lane can only be considered a refuge for pedestrians if the left turning volume is less than 20 vehicles per hour (meaning that in most cases the left turn lane is not occupied while the pedestrian is crossing).
2. A multiple threat lane is defined as a through lane where it is possible for a pedestrian to step out from in front of a stopped vehicle in the adjacent travel lane (either through or turn lane).

Treatment Descriptions:

A ***Install marked crosswalk with enhanced road-side signs***

Specific Guidance : Install marked crosswalk with "State Law - Yield to Pedestrian" signs mounted on the side of the roadway with standard (W11-2) advance pedestrian warning signs; use S1-1 signs for School Crossing locations.

B ***Install marked crosswalk with enhanced road-side and in-roadway (bollard mounted) signs***

Specific Guidance : Install marked crosswalk with "State Law - Yield to Pedestrian" signs mounted on the side of the roadway and on in-roadway bollards; use standard (W11-2) advance pedestrian warning signs; use S1-1 signs for School Crossing locations.

C ***Install marked crosswalk with enhanced signs and geometric improvements to increase pedestrian visibility and reduce exposure***

Specific Guidance : For 2 or 3-lane roadways, install marked crosswalk with "State Law - Yield to Pedestrian" signs mounted on the side of the roadway and on in-roadway bollards or median mounted signs; use standard (W11-2) advance pedestrian warning signs; use S1-1 signs for School Crossing locations. Add neckdowns or median refuge islands to shorten the pedestrian crossing distance and increase pedestrian visibility to motorists.

D ***Install marked crosswalk with enhanced signs, pedestrian activated RRFBs, and geometric improvements to increase pedestrian visibility and reduce exposure***

Specific Guidance : Install raised median refuge island (unless it is a one-way street or one already exists) to shorten the pedestrian crossing distance and increase pedestrian visibility to motorists. [If a median refuge can not be constructed on a two-way street, Go To Scenario F]. *Install marked crosswalk with "State Law - Yield to Pedestrian" signs WITH pedestrian activated RRFBs mounted on the side of the roadway and on median mounted signs; use standard (W11-2) advance pedestrian warning signs; use S1-1 signs for School Crossing locations. Consider adding neckdowns at the crossing if on-street parking exists on the roadway and storm drain considerations will allow. [Note: If pedestrian volume falls above the RRFB limit line on Figure 2, consider Hawk beacon, pedestrian traffic signal, or grade-separated crossing.]*

E ***Do not install marked crosswalk at uncontrolled crossing. Determine if the speed limit can be effectively reduced to 40 mph AND a raised refuge median can be installed. If so, utliize Scenario D criteria above. If this is not possible, or if pedestrian volume falls above the RRFB limit line on Figure 2, consider HAWK beacon, pedestrian traffic signal, or grade-separated crossing.***

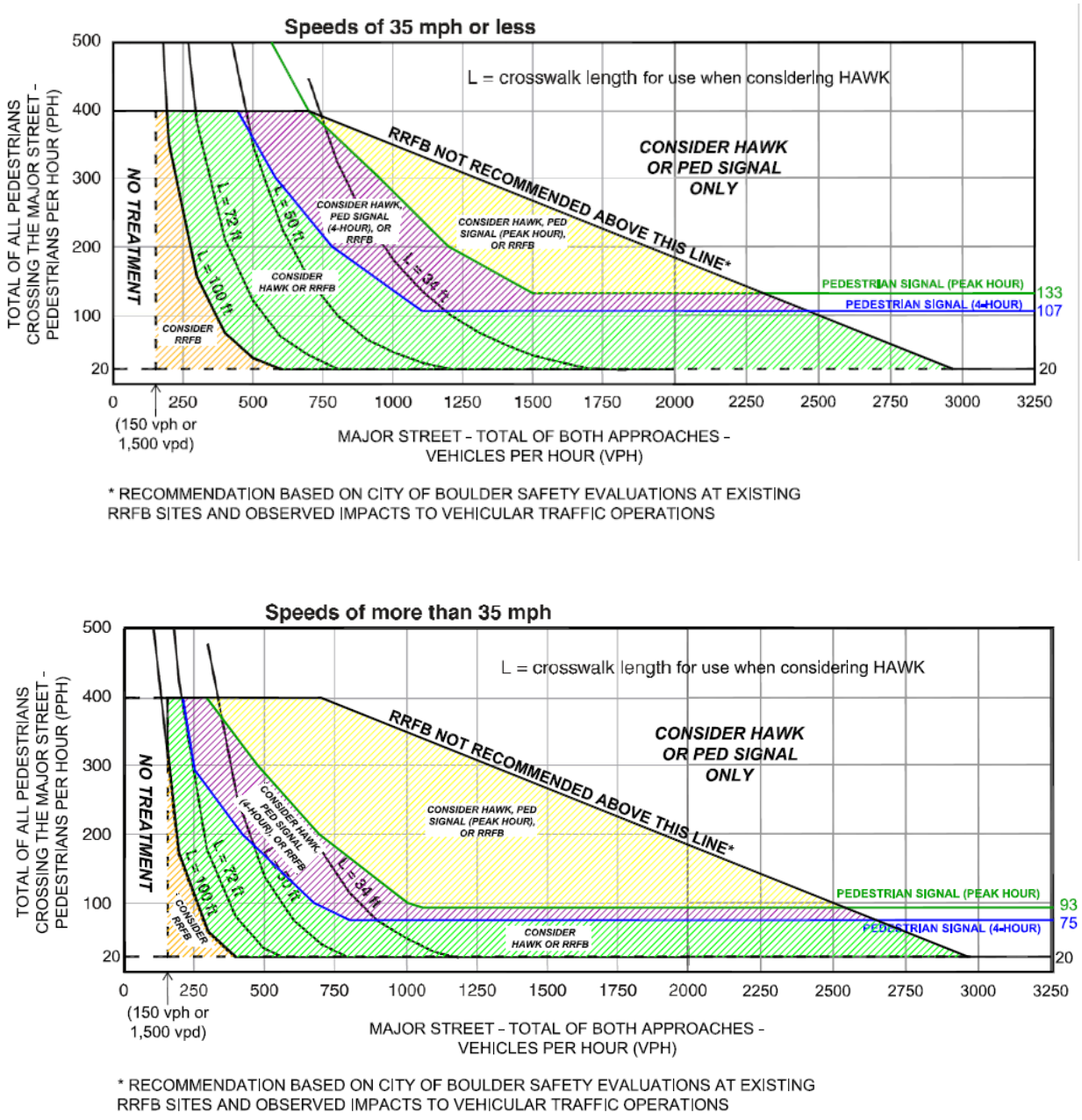
Specific Guidance : Consider HAWK beacon, pedestrian traffic signal or grade-separated crossing; application of these treatments will consider corridor signal progression, existing grades, phyiscal contraints, and other engieering factors

F ***Do not install marked crosswalk at uncontrolled crossing with 3 or more THROUGH lanes per direction or where the speed limit is ≥ 45 mph and/or there is not a median refuge on a 5-lane crossing. Consider HAWK beacon, pedestrian traffic signal, or grade-separated crossing.***

Specific Guidance : Consider HAWK beacon, pedestrian traffic signal or grade-separated crossing; application of these treatments will consider corridor signal progression, existing grades, phyiscal contraints, and other engieering factors

Source: City of Boulder, CO, 2011.

Figure 10. City of Boulder Guidelines for the Installation of HAWK Beacons, Pedestrian Signals, or RRFB Signs on Low- and High-Speed Roadways



Source: City of Boulder, CO, 2011.

Virginia Department of Transportation (DOT)

The Virginia Transportation Research Council (a cooperative organization sponsored by the Virginia DOT and the University of Virginia) developed a marked crosswalk justification process to determine the need for special treatment at uncontrolled crossing locations, which includes the following two-step process:

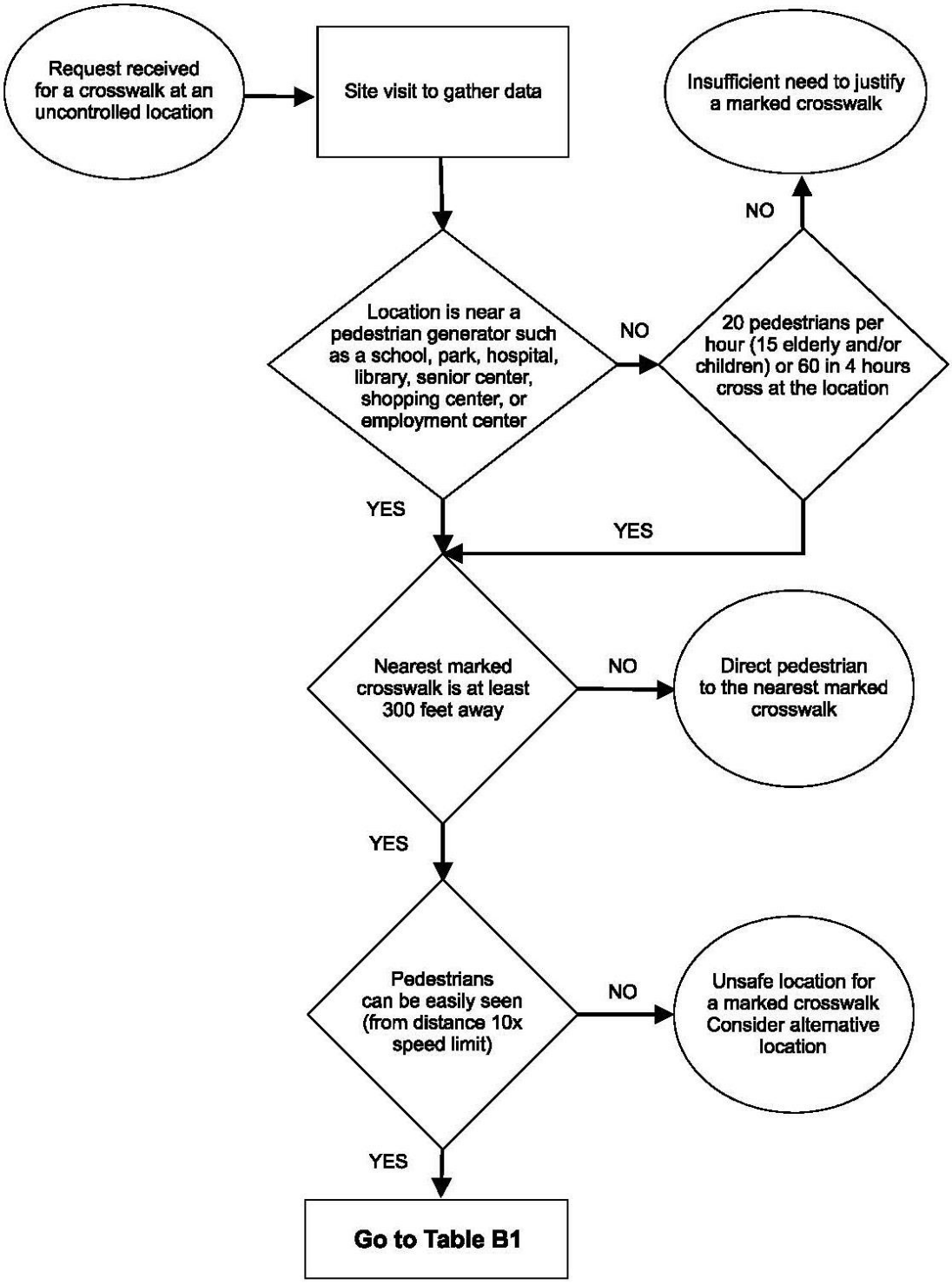
- Sufficient demand for crosswalk installation must exist at uncontrolled crossings, and need must be determined using a flow chart that evaluates the justification for a marked crosswalk at specific locations (See Figure 11 below).
- If the flow chart determines that a location warrants an enhanced crosswalk, an evaluation table provides guidance in determining the recommended crossing treatment type depending on the number of roadway lanes, vehicle ADT, and speed at the location under consideration (See Figure 12 below). The table includes guidance on the recommended action, including specific guidance on a variety of different devices:
    - **Level 1**: Standard crosswalks, raised mid-block crosswalks, and rumble strips
    - **Level 2**: High-visibility crosswalks
    - **Level 3**: Refuge islands, split pedestrian crossovers, bulb-outs (curb extensions)
    - **Level 4**: Overhead signs and flashing beacons, in-roadway warning lights
    - **Level 5**: Pedestrian-actuated signals, grade separated crossings

VDOT's decision tool includes several unique factors that were considered when developing Clark County's decision tool, as described in Table 4.

Table 4. VDOT's Pedestrian Crossing Treatment Tool Features

The flow chart (Figure 11):
• Only considers specific guidance at uncontrolled locations
• Includes general guidance on pedestrian generators (including schools)
• Does not have any minimum ADT threshold, allowing all crossing locations to be considered regardless of roadway volumes
• Considers a variety of minimum pedestrian volume triggers depending on the time period and pedestrian type (20 pedestrians per hour for any one hour, 15 elderly and/or children per hour for any one hour, 60 pedestrians in four hours)
• Does not include any guidance for multi-use paths
The evaluation table (Figure 12):
• Categorizes facility selection for 2-lane, 3-lane, and multi-lane (4+, with and without raised median) roadway facilities
• Categorizes facility selection into three speed groups: 30 mph or under, 35 mph, and 40 mph and over, limiting the need for guidance on higher speed (45+) roadway facilities
• Includes three types of recommended actions, rather than specific treatment type, although suggests considerations of various improvement types

Figure 11. VDOT Flowchart for Justifying Installation of Marked Crosswalks at Uncontrolled Locations



Source: Virginia Transportation Research Council, 2004.

Figure 12. VDOT Enhanced Pedestrian Crossing Selection Evaluation Table

Table B1. Recommendations for Considering Marked Crosswalks and Other Needed Pedestrian Improvements at Uncontrolled Locations[a]

	≤ 9,000 ADT			> 9,000 ADT to ≤ 12,000 ADT			> 12,000 ADT to ≤ 15,000 ADT			> 15,000 ADT		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph[b]
2 lanes												
3 lanes												
++4 lanes, raised median[c]												
++4 lanes, no median												

Candidate sites for marked crosswalks. Marked crosswalks must be installed carefully and selectively. First, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review may be sufficient at some locations, but a more in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, etc., may be needed at other sites. If the speed limit is less than or equal to 30 mph, use **Level 1** or **Level 2** devices. If the speed limit exceeds 30 mph, use **Level 2** devices. *Refer to Level 1 and Level 2 devices in the Special Treatments section*.

Probable candidate sites for marked crosswalks. Pedestrian crash risk may increase if marked crosswalks are added without other pedestrian facility enhancements. Add **Level 3** or **Level 4** devices if feasible. *Refer to Level 3 and Level 4 devices in the Special Treatments section*.

Marked crosswalks alone are insufficient, since pedestrian crash risk may increase if only marked crosswalks are provided. Consider using **Level 5** devices if feasible. If not feasible, use multiple treatments from **Level 2, Level 3,** or **Level 4** devices. *Refer to Level 5 devices in the Special Treatments section*.

[a]These guidelines include intersection and mid-block locations with no traffic signal or stop sign on the approach to the crossing. They do not apply to school crossings. A two-way center turn lane is not considered a median. Crosswalks should not be installed at locations that could present an increased safety risk to pedestrians, such as where there is poor site distance, complex or confusing designs, substantial volumes of heavy trucks, or other dangers, without first providing adequate design features and/or traffic control devices. Adding crosswalks alone will not make a crossing safer or necessarily result in more drivers stopping for pedestrians. Whenever marked crosswalks are installed, it is important to consider other pedestrian facility enhancements, as needed, to improve the safety of the crossing (for example, raised median, traffic signal, roadway narrowing, enhanced overhead lighting, traffic calming measures, curb extensions). **These are general recommendations; an engineering study should be performed to determine where to install marked crosswalks.**

[b]Where the posted speed limit or 85th percentile speed exceeds 40 mph, marked crosswalks alone should not be used at uncontrolled intersections with an ADT greater than 15,000.

[c]The raised median or refuge island must be at least 4 feet (1.2 meters) wide and 6 feet (1.8 meters) long to adequately serve as a refuge area for pedestrians.

Source: Virginia Transportation Research Council, 2004.

Clark County's Enhanced Pedestrian Crossing Treatment Decision Tool

Utilizing research gathered from national best practices and peer agencies described above, the draft Clark County enhanced pedestrian crossing treatment decision tool provides guidance on when a marked crosswalk or other treatments would be appropriate using a set of criteria and triggers. The tool follows a two-step process, similar to the peer agencies reviewed above:

- Figure 13 illustrates the draft Clark County ***pedestrian crossing treatment decision flow chart***, which identifies when an enhanced crosswalk at an existing unmarked location would be appropriate using a series of criteria.
- Figure 14 details the draft Clark County ***enhanced crossing treatment selection table***, providing various treatment options if enhanced pedestrian treatments are justified at a location under consideration. Figure 14 is largely based on the original "Zegeer Table" structure and treatment selection.

Both the flow chart and treatment selection table were influenced by county facility data provided by Clark County staff, including the following:

- Approximately 82% of all Clark County collector and arterials roads are 3 lanes or fewer, with 2-lane roads representing more than 79% of all County collector and arterials roads
- In Clark County, the average ADT is 12,000 for urban arterials and is 2,400 for urban collectors
- In Clark County, the average ADT is 5,000 for rural arterials and is 1,600 for rural collectors

Clark County's decision tool includes several unique factors that incorporate a combination of components from peer agencies and other factors, as described in Table 5.

Table 5. Clark County's Pedestrian Crossing Treatment Tool Features

The flow chart (Figure 13):
• Considers specific guidance on locations that are uncontrolled and controlled (for both signals and stop signs)
• Considers specific guidance on school crossing locations, and refers to the existing Clark County School Zone Traffic Control Policy when appropriate
• Eliminates any location that crosses a roadway with under **2,500 ADT**, increasing the possibility of installing a crosswalk on lower volume facilities
• Considers a variety of minimum pedestrian volume triggers depending on the time period (20 pedestrians per hour for any one hour; 18 pedestrians per hour for any two hours, 15 pedestrians per hour for any three hours)
• Considers 300 feet as minimum separation distance to nearest marked or protected crossing if an uncontrolled multi-use path warrants a crossing, which limits the occurrence of closely spaced crossing locations
The treatment selection table (Figure 14):
• Categorizes facility selection for 2-lane, 3-lane, and multi-lane (4+, with and without raised median) roadway facilities.
• Categorizes facility selection into three speed groups: 30 mph or under, 35 mph, and 40 mph and over
• Includes five types of recommended actions, including marked crosswalks, enhanced pedestrian crossing treatments (e.g., islands and RRFBs), and regulatory traffic controls including hybrid beacon and signalized crossings

Figure 13. Clark County Pedestrian Crossing Treatment Decision Flow Chart

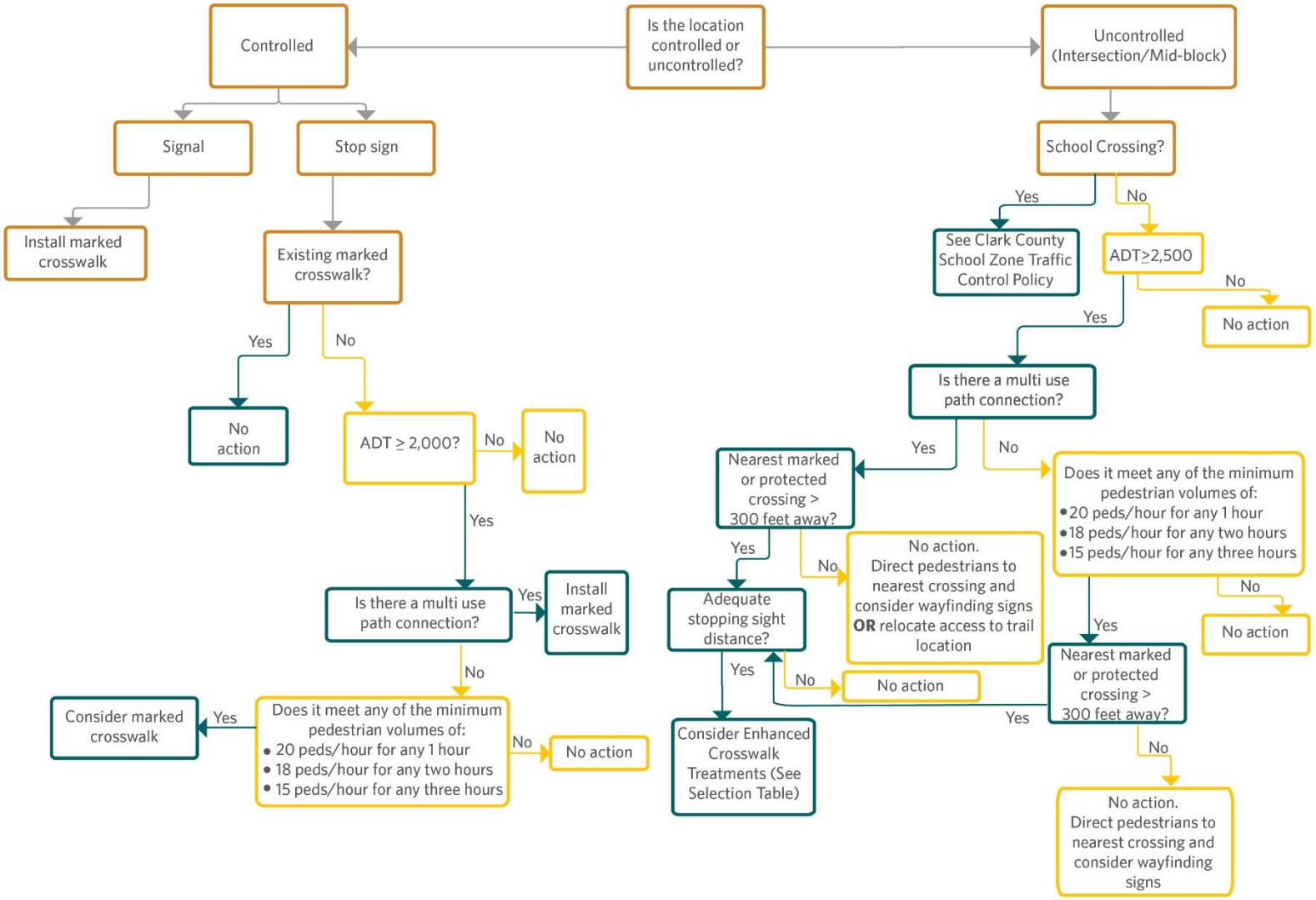


Figure 14. Clark County Enhanced Crossing Treatment Selection Table

ROADWAY TYPE (NUMBER OF TRAVEL LANES)	VEHICLE ADT > 2,500 TO 4,000			VEHICLE ADT > 4,000 TO 9,000			VEHICLE ADT > 9,000 TO 12,000			VEHICLE ADT > 12,000 TO 15,000			VEHICLE ADT >15,000		
	SPEED LIMIT*														
	≤ 30 MPH	35 MPH	≥ 40 MPH	≤ 30 MPH	35 MPH	≥ 40 MPH	≤ 30 MPH	35 MPH	≥ 40 MPH	≤ 30 MPH	35 MPH	≥ 40 MPH	< 30 MPH	35 MPH	> 40 MPH
2 Lanes	A	A	B	B	B	B	B	B	B	B	D/E	E	B	D/E	E
3 Lanes	A	A	B	C	C	D	C	D	D	D	D	E	D	D	E
Multi-Lane (4 or more Lanes)	C	C	C	C	C	D	C	D	E	D	D	E	E	E	E

A Marked Crosswalk

B Marked Crosswalk with RRFB

C Marked Crosswalk with Island

D Marked Crosswalk with enhancement / active warning (islands and RRFB's)

E Marked Crosswalk and pedestrian hybrid or full signal

* Where the speed limit exceeds 40 mph marked crosswalks alone should not be used at unsignalized locations.

Source: Zegeer, Steward, Huang, "Safety Effects of Marked vs Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines", FHWA, 2002.

Appendix B: Crossing Evaluation Worksheets

UNCONTROLLED CROSSING EVALUATION WORKSHEET

LOCATION DESCRIPTION

Major Street: _____ **Crossing or Minor Street Location:** _____

Is this a shared-use path crossing? ☐ **Yes** ☐ **No**

Existing Crossing Treatments (if any): _____

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

PHYSICAL DATA

Major 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 island with pedestrian refuge**

Marked or Protected Pedestrian Crossing Nearby? ☐ **Yes** ☐ **No**

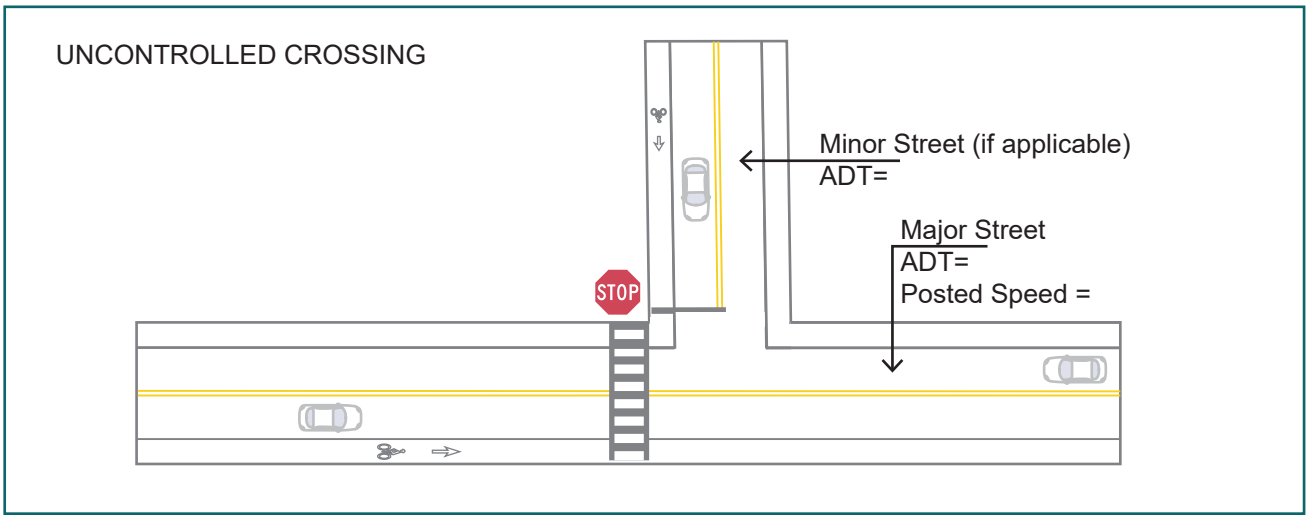
Distance from location: _____**ft**

Stopping Sight Distance (SSD) = _____ **ft**

PEDESTRIAN/TRAFFIC DATA

Pedestrian Crossing Volumes:

	1 hr	2 hr	3 hr	Other
Time:	to	to	to	to
Date/Day of Week:	/	/	/	/
Total Pedestrians:				
Total Pedestrians /hr:	/	/	/	/



CONTROLLED CROSSING EVALUATION WORKSHEET

LOCATION DESCRIPTION

Major Street: _____ **Minor Street:** _____

Is this a shared-use path crossing? ☐ **Yes** ☐ **No**

Existing Traffic Control: ☐ **Stop Sign** ☐ **Traffic Signal** ☐ **Roundabout** ☐ **Other:** _____

Existing Crossing Treatments (if any): _____

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

PHYSICAL DATA

Minor Roadway Configuration: ☐ **2-Lane**
☐ **3-Lane w/Striped Median**
☐ **3 Lane w/Raised Median**

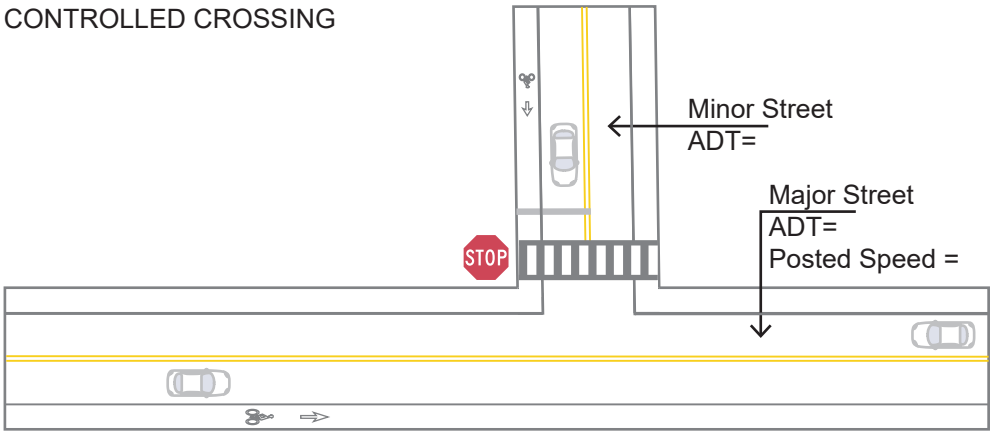
Crossing Distance By Direction: _____ **ft total** ____ **ft to median island with pedestrian refuge**

PEDESTRIAN/TRAFFIC DATA

Pedestrian Crossing Volumes:

	1 hr	2 hr	3 hr	Other
Time:	to	to	to	to
Date/Day of Week:	/	/	/	/
Total Pedestrians:				
Total Pedestrians /hr:	/	/	/	/

STOP CONTROLLED CROSSING



SCHOOL CROSSWALK EVALUATION WORKSHEET

LOCATION DESCRIPTION

Major Street: _____ **Crossing or Minor Street Location:**_____

Is the crossing located adjacent to a school and/or shown in School Route Plan? ☐ **Yes** ☐ **No**

Existing Crossing Treatments (if any): _____

School Level: ☐ **Preschool** ☐ **Elementary** ☐ **Middle** ☐ **High** ☐ **College** ☐ **Other**

PHYSICAL DATA

Major 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 island with pedestrian refuge**

Marked or Protected Pedestrian Crossing Nearby? ☐ **Yes** ☐ **No**

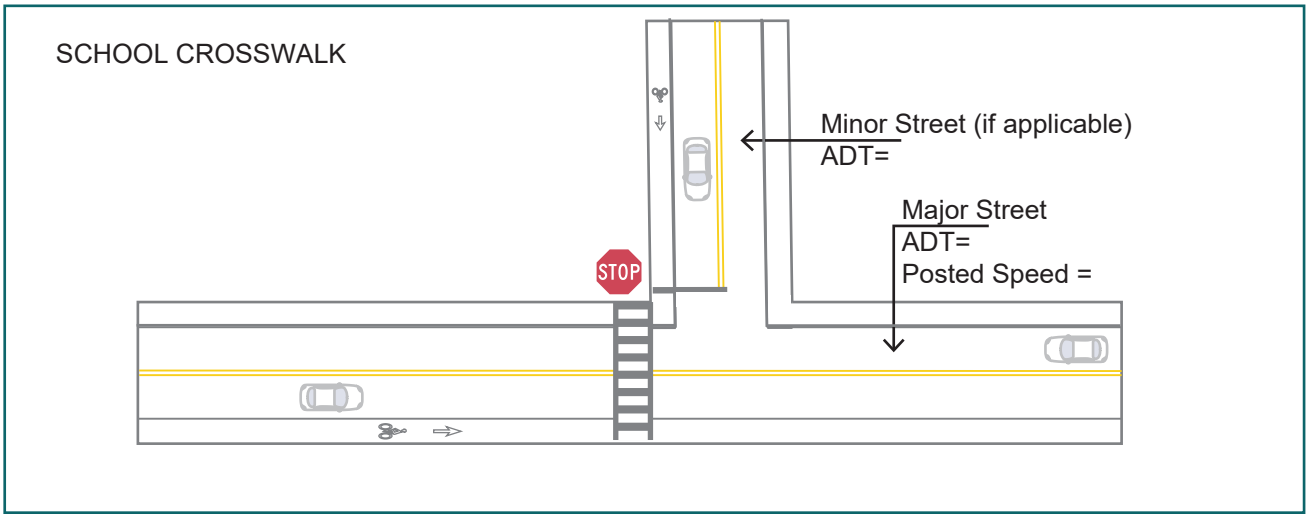
Distance from location: _____**ft**

Stopping Sight Distance (SSD) = _____ **ft**

PEDESTRIAN/TRAFFIC DATA

Children Crossing Volumes:

	1 hr
Time:	to
Date/Day of Week:	/
Total Children:	
Total Children/hr:	/



Appendix C: HCM Pedestrian Delay Analysis Results

Appendix C – HCM Pedestrian Crossing Delay

This appendix describes the Synchro analysis that was used to calculate pedestrian delay for pedestrian crossings across an uncontrolled approach of a two-way stop controlled intersection or at a mid-block location. The Synchro analysis was used to validate the development of the Enhanced Crossing Treatment Selection Table to assess how much delay a crossing pedestrian would experience when using various treatments, including: marked crosswalk, flashing beacon, or a median island with pedestrian refuge.

The Highway Capacity Manual (HCM) 6th Edition analysis calculates pedestrian delay for pedestrian crossings across an uncontrolled approach of a two-way stop controlled intersection or at a mid-block location. The methodology correlates pedestrian delay in seconds per pedestrian to specified level of service standards, as displayed in Table 1.

Table 1. HCM Exhibit 20-3 LOS Criteria: Pedestrian Mode

LOS	Control Delay (s/p)	Comments
A	0-5	Usually no conflicting traffic
B	5-10	Occasionally some delay due to conflicting traffic
C	10-20	Delay noticeable to pedestrians, but not inconveniencing
D	20-30	Delay noticeable and irritating, increased likelihood of risk taking
E	30-45	Delay approaches tolerance level, risk-taking behavior likely
F	>45	Delay exceeds tolerance level, high likelihood of pedestrian risk taking

The County chose a threshold of between LOS B and C, or less than 15 seconds of delay where no treatment would be necessary due to the minor delay incurred by the pedestrian. Additionally, the County selected a threshold of LOS D, or less than 30 seconds of delay where only a marked crosswalk would be sufficient without an enhanced pedestrian crossing treatment. Table 2 details the results of the Synchro analysis for different roadway widths and volumes. Any delay of less than 15 seconds for crossing without a treatment, or less than 30 seconds for crossing with a treatment are highlighted to show treatments or lack of a treatment needed that meet the acceptable County thresholds for pedestrian delay.

The pedestrian delay analysis conducted in Synchro[1] assumed that the minimum pedestrian activity threshold was met, and covered the following parameters:

- Roadway cross sections – from two to five lane sections, with and without bike lanes or shoulders
- Pedestrian crossing distance – from 24 to 74 feet based on the cross section and standards assumed width for each roadway element
- Volume – from 300 to 1,600 vehicles/hour

[1] Trafficware Synchro 10

- Pedestrian crossing treatment – from no treatment (0% yield rate), to signs and markings (20% yield rate) and flashing beacons (81% yield rate) as well as a median island with pedestrian refuge

Table 2. Pedestrian Delay (seconds)

Volume (veh/hr)	Pedestrian Crossing Treatment	Number of Travel Lanes & Crossing Distance (feet)							
		2		3		4		5	
		24	36	38	50	48	60	62	74
300	None	5.4	11.0	12.2	21.4	19.6	32.2	34.7	53.6
	Marked Crosswalk	-	7.4	8.4	15.3	14.7	23.9	25.5	37.2
	Median Island	-	-	-	-	-	-	2.3	3.3
400	None	8.1	17.1	19.1	35.1	31.9	55.2	60.2	98.5
	Marked Crosswalk	-	12.3	13.9	26.4	22.8	36.7	38.7	51.6
	Median Island	-	-	-	-	-	4.7	3.3	4.7
600	None	15.2	35.6	40.6	83.7	74.6	146.1	162.7	305.3
	Marked Crosswalk	11.2	26.5	29.9	55.8	36.4	44.0	44.7	47.4
	Flashing Beacon	-	-	-	-	-	10.2	-	-
	Median Island	-	-	-	1.7	3.0	4.9	3.0	4.9
1,000	None	42.2	127.3	151.6	417.3	353.5	>500	>500	>500
	Marked Crosswalk	29.1	71.6	84.3	235.9	31.7	47.1	52.5	135.4
	Flashing Beacon	-	6.6	6.6	6.9	-	-	-	-
	Median Island	-	-	2.3	4.3	7.9	12.6	7.9	12.6
1,300	None	84.7	319.6	396.0	>500	138.3	>500	>500	>500
	Marked Crosswalk	48.2	180.7	226.5	>500	50.7	221.4	269.9	>500
	Flashing Beacon	5.0	5.3	5.4	5.6	-	-	-	-
	Median Island	3.5	6.6	3.5	6.6	13.1	20.8	13.1	20.8
	Flashing Beacon + Median Island	2.3	3.0	2.3	3.0	7.0	8.1	7.0	8.1
1,600	None	167.7	>500	>500	>500	>500	>500	>500	>500
	Marked Crosswalk	93.1	488.7	>500	>500	224.0	>500	>500	>500
	Flashing Beacon	4.3	4.5	4.5	4.8	-	-	-	-
	Median Island	5.0	8.8	5.0	8.8	19.3	30.5	19.3	30.5
	Flashing Beacon + Median Island	2.4	2.8	2.4	2.8	6.8	7.3	6.8	7.3

Notes:

1) Delay highlighted in green identifies delay of less than 30 seconds for crossings with a pedestrian treatment OR a delay of less than 15 seconds for crossings without a pedestrian treatment, these indicate that the delays meet the acceptable Clark County thresholds for pedestrian delay
2) Delay reported for median island pedestrian crossing treatment is for one stage of the crossing

Appendix A: Crosswalk Policy

Introduction

This citywide Crosswalk Policy is aimed at improving pedestrian safety and enhancing pedestrian mobility by providing a framework and procedures for installation, enhancement, removal, and relocation of crosswalks throughout the City. A comprehensive pedestrian safety strategy contains a three-pronged approach of engineering, enforcement, and education programs. This document focuses on engineering elements, such as pedestrian crossing treatments and intersection design.

This document describes the function of crosswalks and their legal context in the California Vehicle Code. It discusses the advantages and disadvantages of marked crosswalks and summarizes research in the United States focused on pedestrian safety and crosswalks. It provides a summary of best practices related to numerous pedestrian treatments, including geometric, signage and striping, and signal hardware or operational measure treatments.

The purpose of this Policy is to enable the City to respond to crosswalk requests in a manner that improves pedestrian accessibility and maintains public safety. It provides information to be used when making decisions about where standard crosswalks (two, parallel white stripes) can be marked; where crosswalks with special treatments, such as high-visibility crosswalks, flashing beacons and other special features, should be employed; and where crosswalks will not be marked due to safety concerns resulting from volume, speed, or sight distance issues. The policy provides an overview of crosswalk fundamental, uncontrolled crosswalk considerations, and uncontrolled

crosswalk considerations. At both uncontrolled and controlled crosswalk locations, preferred and enhanced measures are described in order to:

- Improve the visibility of pedestrians to motorists and vice-versa
- Communicate to motorists and pedestrians who has the right-of-way
- Accommodate vulnerable populations such as the disabled, children, and the elderly
- Reduce conflicts between pedestrians and vehicles
- Reduce vehicular speeds at locations with potential pedestrian conflicts

Crosswalk Fundamentals

Pedestrian crossing and right-of-way laws vary state to state, and are often a source of driver or pedestrian uncertainty and confusion for when crossing is legal. This section outlines the types of crosswalks, where crossing the street is legal in California, and the steps the City should take in identifying locations for marked crosswalks.

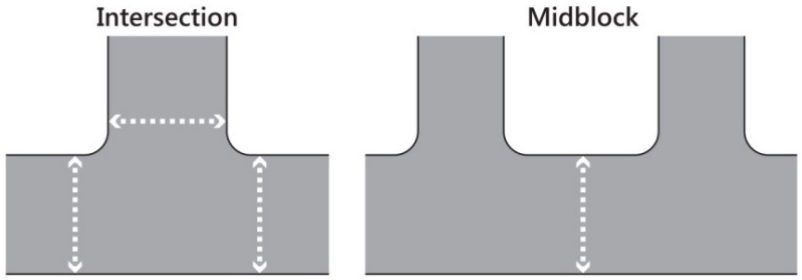
Types of Crosswalks

Crosswalks are primarily classified by three characteristics:

1. Whether they are marked (demarcated with striping on the street) or unmarked (no striping)
2. Whether they are controlled (by a traffic signal or stop-sign) or uncontrolled (with no intersection control)
3. Whether they are located at an intersection (where two streets meet) or mid-block (between intersections)

The following section outlines where crossing the street is legal in California. Based on pedestrian safety and crosswalk marking research, some types of crosswalks are safer than others (e.g., generally marked, controlled crosswalks at an intersection have lower risk of pedestrian collisions than a mid-block, uncontrolled crosswalk.

Where Is Crossing the Street Legal?



In California, a legal crosswalk exists where a sidewalk meets a street, regardless of whether the crosswalk is marked (i.e., with or without striping to denote the crosswalk). Pedestrians may legally cross any street, except at unmarked locations between immediately adjacent signalized crossings, or where crossing is expressly prohibited. Marked crosswalks reinforce the location and legitimacy of a pedestrian crossing.

These legal statues are contained in the California Vehicle Code (CVC) as follows:

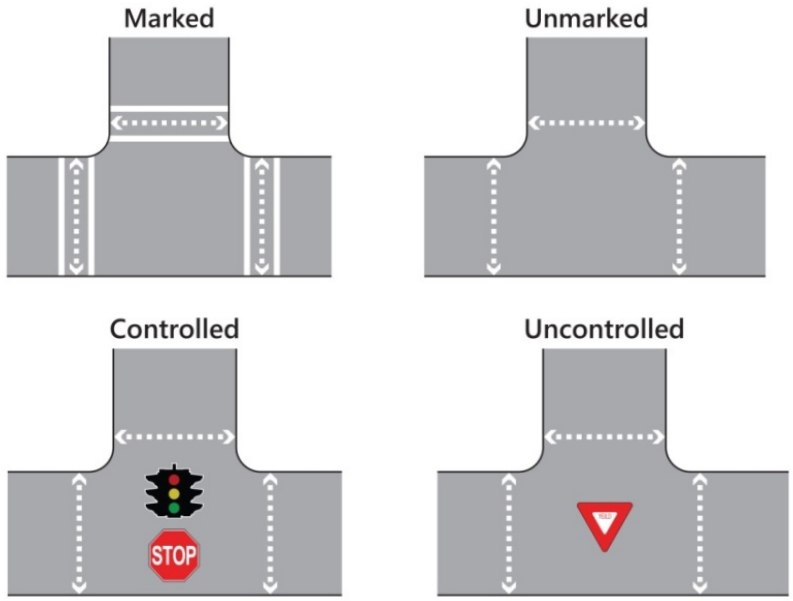
- Section 275 defines a legal crosswalk as:
    - That portion of a roadway included within the prolongation or connection of the boundary lines of sidewalks at intersections where the intersecting roadways meet at approximately right angles, except the prolongation of such lines from an alley across a street.
    - Any portion of a roadway distinctly indicated for pedestrian crossing by lines or other markings on the surface.
- Section 21950 describes right-of-way at a crosswalk:
    - The driver of a marked vehicle shall yield the right-of-way to a pedestrian crossing the roadway within any marked crosswalk or within any unmarked crosswalk at an intersection.
- Section 21955 describes where pedestrians may *not* cross a street:
    - Between adjacent intersections controlled by traffic control signal devices or by police officers, pedestrians shall not cross the roadway at any place except in a crosswalk.

Why Do Cities Mark Crosswalks?

Sidewalks and crosswalks are essential links within a pedestrian network. Whether commuting, running an errand, exercising, or wandering, pedestrians will need safe and convenient crossing opportunities to reach their destinations. A marked crosswalk has three (3) primary functions:

1) To create reasonable expectations where pedestrians may cross a roadway
2) To improve predictability of pedestrian actions and movement
3) To channel pedestrians to designated crossing locations (often selected for their optimal sight distance)

Advantages of Marked Crosswalks



Marked crosswalks offer the following advantages:

- They help pedestrians find their way across complex intersections

- They can designate the shortest path
- They can direct pedestrians to locations of best sight distance
- They assure pedestrians of their legal right to cross a roadway at an intersection or mid-block crossing

This last bullet point is important. The *California Vehicle Code* gives the right-of-way to pedestrians at any marked or unmarked crosswalk (as noted above), although the law is not always obeyed by road users, including both drivers and pedestrians. Drivers often fail to yield the right-of-way without the visual cue of a marked crosswalk. Pedestrians also do not always know the right-of-way law, and will either wait for a gap in traffic, or assert their right-of-way by stepping in to the roadway.

Steps to Identify Candidate Locations for Marked Crosswalks

Identifying candidate locations for marked crosswalks involves two steps.

The first step is to locate the places people would like to cross the street. These locations are called *pedestrian desire lines*, which represent the most desirable, and typically most direct, places that people want to cross a street. Pedestrian desire lines are influenced by elements of the roadway network, such as transit stops, and nearby land uses (homes, schools, parks, trails, commercial centers, etc.). This information provides a basis for identifying pedestrian crossing improvement areas and prioritizing such improvements, thereby creating a convenient, connected, and continuous walking environment. These locations may be identified through engineering studies, walk audits, City staff observations, or public feedback.

The second step in identifying candidate locations for marked crosswalks is to identify where people can cross safely. The primary consideration in this step is adequate stopping sight distance. Of all road users, pedestrians have the highest risk of injury in a collision because they are the least protected. The crosswalk safety treatment toolboxes in this policy provide numerous options for enhancing pedestrian safety at uncontrolled and controlled crossings, respectively, with treatment selection based on the overall context of the crosswalk – including surrounding land uses, roadway characteristics, and user characteristics.

When to Install Marked Crosswalks

Once candidate locations are identified, an engineering evaluation should be conducted to determine if a marked crosswalk should be installed at an uncontrolled or mid-block location, and if so, what visibility enhancements should be included in the design. Crossings should be marked where all of the following occur:

- Sufficient demand exists to justify the installation of a crosswalk
- Sufficient sight distance as measured by stopping sight distance calculations exists and/or sight distance will be improved prior to crosswalk marking
- Safety considerations do not preclude a crosswalk

Appendix A: Crosswalk Policy

Figures A-1 and **A-2** describe the overall procedures from the moment City staff receives a request for a new marked crosswalk (or considers removing an existing marked crosswalk) to the installation of the treatment. As described, the first steps to determine the appropriate location and treatment for the crosswalk include a staff field visit.

Appendix A: Crosswalk Policy

Figure A-1: Marked Crosswalk Placement Flowchart

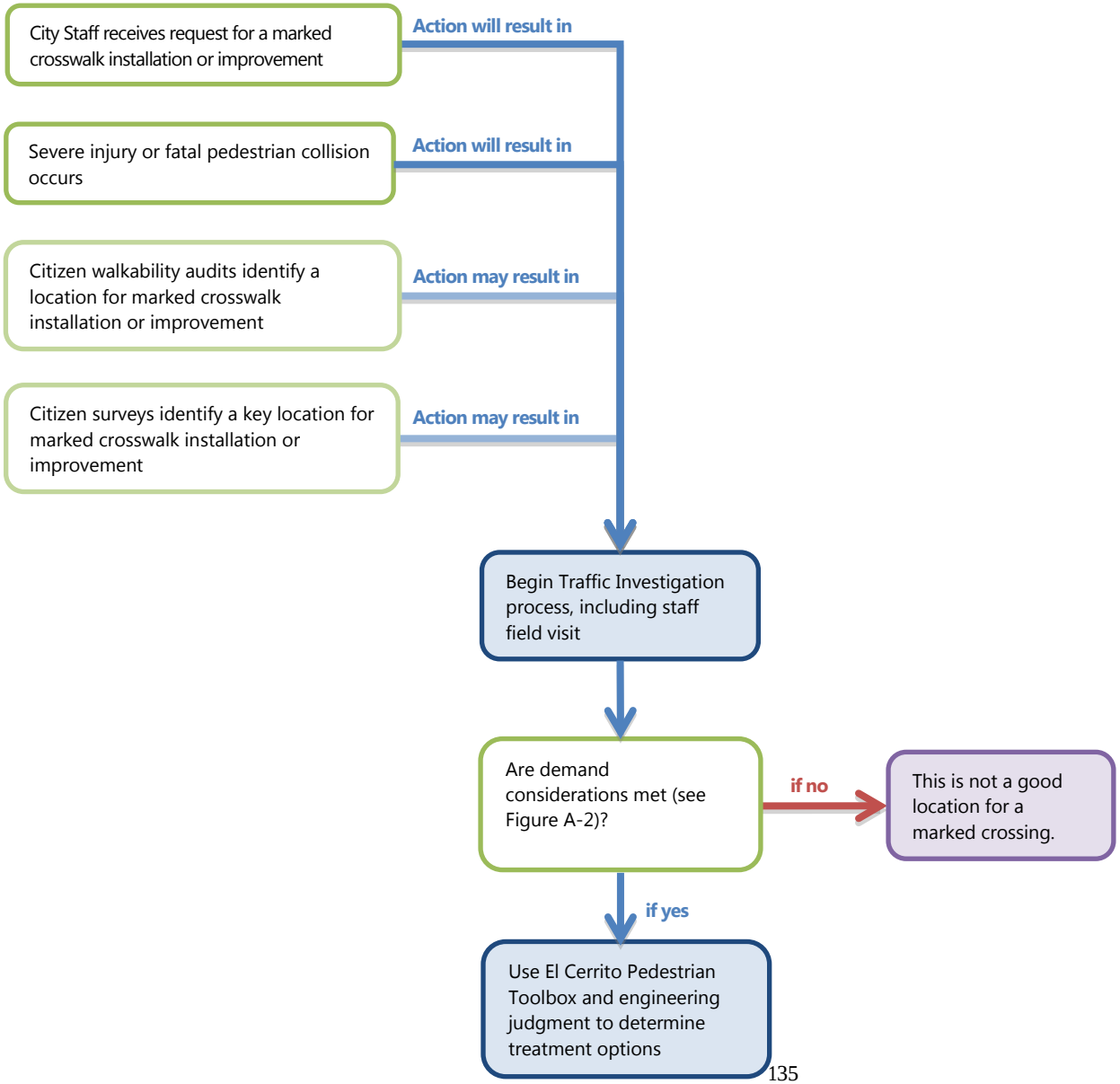
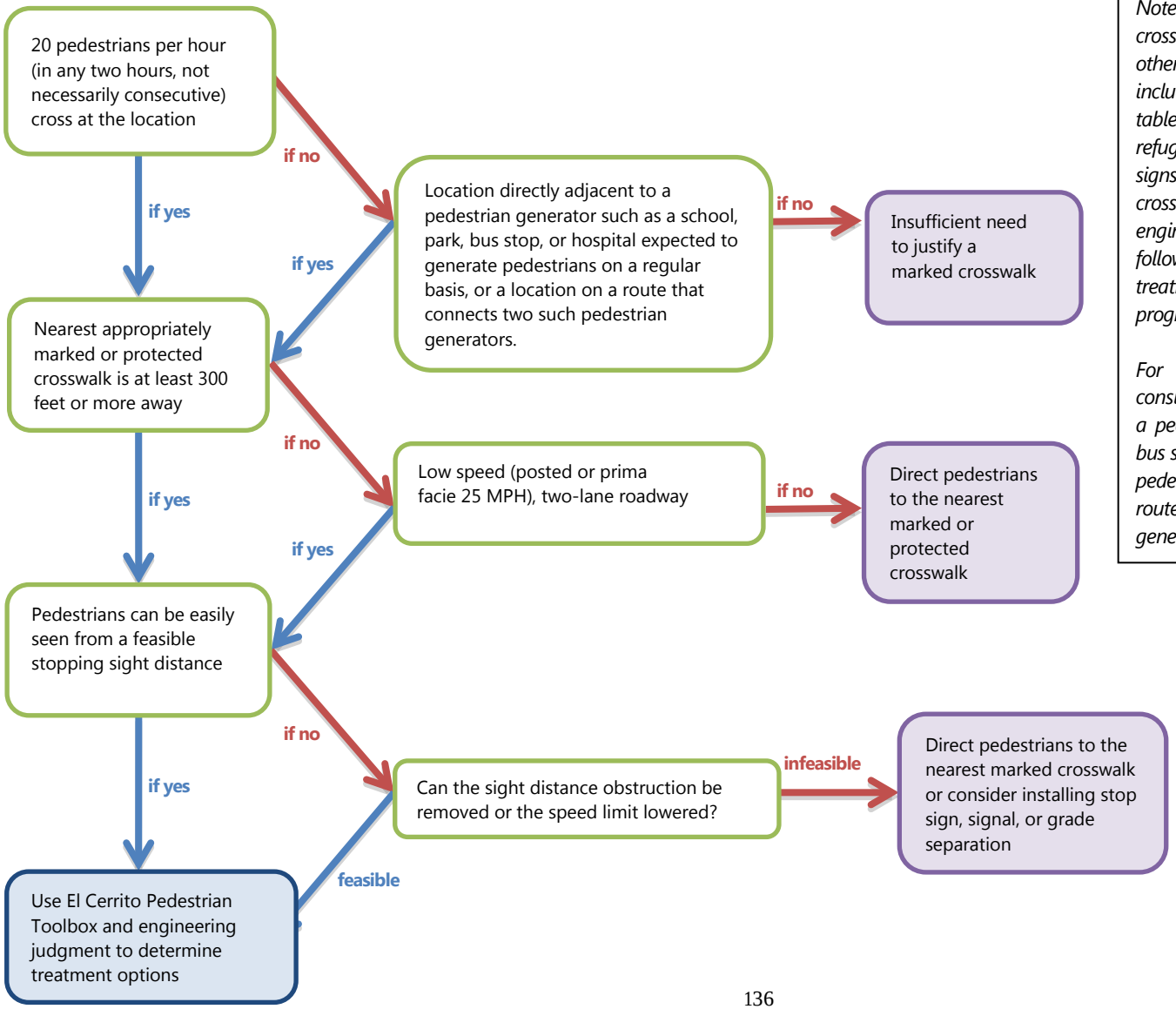


Figure A-2: Feasibility Analysis for Treatments at Uncontrolled Locations



Note: Where it is determined that a marked crosswalk is not necessary based on Figure A-2, other treatment options are available. These include traffic calming measures, such as speeds tables and speed humps; curb extensions and refuges to narrow the roadway, speed feedback signs, and similar treatments to help reducing crossing distances and slow speeds. These engineering treatments are described in the following pages. In addition to engineering treatments, education and enforcement programs should also be considered.

For locations without pedestrian counts, consider whether location is directly adjacent to a pedestrian generator such as a school, park, bus stop, or hospital and is expected to generate pedestrians on a regular basis, or is located on a route that connects two such pedestrian generators.

Uncontrolled Crossing Enhancement Toolbox

This section presents best practices for the installation of marked crosswalks at uncontrolled intersections and mid-block locations. Uncontrolled crossings require additional consideration during planning and design since traffic signals and stop signs are not provided to require motorists to stop – they must recognize the pedestrian and yield accordingly. Thus, providing appropriate enhancements to improve the visibility and safety of pedestrians crossing the street at an uncontrolled location is critical.

Crosswalk Safety Research

Several studies of pedestrian safety at uncontrolled crossings have been completed, from which conflicting research had emerged in the past. Studies conducted in San Diego in the 1970s showed that pedestrian collision risk at marked, uncontrolled crosswalks was greater than at unmarked crossings. This led many cities to remove marked crosswalks, as they were suspected of providing a false sense of security that drivers would yield to pedestrians in the crosswalk. However, a more recent study[1] by the Federal Highway Administration (FHWA) comprehensively reviewed crossing safety at 1,000 marked and 1,000 matching unmarked crosswalks in 30 U.S. cities, controlling for site context factors. The study concluded that site factors related to pedestrian-involved collisions included pedestrian average daily traffic (ADT), vehicle ADT, number of lanes, median type, and the region of the U.S. At uncontrolled locations on two-lane roads and multi-lane roads with ADT below 12,000 vehicles, FHWA found that the presence of a marked crosswalk alone, compared with an unmarked crosswalk, made no statistically significant difference in the pedestrian crash rate. However, on multi-lane roads with an ADT of greater than 12,000 vehicles (without a raised median) and 15,000 vehicles (with a raised median) the presence of a marked crosswalk without other improvements was associated with a statistically significant higher rate of pedestrian collisions compared to sites with an unmarked crosswalk.

Mid-Block Crossings

Crosswalks can be marked at intersections and mid-block points. Mid-block crossings play an important role for pedestrian access; without mid-block crossing locations, pedestrians may face the undesirable choice to detour to a controlled crossing location, detour to an intersection where crossing is legal even if not controlled, or cross illegally (if the midblock crossing is between two signalized intersections). Where signals are spaced far apart (generally more than 600-800 feet), pedestrians may have to detour several minutes to a controlled crossing location. Pedestrians are more likely to wait for a gap in traffic and cross at an unmarked location, rather than travel a distance out of their way to find a marked crosswalk. Mid-block crossings also offer an important safety consideration: fewer potential conflict points between pedestrians and motorists.

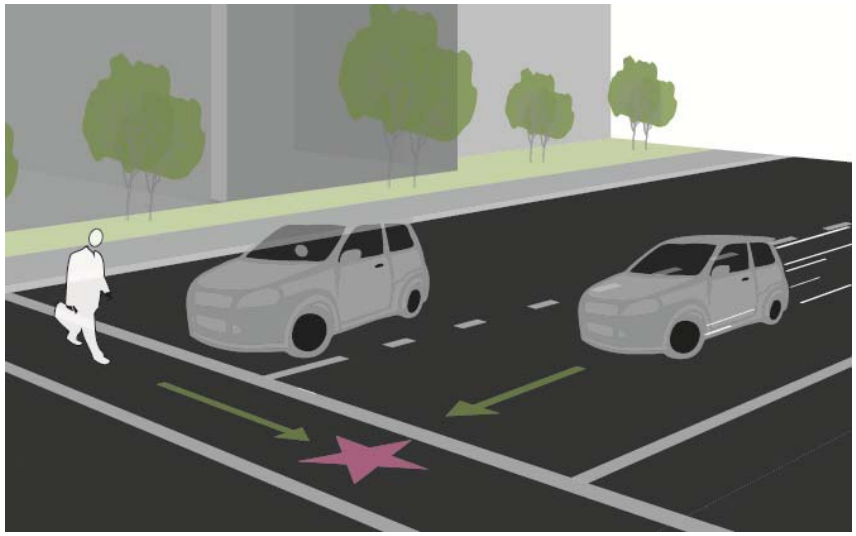
[1] Zeeger, C., J. Stewart, and H. Huang. *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations*. Publication FHWA-RD-01-142, FHWA, U.S. Department of Transportation, 2001.

Appendix A: Crosswalk Policy

FHWA stressed that the results of the study should not encourage city officials to simply remove (or fail to install) marked crosswalks. Rather, he suggested adding crosswalk enhancements to the marked crosswalks to balance mobility needs with safety needs. These improvements include providing raised medians on multi-lane roads, installing traffic and pedestrian signals where warranted, adding curb extensions, providing adequate lighting, and designing intersections with tighter turn radii.

In the FHWA study, about 70 percent of the pedestrian crashes occurred at marked crosswalks on multi-lane roads. Of the pedestrian crashes at marked crosswalks, 17.6 percent were classified as multiple-threat collisions. Multiple-threat collisions occur as one car slows down to allow pedestrians to cross, but a second car approaching from behind in the adjacent lane may not see the pedestrian, as illustrated in the image to the right. The slowing vehicle blocks the sight line of both the pedestrian and the second motorist, leading to the pedestrian-vehicle collision. Multi-lane roadways are therefore not well-served by unmarked or marked crosswalks alone. At these sites, the study concluded, engineers should consider countermeasures that provide additional safety to pedestrians and alert motorists to upcoming crosswalks. These countermeasures include advanced yield lines with corresponding signs informing motorists where to yield. Other more substantial measures may also be considered, such as signalization, illumination, or raised medians. The summary table below shows when marking a crosswalk only should not be considered.

Multiple threat conflicts on multi-lane roadways occur where a vehicle yielding to a pedestrian inhibits sight lines to another oncoming vehicle.



Appendix A: Crosswalk Policy

Table 1. Recommendations for installing marked crosswalks and other needed pedestrian improvements at uncontrolled locations.*

Roadway Type (Number of Travel Lanes and Median Type)	Vehicle ADT ≤ 9,000			Vehicle ADT >9000 to 12,000			Vehicle ADT >12,000 - 15,000			Vehicle ADT > 15,000		
	Speed Limit**											
	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h
2 Lanes	C	C	P	C	C	P	C	C	N	C	P	N
3 Lanes	C	C	P	C	P	P	P	P	N	P	N	N
Multi-Lane (4 or More Lanes) With Raised Median***	C	C	P	C	P	N	P	P	N	N	N	N
Multi-Lane (4 or More Lanes) Without Raised Median	C	P	N	P	P	N	N	N	N	N	N	N

* These guidelines include intersection and midblock locations with no traffic signals or stop signs on the approach to the crossing. They do not apply to school crossings. A two-way center turn lane is not considered a median. Crosswalks should not be installed at locations that could present an increased safety risk to pedestrians, such as where there is poor sight distance, complex or confusing designs, a substantial volume of heavy trucks, or other dangers, without first providing adequate design features and/or traffic control devices. Adding crosswalks alone **will not** make crossings safer, nor will they necessarily result in more vehicles stopping for pedestrians. Whether or not marked crosswalks are installed, it is important to consider other pedestrian facility enhancements (e.g., raised median, traffic signal, roadway narrowing, enhanced overhead lighting, traffic-calming measures, curb extensions), as needed, to improve the safety of the crossing. **These are general recommendations; good engineering judgment should be used in individual cases for deciding where to install crosswalks.**

** Where the speed limit exceeds 40 mi/h (64.4 km/h) marked crosswalks alone should not be used at unsignalized locations.

C = **Candidate sites for marked crosswalks**. Marked crosswalks must be installed carefully and selectively. Before installing new marked crosswalks, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review may be sufficient at some locations, while a more in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, etc. may be needed at other sites. It is recommended that a minimum of 20 pedestrian crossings per peak hour (or 15 or more elderly and/or child pedestrians) exist at a location before placing a high priority on the installation of a marked crosswalk alone.

P = **Possible increase in pedestrian crash risk may occur if crosswalks are added without other pedestrian facility enhancements.** These locations should be closely monitored and enhanced with other pedestrian crossing improvements, if necessary, before adding a marked crosswalk.

N = **Marked crosswalks alone are insufficient, since pedestrian crash risk may be increased due to providing marked crosswalks alone. Consider using other treatments, such as traffic-calming treatments, traffic signals with pedestrian signals where warranted, or other substantial crossing improvement to improve crossing safety for pedestrians.**

*** The raised median or crossing island must be at least 4 ft (1.2 m) wide and 6 ft (1.8 m) long to adequately serve as a refuge area for pedestrians in accordance with MUTCD and American Association of State Highway and Transportation Officials (AASHTO) guidelines.

With these studies as a backdrop, the remainder of this chapter outlines a decision making process to identify appropriate treatments and presents a variety of treatment options to mitigate safety, visibility, or operational concerns at specific locations.

Treatment Selection

At uncontrolled locations, a marked crosswalk with striping only may not provide adequate visibility to the pedestrian crossing, especially at high volume, high speed, or multi-lane crossings. Enhancements should be considered for installation to supplement crosswalk striping. Appropriate treatments should be identified based on:

- Site characteristics: presence of pedestrian desire lines, available sight distance and visibility, lighting
- Geometric configuration of the roadway: number of vehicle travel lanes and presence of curb extensions or median refuge islands
- Travel data: 85th percentile speeds, posted speed limits, and average daily traffic (ADT) volumes.

Marked crosswalks *alone* should not be installed on multi-lane streets (two or more lanes per direction; three or more lanes total) under any of the following conditions[2]:

- Speeds of greater than 40 miles per hour
- Average daily traffic volumes (ADT) greater than 12,000 without a raised median or pedestrian refuge island
- Average daily traffic volumes (ADT) greater than 15,000 with a raised median or pedestrian refuge island

Locations with speeds and ADT volumes below these thresholds may also warrant enhancements. The Uncontrolled Treatment Toolbox outlines considerations for the use of enhancements in various contexts as summarized in **Table A-1**. This Toolbox may be used to identify potential treatments at a candidate uncontrolled crosswalk location based on the results of **Figures A-1** and **A-2**.

A calculation of Pedestrian Level of Service forms the basis for the treatment identification. Pedestrian Level of Service is the average delay experienced by pedestrians as they are waiting to cross the street. Expected motorist compliance is another other key variable for treatment identification. Compliance is based on field observations and engineering judgment. It is meant to reflect typical motorist responses to pedestrians attempting to cross the street. If drivers are likely to stop for a pedestrian, the compliance is rated "high." If drivers rarely stop for pedestrians, compliance is "low." The compliance rate should be assumed to be low for all locations where the speed limit is greater than 30 MPH. **Table 5** summarizes the appropriate treatments based on level of enhancement needed (with the most significant enhancement required with the worst LOS and compliance rates).

[2] California MUTCD, Section 3B. 18.

Appendix A: Crosswalk Policy

Level 1 represents a minor intervention, appropriate for situations with lower speeds and traffic volumes and high driver yielding rates. Higher levels represent more significant interventions, as may be needed on higher speed or volume roadways, wider roadways, and roadways where motorists are less likely to yield to pedestrians. Treatments may be combined with higher level treatments added to lower level treatments (i.e., flashing beacons with curb extensions). Additional funding sources should be identified as needed for these enhancements. Failing to provide an enhanced crosswalk and/or removing a marked crosswalk should be an option of last resort.

Treatment Options

The following tables described preferred pedestrian safety treatments for uncontrolled locations with different roadway characteristics:

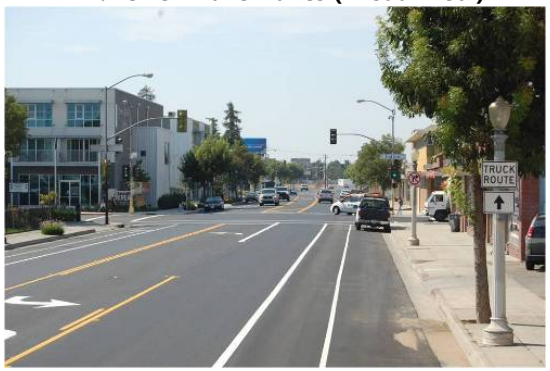
- **Table A-2: Geometric Treatments**
- **Table A-3: Striping and Signage**
- **Table A-4: Signal Hardware and Operational Measures**

Within each table, devices are categorized in three levels based on the level of safety concern they are meant to address: Level 1 (all cases), Level 2 (enhancements), and Level 3 (advanced enhancements). Categories of improvements are cumulative; for example, a Level 2 device should also include appropriate Level 1 devices.

TABLE A-1:
APPLICATION OF ENHANCED TREATMENTS FOR UNCONTROLLED LOCATIONS

Pedestrian Level of Service	Expected Motorist Compliance		
	Low (or Speed >30 mph)	Moderate	High
LOS A-D (average delay up to 30 seconds)	*LEVEL 3* 2 lane road: In-pavement flashers, overhead flashing beacons Multi-lane road: RRFB *Plus LEVELS 1 and 2*	*LEVEL 2* Curb Extensions, Bus Bulb, Reduced Curb Radii, Staggered Pedestrian Refuge *Plus LEVEL 1*	*LEVEL 1* High Visibility Crosswalk Markings, Advanced Yield Lines, Advance Signage
LOS E-F (average delay greater than 30 seconds)	*LEVEL 4* Pedestrian Hybrid Beacon, RRFB, or Direct Pedestrians to Nearest Safe Crossing *Plus LEVELS 1 and 2*	*LEVEL 3* 2 lane road: In-pavement flashers, overhead flashing beacons Multi-lane road: RRFB *Plus LEVELS 1 and 2*	*LEVEL 2* Curb Extensions, Reduced Curb Radii, Staggered Pedestrian Refuge *Plus LEVEL 1*
Notes: A pedestrian refuge island (median) is recommended for consideration in all scenarios with more than 2 lanes of traffic.			

Appendix A: Crosswalk Policy

TABLE A-2: UNCONTROLLED CROSSINGS: GEOMETRIC TREATMENTS			
Treatment	**Description**	**Level**	**Estimated Cost**
2-1. Fewer Travel Lanes ("Road Diet")  *Image Source: Fehr & Peers*	Fewer travel lanes decrease roadway width and crosswalk length, reduce speeds, reduce left-turn and rear-end collisions, and often eliminate the multiple-threat collision. It takes an average pedestrian almost four seconds to cross each additional travel lane. Therefore, reducing the number of travel lanes minimizes the amount of time that pedestrians are in the crosswalk. More travel lanes than necessary can also increase vehicle travel speeds; research has shown that the severity of pedestrian collisions increases with vehicle travel speed. Where fewer travel lanes are not possible, travel lanes can be narrowed to as little as nine feet, especially left- and right-turn pockets.	**Level 1**	$20/LF (Includes removal of existing pavement markings and repainting. Assumes existing curbs remain as is)
2-2. Removal of Sight-Distance Obstructions  *Image Source: Fehr & Peers*	If objects impede sight-distance, this may result in an unsafe condition where motorists and pedestrians are unable to see each other. Items such as parked cards, signage, landscaping, fencing, and street furniture should be placed in a location that will not obstruct sight distance.	**Level 1**	$150/EA (Item removed is anticipated to be no larger than a sign and post)

Appendix A: Crosswalk Policy

TABLE A-2: UNCONTROLLED CROSSINGS: GEOMETRIC TREATMENTS			
Treatment	**Description**	**Level**	**Estimated Cost**
2-3. Pedestrian Refuge Island  *Image Source: Fehr & Peers*	Raised islands are placed in the center of the roadway separating opposing lanes of traffic with cutouts or ramps for accessibility along the pedestrian path. Median refuge islands are recommended where right-of-way allows and conditions warrant. Studies show medians are one of the most important safety enhancements available for crosswalks. They simplify complicated multi-lane crossings by breaking the crossings/conflicts into two stages.	**Level 1**	$130/LF (New curb and new concrete barrier. Assumes 6 foot median)
2-4. Curb Extensions  *Image Source: Fehr & Peers*	Curb extensions extend the curb and sidewalks further into the roadway, shortening the length of the crosswalk. They act as a traffic calming device by narrowing the effective width of the roadway and slowing turning speeds. Because they extend into the roadway, often past parallel-parked vehicles, they improve visibility for pedestrians. They also provide space for street furniture, landscaping, bicycle parking, and signs and signal poles. Curb extensions can be constructed with reduced curb radii and to accommodate ADA improvements, such as directional curb ramps.	**Level 1**	$140/LF (Curb, sidewalk, removal of existing curb, new bollards, does not include curb ramps)

Appendix A: Crosswalk Policy

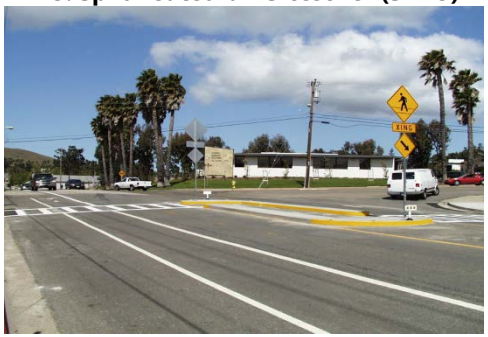
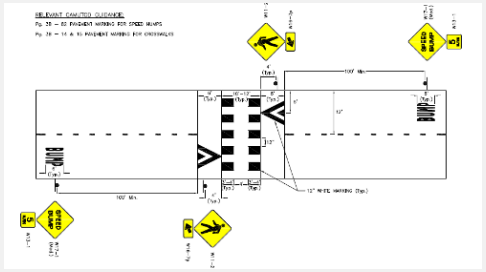
TABLE A-2: UNCONTROLLED CROSSINGS: GEOMETRIC TREATMENTS			
Treatment	**Description**	**Level**	**Estimated Cost**
2-5. Split Pedestrian Crossover (SPXO)  *Image Source: Fehr & Peers*	This measure is similar to traditional median refuge islands; the difference is that the crosswalks in the roadway are staggered such that a pedestrian crosses half of the street and then walks toward traffic to reach the second half of the crosswalk. This measure must be designed for accessibility by including rails and truncated domes to direct sight-impaired pedestrians along the path of travel.	**Level 1** Note: see Table 11 for a Pedestrian Signal	$130/LF (Same materials as 6-3)
2-6. Raised Crosswalk  *Image Source: Fehr & Peers*	Raised crosswalks are speed tables (flat-topped speed humps) outfitted with crosswalk markings and signage, providing pedestrians with a level street crossing. By raising the level of the crossing, vehicles drive more slowly through the crosswalk and pedestrians are more visible to approaching motorists.	**Level 2**	$18,000/EA

TABLE A-2: UNCONTROLLED CROSSINGS: GEOMETRIC TREATMENTS			
Treatment	**Description**	**Level**	**Estimated Cost**
2-7. Pedestrian Overpass/Underpass  *Image Source: Fehr & Peers*	This measure consists of a pedestrian or pedestrian/bicycle overpass or underpass of a roadway. It provides complete separation from motor vehicle traffic, normally where no other pedestrian facility is available, and connects off-road trails and paths across major barriers. Overpasses and underpasses should be used as a measure of last resort because of their cost and barriers to their effective/efficient use, with topographical and desire line considerations influencing their design.	**Level 3**	$150/SF

Source: Fehr & Peers, 2014.

Appendix A: Crosswalk Policy

TABLE A-3: UNCONTROLLED CROSSINGS: STRIPING AND SIGNAGE			
Treatment	**Description**	**Level**	**Estimated Cost**
3-1. High Visibility Markings  *Image Source: Fehr & Peers*	All uncontrolled marked crosswalks should feature high-visibility markings. Various striping patterns are available. At trail crossings, such as at the Ohlone Greenway, a triple-four crossing with bicycle stencils in the middle to denote a shared crosswalk for bicyclist s and pedestrians should be considered.	**Level 1**	$6/Foot
3-2. Advanced Yield Line  *Image Source: Fehr & Peers*	Advanced yield lines, often referred to as "sharks teeth", should be striped at all marked, uncontrolled crosswalks on multi-lane roadways. They should be placed 20-30 feet in front of the crosswalk. Their intention is to identify where vehicles should stop when yielding to a pedestrian to maintain adequate sight lines. These are typically use on multi-lane roadways but could be considered on two-lane roadways were driver encroachment and yielding are a concern. They should be used with the "Yield Here to Pedestrians" sign.	**Level 1**	$100/EA

Appendix A: Crosswalk Policy

TABLE A-3: UNCONTROLLED CROSSINGS: STRIPING AND SIGNAGE			
Treatment	**Description**	**Level**	**Estimated Cost**
3-3. Advanced Warning Signs  *Image Source: Fehr & Peers*	High-visibility yellow or fluorescent-yellow-green (FYG) signs are posted at crossings to increase the visibility of a pedestrian crossing.	**Level 1**	$1,000/EA

TABLE A-3: UNCONTROLLED CROSSINGS: STRIPING AND SIGNAGE			
Treatment	**Description**	**Level**	**Estimated Cost**
3-4. In-Street Pedestrian Crossing Sign  *Image Source: FHWA*	This measure involves posting regulatory pedestrian signage on lane edge lines and/or road centerlines. The in-street pedestrian crossing sign may be used to remind road users of laws regarding right-of-way at an uncontrolled pedestrian crossing. They can be installed on medians and may also be temporary signs, placed by school crossing guards during school hours.	**Level 1**	$400/EA

Source: Fehr & Peers, 2014.

Appendix A: Crosswalk Policy

TABLE A-4: UNCONTROLLED CROSSINGS: BEACON, LIGHTING, AND SIGNAL TREATMENTS			
Treatment	**Description**	**Level**	**Estimated Cost**
4-1. Pedestrian-Scale Lighting  *Image source: www.ci.mil.wi.us*	Pedestrian-scale lighting improves visibility along a pedestrian's path and across driveways. It also improves visibility at pedestrian/vehicle conflict points in crosswalks.	**Level 1**	$10,000 per light assuming light every 100 feet
4-2. Flashing Beacon  *Image Source: Fehr & Peers*	Flashing amber lights are installed on overhead or post-mounted signs, in advance of the crosswalk or at the crosswalk's entrance. Full-time flashing beacons are not recommended; flashing beacons are most effective when they are activated by the crosswalk user (they should rest on dark). By resting on dark, they can also be solar powered.	**Level 2**	$20,000/EA

TABLE A-4: UNCONTROLLED CROSSINGS: BEACON, LIGHTING, AND SIGNAL TREATMENTS			
Treatment	**Description**	**Level**	**Estimated Cost**
4-3. Rectangular Rapid Flashing Beacon (RRFB)  *Image Source: Fehr & Peers*	The RRFB is an enhancement of the flashing beacon that replaced the traditional slow flashing incandescent lamps with rapid flashing LED lamps. The RRFB may be push-button activated or activated with passive detection. This treatment was approved for use in California via Interim Approval IA-11-83 in 2011. Any installations should be reported to Caltrans for documentation, but do not require pre-approval for experimentation.	**Level 2**	$20,000/EA
4-4. Pedestrian Hybrid Beacon (PHB)  *Image Source: FHWA*	The PHB is a pedestrian-activated beacon that is a combination of a beacon flasher and a traffic control signal. When actuated, the PHB displays a yellow (warning) indication followed by a solid red indication. During the pedestrian clearance interval, the driver sees a flashing red "wig-wag" pattern until the clearance interval has ended and the beacon goes dark. The device is included in the 2012 California MUTCD for use at midblock locations.	**Level 3**	$80,000/EA

TABLE A-4: UNCONTROLLED CROSSINGS: BEACON, LIGHTING, AND SIGNAL TREATMENTS			
Treatment	**Description**	**Level**	**Estimated Cost**
4-5. Pedestrian Signal  *Image Source: Fehr & Peers*	A pedestrian signal is a conventional traffic control device with warrants for use based on the MUTCD. The pedestrian warrants were revised with the 2009 Federal and 2012 California MUTCD.	**Level 4**	$250,000/EA

Source: Fehr & Peers, 2013.

Controlled Crosswalk Treatment Toolbox

Controlled crosswalks are located at stop-controlled or signalized intersections. Generally, these crossings do not need enhancements beyond standard crosswalk markings (two parallel lines), as the traffic signal or stop-sign controls allocation of right-of-way. However, in some cases, such as in the Downtown, at skewed intersections, or near schools, the City may consider providing enhanced crossings to create a sense of place or improved aesthetics, or to improve visibility.

All treatments identified in this chapter are required or allowed by the standards and specifications in the *California Manual on Uniform Traffic Control Devices* (CA MUTCD).

Preferred Crossing Treatments

Preferred crossing treatments are identified as the basic pedestrian crossing improvements to be provided at all stop-controlled and signalized intersections. New controlled intersections should be designed with these treatments included; existing controlled intersections that require retrofits may be prioritized and upgraded as City funds become available. These treatments are based on recommended best practices in pedestrian safety:[3]

- Mark crosswalks on all legs of the intersection
- Provide advanced stop bars in advance of each crosswalk
- Minimize the number of vehicle traffic lanes pedestrians must cross
- Provide median refuge islands and thumbnails, as width and path of turn maneuvers allow
- Remove sight-distance obstructions
- Provide directional curb ramps for each crosswalk (e.g., two per corner)
- Eliminate free right-turn slip lanes, where feasible, and mitigate for pedestrian safety where they remain
- Locate bus stops on the far-side of the intersection (or in front of mid-block crossings)
- Minimize cycle lengths
- Reduce prevalence or eliminate permitted signal phasing where pedestrian crossings exist
- Provide pedestrian signal heads for all crossings at signalized intersections

[3] See America Walks *Signalized Intersection Enhancements that Benefit Pedestrians* http://americawalks.org/wp-content/upload/America-Walks-Signalized-Intersection-Enhancement-Report-Updated-8.16.2012.pdf (2012).

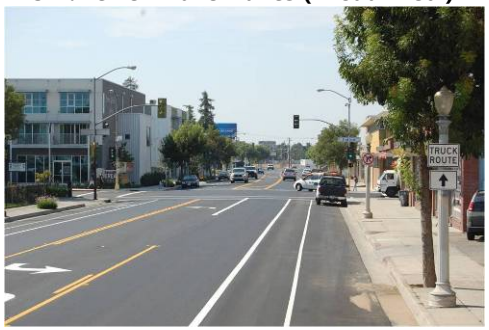
- Provide adequate pedestrian clearance intervals (crossing time) at signalized intersections

Enhanced Crossing Treatments

At high volume pedestrian crossing locations or other areas designated by the City as pedestrian zones, the City may provide additional crosswalk enhancements at controlled intersections. These treatments provide improve drivers' awareness of pedestrians by slowing traffic through geometric changes, providing signal timing or phasing modifications, or enhancing striping or signing to improve visibility.

The following tables describe the preferred and optional enhanced pedestrian safety treatments that may be used at the City's discretion for controlled locations:

- **Table A-5: Geometric Treatments**
- **Table A-6: Striping and Signage**
- **Table A-7: Signal Hardware and Operational Measures**

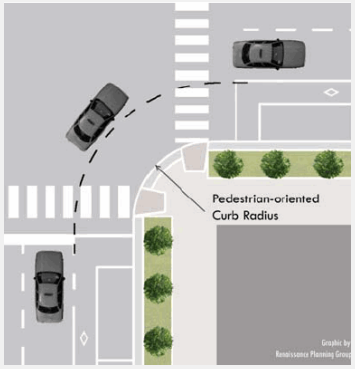
TABLE A-5: CONTROLLED INTERSECTIONS: GEOMETRIC TREATMENTS		
Treatment	**Description**	**Level**
5-1. Fewer Travel Lanes ("Road Diet")  *Image Source: Fehr & Peers*	Fewer travel lanes decrease roadway width and crosswalk length, reduce speeds, reduce left-turn and rear-end collisions, and often eliminate the multiple-threat collision. An average pedestrian takes almost four seconds to cross each additional travel lane. Therefore, reducing the number of travel lanes minimizes the amount of time that pedestrians are in the crosswalk. More travel lanes than necessary can also increase vehicle travel speeds; research has shown that the severity of pedestrian collisions increases with vehicle travel speed. Where fewer travel lanes are not possible, travel lanes can be narrowed to as little as nine feet, especially left- and right-turn pockets.	Preferred
5-2. Pedestrian Refuge Island with "Thumbnail"  *Image Source: Fehr & Peers*	Median pedestrian islands provide a refuge for pedestrians to stand if they do not have sufficient time to cross a street. They can be enhanced with median pedestrian push buttons at signalized crossings. Median islands can be installed throughout a corridor or only at specific crosswalks.	Preferred

Appendix A: Crosswalk Policy

TABLE A-5: CONTROLLED INTERSECTIONS: GEOMETRIC TREATMENTS		
Treatment	**Description**	**Level**
5-3. Removal of Sight-Distance Obstructions  *Image Source: Fehr & Peers*	If objects impede sight-distance, an unsafe condition may arise where motorists and pedestrians are unable to see each other. Items such as parked cards, signage, landscaping, fencing, and street furniture should be placed in a location that will not obstruct sight-distance.	Preferred
5-4. Directional Curb Ramps with Truncated Domes  *Image Source: Fehr & Peers*	Curb ramps offer wheelchair access to/from the sidewalk and crosswalk. Truncated domes, or tactile strips, warn blind pedestrians that they are about to enter a crosswalk. The best practice for curb ramps is to install two per corner so that each ramp points directly into the crosswalk and to the curb ramp at the other side of the street. Corner bulbouts can be used to increase the amount of space available for directional curb ramps.	Preferred

TABLE A-5: CONTROLLED INTERSECTIONS: GEOMETRIC TREATMENTS		
Treatment	**Description**	**Level**
5-5. Right-Turn Lane Design  *Image Source: Fehr & Peers*	Free right-turns allow vehicles to turn right at high speeds. Since the vehicles are not typically controlled by the traffic signal in this circumstance, crosswalks across the turn lanes are usually uncontrolled crosswalks. Controlled right-turn movements are preferable for pedestrians because they require a vehicle to stop on red before turning right. Where "pork-chop" islands that channelize right-turns are necessary to provide acceptable turning radii, raised crosswalks are a pedestrian enhancement. Other options include signalizing the crossing (especially if it is multi-lane) and designing the "pork-chop" for slower speeds and better visibility of pedestrians.	Preferred
5-6. Far-Side Bus Stops  *Image Source: Fehr & Peers*	Far-side bus stops allow pedestrians to cross behind the bus, improving pedestrian visibility. Far side bus stops also enhance transit operations by providing a guaranteed merging opportunity for buses. Exceptions for far-side bus stops include considerations for bus routing, sufficient sidewalk area, and conflicts with parking, land uses, or driveways.	Preferred

Appendix A: Crosswalk Policy

TABLE A-5: CONTROLLED INTERSECTIONS: GEOMETRIC TREATMENTS		
Treatment	**Description**	**Level**
5-7. Curb Extensions  *Image Source: Fehr & Peers*	Curb extensions extend the curb and sidewalks farther into the roadway, shortening the length of the crosswalk. They act as a traffic calming device by narrowing the effective width of the roadway and slowing turning speeds. Because they extend into the roadway, often past parallel-parked vehicles, they improve visibility for pedestrians. They also provide space for street furniture, landscaping, bicycle parking, and signs and signal poles. Curb extensions can be constructed to accommodate ADA improvements, such as directional curb ramps.	Enhanced
5-8. Reduced Turn Radius  *Image Source: AARP*	Vehicles travel faster through turns with a large radius. Reducing the radius of a corner is an effective way of reducing vehicle speeds. In suburban environments, turn radii generally do not need to exceed 30 feet. In urban environments turn radii can be 10 feet or less, especially where the meeting of one-way streets prohibits turning movements. Where on-street parking is permitted and/or bicycle lanes are present on one or both streets, consideration for further reductions of radii should occur acknowledging that the effective radius is increased with on-street parking. Corner curb radii on multi-lane streets should acknowledge that trucks turning right can turn into two lanes.	Enhanced

Appendix A: Crosswalk Policy

TABLE A-6: CONTROLLED INTERSECTIONS: STRIPING AND SIGNAGE		
Treatment	**Description**	**Level**
6-1. Marked Crosswalks  *Image Source: Google Maps*	Marking a crosswalk across all approaches of an intersection improves pedestrian accessibility. At a four-way intersection, a closed crosswalk forces pedestrians to cross via three crosswalks instead of one. Crosswalks on all approaches can often be accommodated without a significant impact to traffic signal operations. At controlled trail crossings, high-visibility triple-four trail crossings with bicycle legends in the middle should be considered to indicate a shared crossing space for bicyclists and pedestrians.	Preferred
6-2. Advanced Stop Bar  *Image Source: Fehr & Peers*	Advanced stop bars are placed five to seven feet in front of crosswalks. They keep vehicles from encroaching into the crosswalk when stopped at a red signal or stop sign.	Preferred

TABLE A-6: CONTROLLED INTERSECTIONS: STRIPING AND SIGNAGE		
Treatment	**Description**	**Level**
6-3. High Visibility Markings  *Image Source: Fehr & Peers*	High-visibility crosswalks at controlled locations are appropriate in areas with high pedestrian volumes, at crosswalks with skewed geometries, or near sensitive land uses (such as schools).	Enhanced
6-4. Textured Pavement or Colored Crosswalks  *Image Source: Fehr & Peers*	Textured pavement can be used in crosswalks or in intersections as an aesthetic enhancement. Because of its texture, it may also calm traffic by slowing vehicles before they cross an intersection. It can also make crosswalks more visible. Textured pavement can be made of brick or, alternatively, both concrete and asphalt can be stamped to look like brick or stone. At controlled locations, standard crosswalk striping should be provided in addition to the textured pavement. A smooth, non-slip surface is preferable.	Enhanced

TABLE A-7: CONTROLLED INTERSECTIONS: SIGNAL HARDWARE AND OPERATIONAL MEASURES		
Treatment	**Description**	**Level**
7-1. Adequate Crossing Times  **Image Source: Fehr & Peers**	The 2012 California MUTCD requires a walking speed of 3.5 feet per second be assumed to determine crossing times as a default minimum (4.0 feet per second was previously the guidance). A speed slower than 3.5 feet per second can be used where slower pedestrians routinely use the crosswalk, such as locations near schools, hospitals, or senior centers.	Preferred
7-2. Pedestrian Countdown Signal  *Image Source: Fehr & Peers*	Pedestrian countdown signals give pedestrians "Walk" and "Don't Walk" signals with a second-by-second countdown for each phase. Research suggests that pedestrians are more likely to obey the "Don't Walk" signal when delivered using a countdown signal. The device has been shown to enhance safety for all road users. The 2012 California MUTCD requires that all new pedestrian signals be countdown signals.	Preferred

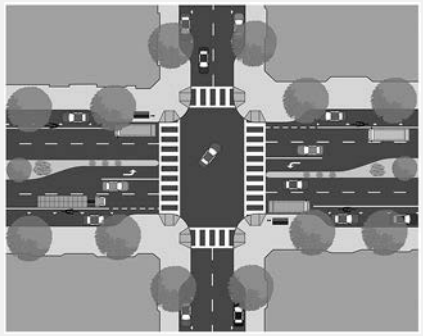
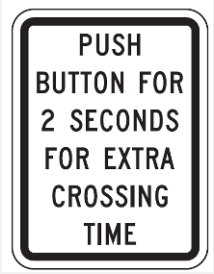
TABLE A-7: CONTROLLED INTERSECTIONS: SIGNAL HARDWARE AND OPERATIONAL MEASURES		
Treatment	**Description**	**Level**
7-3. Pedestrian Signals and Push Buttons  *Image Source: Fehr & Peers*	Mounting push buttons for different crosswalks on one pole can be confusing for blind pedestrians. Push buttons should be separated by ten feet and placed within five feet of each curb ramp, one per crosswalk. At long crosswalks (≥60 feet) with a median refuge island, push buttons can be placed in the median for pedestrians who may not be able to cross the entire crosswalk in one cycle length. In areas with high pedestrian volumes, eliminating pedestrian push buttons and providing a pedestrian phase in every cycle, can enhance walkability (and signal compliance).	Preferred
7-4. Short Cycle Lengths  *Image Source: Institute of Transportation Engineers*	Long cycle lengths at signalized intersections result in long pedestrian wait times to cross a street. By shortening an intersection's cycle length, pedestrians do not have to wait as long to cross after pushing the button to request a "Walk" signal.	Preferred

TABLE A-7: CONTROLLED INTERSECTIONS: SIGNAL HARDWARE AND OPERATIONAL MEASURES		
Treatment	**Description**	**Level**
7-5. Protected Left-Turns  *Image Source: Fehr & Peers*	Where permitted left-turns are allowed, denoted by a "Left Turn Yield on Green" sign, left-turning vehicles can conflict with pedestrians in the crosswalk. By making the left-turn protected, so that it is allowed only with a green arrow, the "Walk" signal at a crosswalk occurs at the same time that through- and right-turning vehicles in the same direction receive a green light. This reduces the risk of left-turning vehicle conflicts with the opposing crosswalk; since left-turns typically occur at a higher speed than right-turns, collisions of increased severity can be avoided by protecting left-turns.	Preferred
7-6. Accessible Pedestrian Signals  *Image Source: Fehr & Peers*	Accessible pedestrian signals (APS) and detectors provide information, such as "Walk" indications and direction of crossing, in non-visual formats to improve accessibility for blind pedestrians. Audible options for accessible pedestrian signals include audible tones and speech messages. Vibrotactile push-buttons are effective options that alleviate the impacts of noise created by audible pedestrian signals. They are also accessible to deaf pedestrians. APS should always be provided when two push buttons are located on one pole and where persons with disabilities are expected frequently at a crossing. At other locations, APS is currently a best practice, but is expected to become a requirement when the proposed rulemaking of the *Public Rights of Way Accessibility Guidelines* (PROWAG) is finalized.	Enhanced

TABLE A-7: CONTROLLED INTERSECTIONS: SIGNAL HARDWARE AND OPERATIONAL MEASURES		
Treatment	**Description**	**Level**
7-7. Pedestrian Recall  *Image Source: Fehr & Peers*	Pedestrian recall gives pedestrians a "Walk" signal at every cycle. No push-button or detection is necessary since a "Walk" signal will always be given. Pedestrian recalls are useful in areas with high levels of pedestrian activity. They demonstrate that an intersection is meant to serve both vehicles and pedestrians. In general, pedestrian recall should be used if pedestrians actuate a "Walk" signal 75 percent of the time during three or more hours per day. Recall can be used 24-hours a day or during peak hours for pedestrians (in which case push buttons should continue to be provided).	Enhanced
7-8. No Right Turn on Red  *Image Source: FHWA*	When attempting to turn right on red, motorists must look left to see if the road is clear; motorists often do not look right before turning and may not see pedestrians to their right. Restricting right turns on red can reduce conflicts between vehicles and pedestrians. "Blank out" turn restriction signs (see 11-9 below) are more effective than conventional "No Right Turn on Red" signs. "No Right Turn on Red" signs that specify time-of-day restrictions or "When Pedestrians are Present" are confusing to motorists and are often disregarded.	Enhanced

TABLE A-7: CONTROLLED INTERSECTIONS: SIGNAL HARDWARE AND OPERATIONAL MEASURES		
Treatment	**Description**	**Level**
7-9. Blank-Out Turn Restriction LED Sign  *Image Source: Fehr & Peers*	The ubiquity of conventional turn restriction signs, usually for no right turn on red, contributes to their disregard by motorists. Blank out turn restriction signs activate only when the specified movement is prohibited. The LED sign is also very visible.	Enhanced
7-10. Animated Eyes  *Image Source: Fehr & Peers*	Animated eyes pedestrian signals feature eyes that move from side to side when a "Walk" signal is given. The signals remind pedestrians to look for turning vehicles before proceeding into the crosswalk. Research has indicated that animated eyes pedestrian signals reduce conflicts between vehicles and pedestrians.	Enhanced

TABLE A-7: CONTROLLED INTERSECTIONS: SIGNAL HARDWARE AND OPERATIONAL MEASURES		
Treatment	**Description**	**Level**
7-11. Leading Pedestrian Interval (LPI)  *Image Source: Fehr & Peers*	A leading pedestrian interval (LPI) advances the "Walk" signal for a few seconds while through-vehicles continue to receive a red indication. By allowing pedestrians to get a head start into the crosswalk, it can reduce conflicts between pedestrians and turning vehicles. The 2012 California MUTCD recommends that LPIs be at least three seconds in duration. Right-turn on red restrictions may be needed with LPIs are installed in locations with lower pedestrian volumes.	Enhanced
7-12. Push Button for Extended Crossing Time  *Image Source: FHWA*	Some pedestrians may need extra time to safely cross a street. Traffic signals can be retrofitted to provide pedestrians with increased crossing time by extending the duration of a pushbutton press.	Enhanced

Source: Fehr & Peers, 2014.

City of SACRAMENTO

2021

PEDESTRIAN CROSSING GUIDELINES



April 2021

DEFINING CROSSWALKS

The following California Vehicle Code (CVC) excerpts provide the legal definitions and right-of-way control for crosswalks:

CVC Section 275. Crosswalk is either:

(a) That portion of a roadway included within the prolongation or connection of the boundary lines of sidewalks at intersection where the intersecting roadways meet at approximately right angles, except the prolongation of such lines from an alley across a street.

(b) Any portion of a roadway distinctly indicated for pedestrian crossing by lines or other markings on the surface. Notwithstanding the foregoing provisions of this section, there shall not be a crosswalk where local authorities have placed signs indicating no crossing.

CVC Section 21950. Right-of-Way at Crosswalks:

(a) The driver of a vehicle shall yield the right-of-way to a pedestrian crossing the roadway within any marked crosswalk or within any unmarked crosswalk at an intersection, except as otherwise provided in this chapter.

(b) This section does not relieve a pedestrian from the duty of using due care for his or her safety. No pedestrian may suddenly leave a curb or other place of safety and walk or run into the path of a vehicle that is so close as to constitute an immediate hazard. No pedestrian may unnecessarily stop or delay traffic while in a marked or unmarked crosswalk.

(c) The driver of a vehicle approaching a pedestrian within any marked or unmarked crosswalk shall exercise all due care and shall reduce the speed of the vehicle or take any other action relating to the operation of the vehicle as necessary to safeguard the safety of the pedestrian.

(d) Subdivision (b) does not relieve a driver of a vehicle from the duty of exercising due care for the safety of any pedestrian within any marked crosswalk or within any unmarked crosswalk at an intersection.

City of SACRAMENTO

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TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS III

EXECUTIVE SUMMARY IV

1.0 INTRODUCTION 1

1.1 Purpose and Scope 1

1.2 Flexibility and the Role of Engineering Judgement 2

1.3 Crosswalk Overview 2

1.4 Updating the Guidance 2

2.0 EVALUATING CANDIDATE MARKED CROSSWALK LOCATIONS 3

2.1 Overview 3

2.2 Crosswalks at Uncontrolled Crossing Locations 3

STEP 1: INITIAL LOCATION SCREENING 5
STEP 2: DATA COLLECTION 9
STEP 3: TREATMENT SELECTION 13

2.3 Crosswalks at Controlled Crossing Locations 15

2.4 Crossings at Mid-Block Locations 15

2.5 Crosswalks at Trail Crossings 16

2.6 Prohibiting Pedestrian Crossings 16

3.0 EXISTING UNCONTROLLED MARKED CROSSWALKS 17

3.1 When Should The City Evaluate Existing Crosswalks? 18

3.2 Evaluation And Enhancement Approach 18

3.3 What If Enhancement Of An Existing Crosswalk Is Not Feasible? 19

3.4 Uncontrolled Marked Crosswalk Removal 21

3.5 Prioritizing Enhancements for Existing Uncontrolled Marked Crosswalks 22

4.0 PEDESTRIAN CROSSING TREATMENT GUIDANCE 23

4.1 Treatments for Marked Crosswalks at Uncontrolled Locations 23

4.2 Crosswalks at Mid-Block 29

4.3 Crosswalks at Trails or Shared-Use Paths 31

4.4 Crosswalks at Controlled Locations 33

APPENDCIES

Appendix A – Crosswalk Basics and Key Definitions

Appendix B – City of Sacramento Crosswalk Removal Outreach Policy

ABBREVIATIONS AND ACRONYMS

ADA	Americans with Disabilities Act
ADT	Average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
APS	Accessible pedestrian signal
CA MUTCD	(Caltrans) California Manual on Uniform Traffic Control Devices
Caltrans	California Department of Transportation
CPUC	California Public Utilities Commission
CTCDC	California Traffic Control Devices Committee
CVC	California Vehicle Code
DPM	(City of Sacramento) Design and Procedures Manual
FHWA	Federal Highway Administration
HDM	(Caltrans) Highway Design Manual
IA	Interim Approval
IRWLs	In-Roadway Warning Lights
ITE	Institute of Transportation Engineers
LED	Light emitting diode
mph or mi/h	Miles per hour
MUTCD	Manual on Uniform Traffic Control Devices
NACTO	National Association of City Transportation Officials
NCHRP	National Cooperative Highway Research Program
PHB	Pedestrian Hybrid Beacon
RRFB	Rectangular Rapid Flashing Beacon
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
VPH or vph	Vehicles per hour

EXECUTIVE SUMMARY

Purpose

The City of Sacramento 2021 Pedestrian Crossing Guidelines (Guidelines) provide guidance for the design and installation of marked crosswalks within the City of Sacramento. These guidelines document the preferred practice for the design and installation of marked crosswalks in Sacramento, subject to engineering judgement on a site-by-site basis. This document integrates available research related to pedestrian crossing facilities and recommended treatments with emphasis on designing streets that support a safe and walkable urban environment.

These guidelines are not meant to be rigid standards, rather, they provide additional guidance subject to engineering judgement on a case-by-case basis. The guidance seeks to maintain a reasonable balance between prescriptive requirements and flexibility based on engineering judgement, engineering study, and other necessary and useful considerations.

Candidate Marked Crosswalk Locations

The Guidelines provide suggested practices for evaluating candidate Marked Crosswalk Locations at uncontrolled crossing locations (i.e., at intersections and midblock locations that are not controlled by a traffic signal, stop, or yield sign). These locations may be identified as candidate locations either by City staff or as a request from the public. The guidance provides the following stepwise process (**Section 2.2**):

Step 1: Initial Location Screening

Uncontrolled marked crosswalks are ultimately appropriate at locations that meet the following conditions:

DEMAND:

Is there sufficient observed or latent demand?

↓

DISTANCE TO NEAREST CROSSING:

Is the nearest marked crossing at least 300 feet away?

↓

VISIBILITY:

Are the roadway and traffic conditions appropriate for providing a marked crossing?

↓

CROSSING SPACING:

Will the marked crossing fill a gap in marked crosswalk spacing?

Exceptions to these conditions on a case-by-case basis. Refer to **Section 2.2** on page 3 and the **Crossing Location Evaluation Overview Flowchart** on page 8 for more information.

Step 2: Data Collection

If a location is appropriate for a marked crosswalk, the Guidelines recommend collecting the following data to inform treatment selection:

ROADWAY CHARACTERISTICS

BEHAVIORAL CHARACTERISTICS

LOCATION CHARACTERISTICS

Refer to pages 10-12 for a complete list of data to collect and collection worksheets.

Step 3: Treatment Selection

Step 3 provides guidance for selecting the following crossing enhancements (refer to **TABLE 2** on Page 14 and to the *Treatment Applications Guide*) based on the data collected in Step 2:

- High-visibility crosswalk markings (with parking restrictions, adequate nighttime lighting levels, and crossing warning signs)
- Raised crosswalk
- Advance yield sign and markings
- In-street pedestrian crossing sign
- Curb extension
- Pedestrian refuge island
- Rectangular Rapid Flashing Beacon (RRFB)
- Road diet
- Pedestrian hybrid beacon (PHB)



Evaluating Existing Uncontrolled Marked Crosswalks

The Guidelines provide suggested practices for evaluating existing uncontrolled marked crosswalks, with the following considerations:

WHEN TO EVALUATE (SECTION 3.1)

Evaluate as…

Part of a land use project

Part of a roadway project

Part of a resurfacing project

Outcome of traffic investigation[1]

HOW TO EVALUATE, ENHANCE, OR UPGRADE (SECTION 3.2)

Add location to citywide inventory

Consult context classification guidance in Section 2 and treatment guidance in Section 4

HOW TO CONSIDER FEASIBILITY (SECTION 3.3)

Evaluate based on location Type guidance

Document determination

WHEN TO REMOVE MARKED CROSSWALKS (SECTION 3.4)

Remove as an exceptional case subject to:

Engineering evaluation

Overriding safety considerations

Improvements determined to be infeasible[2]

Appropriate outreach conducted

Prioritizing Enhancement Locations

The Guidelines provide the criteria and process for prioritizing locations for crosswalk enhancement (**Section 3.5**). The criteria include:

- Crash history
- Demand
- Transit stop presence
- Vision Zero High Injury Network
- School Zone
- Social Equity (location is within a disadvantaged community)

Defining Crosswalk Marking Treatments

Section 4 of the guidance establishes basic signing and markings associated with different crosswalk types. The guidance uses the 2018 FHWA *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* as the basis for location types where enhancements may be necessary or desirable (see **TABLE 3** on page 28).

[1] A traffic investigation is a review of a specific location by City staff due to a traffic safety concern based on a public or internal request, including crosswalk reviews.

[2] Improvements may be determined to be infeasible due to a variety of factors including cost, right of way constraints, or a lack of infrastructure, among others.

1.0 INTRODUCTION

1.1 Purpose and Scope

The City of Sacramento 2021 Pedestrian Crossing Guidelines provide guidance for the design and installation of marked crosswalks within the City of Sacramento. These guidelines document the preferred practice for the design and installation of marked crosswalks in Sacramento, subject to engineering judgement on a site-by-site basis. This document was adopted by City Council on April 20, 2021 (Resolution No. 2021-0093) and, as such, supersedes the 2014 Pedestrian Crossing Guidelines.

This document integrates available research related to pedestrian crossing facilities and recommended treatments with emphasis on designing streets that support a safe and walkable urban environment. Where applicable, the guidelines reflect pertinent current standards or regulations at the time of preparation of these guidelines (2021).

The City regularly receives requests to install marked crosswalks from various customers including residents, businesses, and institutions. This document provides guidance on the fundamental aspects of pedestrian crossings. The guidance can be used to determine if a marked crosswalk would be appropriate at a requested location and identifies a range of pedestrian crossing enhancement treatments that can be used to help accomplish the goal of getting pedestrians safely across the roadway. Accordingly, the guidelines and other provisions set forth in this document are based on the current versions of pertinent codes and treatises such as the California Vehicle Code (CVC), Caltrans' Manual on Uniform Traffic Control Devices (CA MUTCD), and the Highway Design Manual (HDM), among other standards or regulations. **Appendix A** provides details on the legal definition of a crosswalk, the relationship between crosswalks and associated standards and regulations, as well as key definitions.

These guidelines integrate these referenced resources and 2021 best practices to provide guidance on concepts and treatments related to pedestrian crossings in the City of Sacramento with a focus on uncontrolled pedestrian crossings. For pedestrian crossing treatments or enhancements, please note the following:

- the City of Sacramento's practice is to use traffic control devices that are approved for use in California.
- with advancement in engineering practice and technology, new treatments and devices may become available in the future. The City Traffic Engineer may approve the use of such treatments and devices, as determined appropriate. The City Traffic Engineer's powers and duties are defined in Section 10.08.040 of the Sacramento City Code as:

The city traffic engineer shall: determine the installation and proper timing and maintenance of traffic-control devices and signals; conduct engineering analyses of traffic accidents and devise remedial measures; conduct engineering investigation of traffic conditions and co-operate with other city officials in the development of ways and means to improve traffic conditions; and carry out the additional powers and duties imposed by this title and other ordinances of the city.

- treatments recommended in these guidelines reflect common treatments currently in use and may not include every treatment available.
- multiple treatment options are provided, where feasible, to provide flexibility in selection of appropriate treatments depending on the context and site-specific conditions of the crossing locations.

This is a technical document to guide the decision-making for marking crosswalks and the determination of appropriate crossing enhancement treatments. It is not aimed at addressing planning or policy-related aspects of walking as a mode of transportation. Those aspects are addressed in the City's *Pedestrian Master Plan*. The companion document City of Sacramento *Pedestrian Crossing Guidelines Treatment Applications Guide* contains more information and guidance for crossing treatments.

1.2 Flexibility and the Role of Engineering Judgement

These guidelines are not meant to be rigid standards, rather, they provide additional guidance subject to engineering judgement on a case-by-case basis. The guidance seeks to maintain a reasonable balance between prescriptive requirements and flexibility based on engineering judgement, engineering study, and other necessary and useful considerations. Accordingly, the guidelines incorporate provisions pursuant to which the City Traffic Engineer may consider variations and exceptions in certain circumstances.

In some instances, this document may not provide a definitive solution absent the exercise of engineering judgement or engineering study by the City Traffic Engineer. In all situations, the exercise of engineering judgement and/or engineering study are emphasized as integral components of the decision-making process.

1.3 Crosswalk Overview

Legal pedestrian crossings exist at all non-alley intersections that meet at approximately right angles, whether marked crosswalks are present or not, except where a pedestrian crossing is specifically prohibited. Marked crosswalks serve to alert road users to expect crossing pedestrians and to direct pedestrians to desirable crossing locations. At mid-block locations, crosswalks only exist where marked. At these non-intersection locations, it is the crosswalk markings that legally establish a crosswalk.

These guidelines are consistent with the CA MUTCD which at the time of publication provides uniform standards and specifications for crosswalk markings and all other official traffic control devices in California.

1.4 Updating the Guidance

These guidelines should be updated to reflect advancements in the engineering practice and changes in best practices for pedestrian crossings, as needed. The City Traffic Engineer shall determine when and the extent to which any update to the Pedestrian Crossing Guidelines is necessary to maintain consistency with best practices and engineering guidance.



2.0 EVALUATING CANDIDATE MARKED CROSSWALK LOCATIONS

2.1 Overview

This chapter describes suggested practices for evaluating candidate marked crosswalk locations. Candidate marked crosswalk location are sites identified by City staff or requested by members of the public. Crosswalk marking practices at signalized and stop- or yield- controlled locations differ from uncontrolled crossings. The identification of candidate marked crosswalk locations is a two-stage process:

Locate pedestrian desire lines. Pedestrian desire lines for crossings are the places where people would like to cross the street. These locations are influenced by elements of the roadway network, such as transit stops, and nearby land uses (homes, schools, parks, trails, commercial centers, etc.).

Identify where people can cross safely. Of all road users, pedestrians have the highest risk of injury in a collision because they are the least protected. Choosing the location for a marked crosswalk must consider the site context to determine the most appropriate crossing location to improve walking accessibility and safety.

2.2 Crosswalks at Uncontrolled Crossing Locations

Uncontrolled crossings are:

- At intersections and midblock locations that are not controlled by a traffic signal, stop, or yield sign; and,
- may have marked crosswalks or unmarked crosswalks (as defined in CVC Section 275).

Notwithstanding the provisions of the CVC, there shall not be a crosswalk where local authorities have placed signs indicating no crossing.

The guidance below is provided to assist in the interpretation of the CVC for City of Sacramento staff and public users when determining the presence of an unmarked crosswalk:

- An unmarked crosswalk must be at an intersection.
- There cannot be an unmarked mid-block crosswalk.
- There cannot be an unmarked crosswalk at an intersection without sidewalks on at least one side.
- Intersecting roadways must meet at approximately right angles and cannot include an alley.

The CA MUTCD Section 3B.18 provides standards, guidance, and supporting information for crosswalk markings.

For uncontrolled crossing locations, the CA MUTCD recommends an engineering study should be performed before a marked crosswalk is installed at a location away from a traffic control signal or an approach controlled by a STOP or YIELD sign. This engineering study should consider:

- number of lanes;
- median presence;
- distance from adjacent signalized intersections;
- pedestrian volumes and delays;
- average daily traffic;
- posted and 85th percentile speed (when available);
- roadway or intersection geometry;
- pedestrian desire lines;
- crossing point consolidation;
- lighting presence; and,
- other appropriate factors, as needed.

A three-step process has been developed and refined by the City of Sacramento to help determine if an uncontrolled location is a potential candidate for a marked crosswalk. The steps provide guidance on the appropriateness of various additional crossing treatments for consideration if marking the crosswalk based on speed, average daily traffic, and roadway geometry.

Step 1:

Initial Location Screening provides a flow chart to assist City staff in evaluating the appropriateness of an uncontrolled crossing location for a marked crosswalk.

Step 2:

Data Collection provides data collection forms to assist City staff in gathering appropriate data to determine a recommended marked crosswalk location and associated treatments.

Step 3:

Treatment Selection provides guidance on selecting between additional treatments appropriate at the uncontrolled crossing site if it is recommended for crosswalk marking.



Step 1: Initial Location Screening

The first step of the uncontrolled crossing location evaluation is an initial screening process to objectively evaluate the general appropriateness of an uncontrolled marked crosswalk at a specific location; this is undertaken in coordination with engineering judgement. This evaluation of the proposed pedestrian crossing site conditions addresses the following fundamental questions:

- Is there sufficient observed or latent demand?
- Is there another appropriate crossing location nearby?
- Are the roadway and traffic conditions appropriate for providing a marked crossing?
- Will the marked crossing fill a gap in marked crosswalk spacing?

These questions form the basis for determining whether to mark a crosswalk at a location. **FIGURE 1** (page 8) illustrates the flow of the decision-making process for evaluating a crossing location for a potential marked crosswalk. Each factor for the decision-making process is discussed in the subsections that follow.

DEMAND

GUIDANCE:
Uncontrolled locations should be considered for marking if there is sufficient pedestrian crossing demand (either measured through actual counts or latent demand) at the study location according to the following criteria:

- Pedestrian volumes of 20 or more are expected during the peak hour of pedestrian demand; or,
- Elderly, children, disabled, and/or sight-impaired pedestrian volumes of 15 or more are expected during the peak hour of pedestrian demand; or,
- Pedestrians volumes of 15 or more are expected during any two or more hours throughout the day.
- **Demand Exceptions:** If the proposed marked crosswalk location provides access to a trail/shared-use path, is on the Vision Zero Action Plan High-Injury Network, or is on a direct pedestrian route to certain destinations like a school, park, senior center, community center, hospital, transit stop, the City Traffic Engineer may consider an exception to the minimum demand requirements on a case-by-case basis.

In evaluating demand for new crossings, the minimum thresholds should consider both existing and estimated future demand at the site. Estimated future demand should be determined using engineering judgement based on anticipated impending land use or other contextual changes to the area near the study location that could increase pedestrian activity and crossing demand at the study location. When considering estimated future demand City staff should also consider whether pedestrian crossings are currently reduced due to the lack of a marked crosswalk or, when appropriate, enhanced crosswalk at the study location.

If the study location does not meet the pedestrian demand guidance the location may still be evaluated through the remaining steps of the evaluation process to consider its overall context within the transportation network, using engineering judgement. If the result of such an evaluation suggests that the location is appropriate for marking the crosswalk considering the overall context, the City Traffic Engineer may make a determination (on a case–by–case basis) as to whether or not to mark the crossing at the study location, even if the pedestrian demand requirements are not satisfied.

DISTANCE TO THE NEAREST CROSSWALK

GUIDANCE:
At an uncontrolled crossing location, crosswalks should be considered for marking if the nearest marked or controlled pedestrian crossing distance is greater than or equal to 300 feet from the study location.

The nearest crosswalk may be controlled or an appropriately treated marked uncontrolled crossing. An appropriately treated uncontrolled crossing is considered as one having the signage, pavement markings, and the pedestrian crossing treatments that are consistent with the applicable guidelines in this document.

Staff should evaluate and confirm that the proposed marked crosswalk at the location under consideration is appropriate based on the site conditions, the ability to consolidate multiple crossing locations, and to effectively channelize pedestrians.

The 300-foot distance is general guidance, rather than an absolute minimum requirement or a controlling design criterion. The City Traffic Engineer may consider an exception in this regard on a case-by-case basis based on engineering judgement, and other considerations such as:

- pedestrian crossing demand;
- unique conditions pertaining to the proposed crossing site;
- the need to consolidate multiple crossing points or to channel pedestrians to preferred crossing locations, such as controlled approaches, and/or appropriately treated uncontrolled crosswalks; or,
- overall context pertaining to the crossing site (e.g., land uses or roadway and traffic conditions such as number of lanes, traffic volume, and speed), that may justify marking the pedestrian crossing at the desired location.

VISIBILITY

GUIDANCE:

Sight distance should be measured in the field to determine adequacy for approaching motorists to see and stop for a pedestrian starting to cross the street at the crosswalk. Stopping sight distance should be measured based on a pedestrian having stepped with one foot in the bike lane or roadway at the crossing, showing the intent to cross. If minimum stopping sight distance is not met, consideration should be given to removing the obstruction(s) or implementing treatments to slow vehicle speeds on the approach to the crossing to reduce the required stopping sight distance. Vehicle stopping sight distance should be measured in accordance with the Caltrans HDM as shown in **TABLE 1**. If stopping sight distance cannot be adequately provided, the location is not appropriate for an uncontrolled marked crosswalk.

The availability of lighting to illuminate the proposed crosswalk should be evaluated to determine nighttime visibility as per the CA MUTCD. If there are special circumstances that necessitate nighttime illumination and illumination is not present, the location may not be appropriate for an uncontrolled marked crosswalk. Special circumstances may include high levels of nighttime pedestrian activity due to adjacent land uses such as a theater or anticipated frequent vehicle-pedestrian conflicts under nighttime conditions.

Sight distance is the length of the roadway ahead that is visible to the driver or pedestrian. The available stopping sight distance on a roadway should be sufficient to enable a vehicle traveling at or near the design speed to stop before reaching a pedestrian in the crosswalk. This assessment should be based on the posted speed limit or 85th percentile speed, when available. For locations with separated bike lanes (Class IV bikeways) with painted or raised islands separating the bike lane from vehicle traffic, stopping sight distance should be measured from the crossing point from the location furthest into the roadway cross-section that provides a detectable warning surface to assist and warn pedestrians who are blind or visually-impaired.

Overhead lighting at a crossing provides increased visibility of pedestrians and the crossing by increasing the luminance contrast at the location. Luminance contrast is based on the difference in the measured brightness of the object of interest and its background. The presence of lighting should be determined when evaluating a crossing location. Where lighting is not present, the City Traffic Engineer may consider an exception on a case-by-case basis based on engineering judgement.

STOPPING SIGHT DISTANCE VALUES

The stopping sight distances for various speeds on level roadways are shown in the following table. The posted speed or 85th percentile speed, when available, should be used as the design speed for evaluating stopping sight distance for this guidance. When both the posted speed and 85th percentile speed are available, the higher of the two values should be used to determine the appropriate stopping sight distance.

TABLE 1 Stopping Sight Distance on Level Roadways

DESIGN SPEED (MPH)	STOPPING SIGHT DISTANCE (FT)
10	50
15	100
20	125
25	150
30	200
35	250
40	300
45	360
50	430
55	500
60	580
65	660

Source: Adapted from the Caltrans Highway Design Manual, 2018.

CROSSWALK SPACING

GUIDANCE:

The distance between existing marked crosswalks should be measured from the evaluation site. The desired spacing frequency for marked crossings in the City of Sacramento is context-based, such that certain areas of the City have a higher crossing frequency standard than others based on the expected pedestrian demand and land use. The City's crosswalk spacing standards are detailed below and based on a typical 400-foot block in Downtown Sacramento. Block lengths were measured from the center of adjacent intersections. Using this typical block as a reference for crossing frequencies, minimum desired crossing frequencies were established.

THE GRID:

- This context zone is made up of the area bounded by the American River, Interstate 5, Broadway, and the Capital City Freeway.
- Desired marked crossing frequency: 800 feet (every other block)

VISION ZERO HIGH INJURY NETWORK:

- This context zone is made up of the High Injury Network as designated in the Vision Zero Action Plan.
- Desired marked crossing frequency: 1,200 feet (every third block)

TRANSIT STOPS:

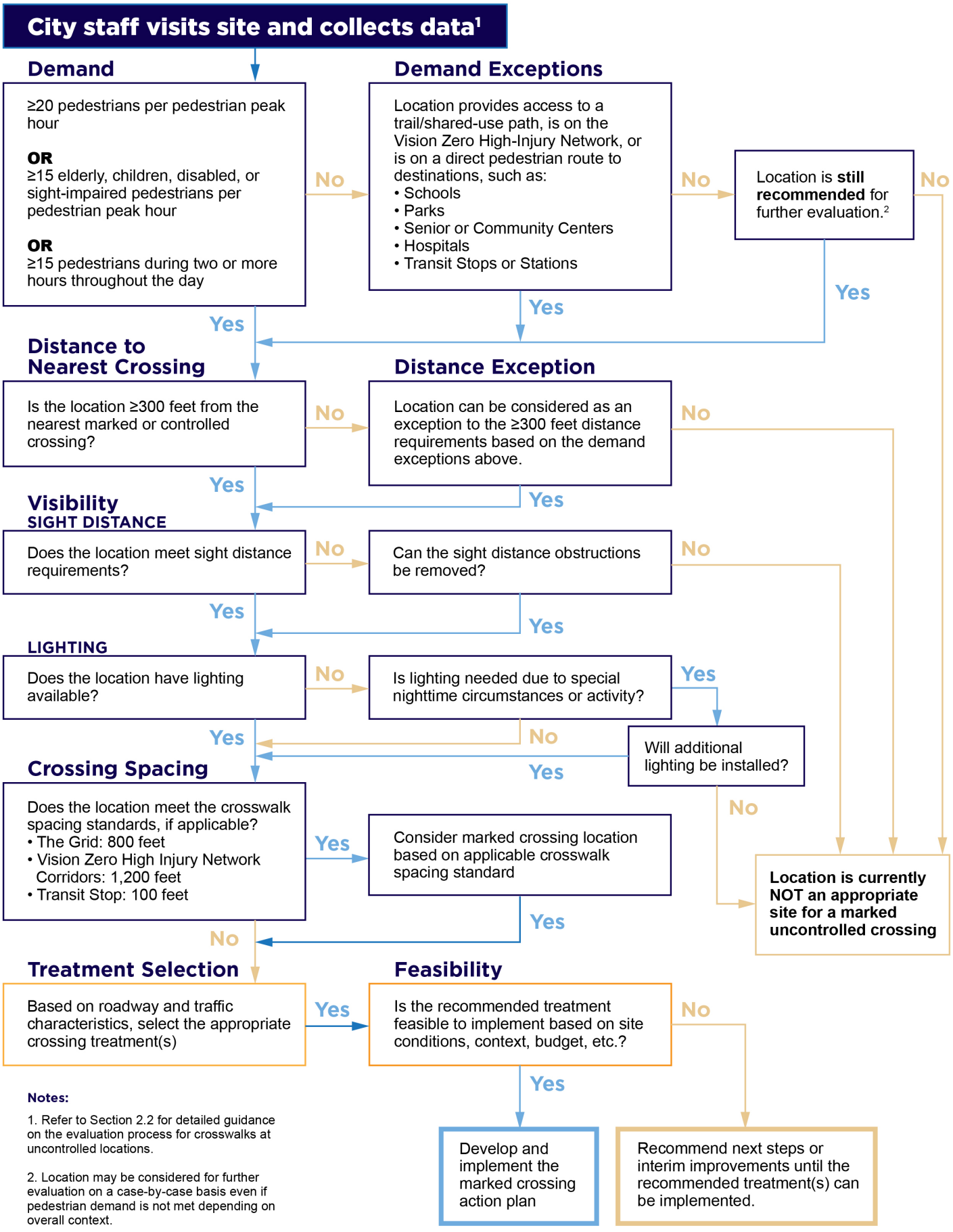
- Marked or enhanced crossings should be provided within 100 feet of all new transit stops if pedestrians can reasonably be expected to desire crossing the street at the transit stop.
- If a marked crossing cannot be installed within 100 feet of a new transit stop, the City should coordinate with the transit provider to identify an alternative crossing location to serve the transit stop, or coordinate to relocate the transit stop to a location where a marked or enhanced crossing can be provided.

ADDITIONAL GUIDANCE:

- For all other locations, no marked crosswalk spacing standard has been established.
- The City Traffic Engineer may consider an exception to the spacing guidance on a case-by-case basis based on engineering judgement, and other considerations at the potential crossing location.



FIGURE I Crossing Location Evaluation Overview Flowchart



Notes:

1. Refer to Section 2.2 for detailed guidance on the evaluation process for crosswalks at uncontrolled locations.

2. Location may be considered for further evaluation on a case-by-case basis even if pedestrian demand is not met depending on overall context.

Step 2: Data Collection

Once a location is determined to be appropriate for marking a crosswalk in Step 1, additional data should be obtained for roadway and traffic characteristics at the candidate location. In addition to collecting the data to determine the appropriateness of marking the crosswalk in Step 1, the following roadway characteristics should be documented for the candidate location:

ROADWAY CHARACTERISTICS

- existing pedestrian-related signs, markings, or other treatments/devices;
- posted speed or 85th percentile speed (when available);
- number of travel lanes for each approach;
- turn lane presence and type;
- medians or refuge islands;
- roadway width (curb to curb);
- sidewalk, bike lane, and/or trail presence;
- curb ramps and driveways;
- street lighting presence at the crossing location;
- drain inlets;
- on-street parking, alignment, and marked or signed restrictions; and,
- any other pertinent details

In addition to the roadway characteristics, pedestrian crossing and vehicle traffic behaviors should be observed and documented during the data collection. Behavioral observations should be recorded where pedestrian or vehicle activity is determined based on engineering judgement to have the potential to influence how pedestrians and vehicles may interact at the crossing locations. Potential behavioral characteristics that may be observed and recorded are summarized below.

BEHAVIORAL CHARACTERISTICS

- pedestrian crossing patterns near activity centers and pedestrian generators such as transit stops, schools, commercial districts, senior facilities, etc.;
- driver compliance at crosswalks and intersections; and,
- other pertinent pedestrian or driver actions based on observation.

Plans and historical data should also be reviewed to identify additional characteristics that may influence the decision to mark a crosswalk or include additional treatments. Additional data to consider include:

ADDITIONAL LOCATION CHARACTERISTICS:

- average daily traffic (ADT);
- transit boarding volumes from nearby stops;
- the most recent five years of available pedestrian-involved crash data within 250 feet of the location under evaluation;
- relevant traffic investigation history for the prior five years;
- surrounding existing and future land use;
- known programmed or planned improvements at the location; and
- other pertinent information, as available.

The recommended data collection form is provided in **FIGURE 2**.

FIGURE 2 Uncontrolled Crosswalk Data Collection Form

Uncontrolled Crosswalk Data Collection Form

Location: _____

Prepared By: _____

Date Review Initiated: _____

Data Collection Type:

☐ Request to mark new crosswalk

☐ Existing marked crosswalk

ROADWAY CONDITIONS INVENTORY

Posted or 85th Percentile Speed

☐ ≤ 30 mph ☐ 35 mph ☐ ≥ 40 mph

Total Vehicles per Day

Average Daily Traffic (ADT): _____

Approximate Vehicles per Hour (VPH)*: _____

☐ ADT < 9,000

☐ ADT 9,000–15,000

☐ ADT > 15,000

Travel Lane Configuration

☐ 2 lanes

☐ 2 lanes one-way

☐ 3 lanes without raised median

☐ 3 lanes with raised median

☐ 3 lanes one-way

☐ 4+ lanes without raised median

☐ 4+ lanes with raised median

Crossing Length (feet):) _____

Raised median width (if present): _____

Refuge island present: ☐ Yes ☐ No

If yes, width of refuge island: _____

**VPH should be estimated if a PHB may be considered at the site. VPH is used to determine consistency with the PHB guidance in CA MUTCD Section 4F.1. VPH may be estimated by dividing the ADT by 24.*

INITIAL LOCATION SCREENING

Demand

☐ Location provides access to a trail, is on the Vision Zero High Injury Network, or is on a direct pedestrian route to destinations like a school, park, senior center, hospital, or transit stop.

☐ Location is recommended for further evaluation, even though it does not meet demand requirements

Notes and/or Justification:

_____

_____

_____

Distance to Nearest Crossing

Name of nearest pedestrian crossing location on an approach controlled by a traffic signal, stop, or yield:

_____

Distance to crossing above: _____

☐ Location is recommended for further evaluation, even though it does not meet crossing distance requirements

Name of nearest location with appropriately treated uncontrolled marked crosswalk:

_____

Distance to marked crosswalk above:

_____

Notes and/or justification:

_____

_____

FIGURE 2 Uncontrolled Crosswalk Data Collection Form (Continued)

Visibility

SIGHT DISTANCE

Required stopping sight distance: _____

Stopping sight distance met (both approaches):

☐ Yes ☐ No

Location has adequate sight distance:

☐ Yes ☐ No

If no, can obstructions be removed:

☐ Yes ☐ No

If yes, note recommended measures:

_____

LIGHTING

Lighting is present at the crossing location:

☐ Yes ☐ No

If no, note recommended measures:

_____

_____

_____

Crosswalk Spacing

Location is subject to crosswalk spacing standards:

☐ Yes, Grid

☐ Yes, Vision Zero High Injury Network

☐ No

If yes, existing marked crossings locations:

_____

_____

Distance between marked crossing locations:

_____

PEDESTRIAN SAFETY ISSUES INVENTORY

Noted conflicts at crossing locations ☐ Yes ☐ No

☐ History of turning movement crashes

☐ Observed conflicts at permitted crossing

Vehicle speed ☐ Yes ☐ No

☐ History of speed-related crashes

Drivers not yielding to pedestrians in crosswalks ☐ Yes ☐ No

☐ Crash history in marked crosswalks

Separation between pedestrians and traffic: ☐ Yes ☐ No

☐ No buffer (e.g., landscape buffer, on-street parking, bike lanes)

Notes:

_____

FIGURE 2 Uncontrolled Crosswalk Data Collection Form (Continued)

Would a marked crosswalk be appropriate based on site conditions, the ability to channelize pedestrians, and the consolidation of multiple crossings?

☐ Yes ☐ No

If no, state reasons or contributing factors:

_____

_____

Recommend measures (if any) to make the location appropriate for marking the crosswalk:

_____

_____

Describe any known improvements programmed or planned at the location:

_____

_____

_____

Five-year crash history (attach crash diagram or incident summary):

☐ Pedestrian-related crashes: _____

☐ Total crashes: _____

Crash history notes:

_____

_____

Five-year relevant traffic investigation history notes:

_____

_____

ADDITIONAL DATA COLLECTION

Attach aerial(s) or sketches showing the following, as applicable:

☐ Study location

☐ Number of travel lanes/direction

☐ Median/pedestrian refuge island

☐ Pedestrian-related improvements

☐ Sidewalks + Bike Lanes

☐ Trail

☐ Parking

☐ Curb ramps/driveways

☐ Street lights

☐ Drain inlets

☐ Other pertinent details

Step 3: Treatment Selection

Step 3 focuses on determining whether a marked crosswalk alone is sufficient and, if not, what treatments are most appropriate. This determination is based on the candidate location's characteristics collected as part of Step 2, the recommended treatments by location type in **TABLE 2**, and engineering judgement.

TABLE 2 is adapted from the 2018 FHWA *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* which synthesizes the latest research and best practices for safety at uncontrolled pedestrian crossings. The table provides recommended treatments in a matrix by roadway configuration, posted speed, and traffic volumes. Given the conditions of each cell of the matrix, the treatments identified in the cell are classified into three levels of guidance:

- treatments that are candidates for the location type;
- treatments that should always be considered, but are not mandated or required (shown as a bolded number in a darkened box); and,
- crosswalk visibility enhancements that should always occur in conjunction with other identified treatments (shown as a bolded number in a darkened box with a black outline).

Once the candidate location context type and associated recommended treatments are identified, the selection of a treatment or package of treatments can proceed based on the specific site context and engineering judgement. Section 4 provides detailed guidance on appropriate treatments or enhancements based on the location type. The companion document City of Sacramento *Pedestrian Crossing Treatment Applications Guide* contains more detailed background information and guidance for crossing treatments.



TABLE 2 Application of Pedestrian Crossing Treatments by Location Type

Roadway Configuration	Posted Speed Limit and ADT																								
	Vehicle ADT <9,000									Vehicle ADT 9,000-15,000									Vehicle ADT >15,000						
	≤30 mph			35 mph			≥40mph			≤30 mph			35 mph			≥40mph			≤30 mph			35 mph			≥40mph		
2 lanes	**1**	2		**1**		3	**1**		3	**1**			1		3	**1**		3	**1**			**1**		3	**1**		3
	4	5	6		5	6		5	6	4	5	6		5	6		5	6	4	5	6		5	6		5	6
				7		9	**7**		**9**				7		9	**7**		**9**	7		9	7		9			**9**
2 lanes one-way	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
		5			**5**			**5**			**5**			**5**			**5**			**5**			**5**			**5**	
	7		9	7		9	7		**9**	7		9	**7**		**9**	**7**		**9**	**7**		9	7		**9**			**9**
3 lanes with raised median	**1**	2	3	**1**		**3**	**1**		**3**	**1**		3	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
	4	5			5			5		4	5			5			5		4	5			5			5	
				7		9	**7**		**9**	7		9	**7**		**9**	**7**		**9**	7		9	**7**		**9**			**9**
3 lanes without raised median	**1**	2	3	**1**		**3**	**1**		**3**	**1**		3	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
	4	5	6		5	6		5	6	4	**5**	6		5	6		5	6	4	5	6		5	6		5	6
	7		9	7		9	7		**9**	7		9	**7**		**9**	7		**9**	7		9			**9**			**9**
3 lanes one-way	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
		5			**5**			**5**			**5**			**5**			**5**			5			**5**			**5**	
	7	8	9	7	8	9	7	8	**9**	7	8	9	**7**	8	**9**	7	8	**9**	**7**	8	**9**		8	**9**		8	**9**
4+ lanes with raised median	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
		5			**5**			**5**			**5**			**5**			**5**			**5**			**5**			**5**	
	7	8	9	7	8	**9**	7	8	**9**		8	9	**7**	8	**9**		8	**9**	**7**	8	**9**		8	**9**		8	**9**
4+ lanes without raised median	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
		5	6		5	**6**		5	**6**		5	**6**		5	**6**		5	**6**		5	**6**		5	**6**		5	**6**
	7	8	9	7	8	9		8	**9**		8	9	**7**	8	**9**		8	**9**	**7**	8	**9**		8	**9**		8	**9**

Treatments:

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)**

Selection Guidance:

#: treatments that are candidates for the location type

#: treatments shown as a bold number within a darkened box should always be considered, but are not mandated or required.

: treatments shown as a bolded number in a darkened box with a black outline are crosswalk visibility enhancements that should always occur in conjunction with other identified treatments.

** Note: The PHB and RRFB are not installed at the same crossing location

Source: Adapted from FHWA Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations (July 2018)

2.3 Crosswalks at Controlled Crossing Locations

Controlled pedestrian crossing locations are intersection approaches as well as midblock crossing sites that are controlled by a traffic signal, stop, or yield control.

GUIDANCE:

- At locations controlled by traffic control signals or on approaches controlled by STOP or YIELD signs, crosswalk lines should be installed where engineering judgement indicates they are needed to direct pedestrians to the proper crossing path(s).
- At controlled approaches, limit lines (stop lines) help to define pedestrian paths and are therefore a factor the engineer may consider in deciding whether or not to mark the crosswalk.
- See CA MUTCD Section 3B.18 for more information.
- High-visibility crosswalk markings may be considered at controlled crossing locations on the Vision Zero High-Injury Network. Additional locations may be considered on a case-by-case basis by the City Traffic Engineer based on engineering judgement.

Section 4.4 of this document provides treatment guidance on crosswalks at signalized, stop, and/or yield controlled approaches.

2.4 Crossings at Mid-Block Locations

As defined above and because excluded from the definition of "crosswalk" in Section 275 of the CVC mid-block locations cannot have an unmarked crosswalk. In order to establish a crosswalk at a mid-block location, it must be marked.

GUIDANCE:

Mid-block crosswalks may not be expected by motorists. As a result, additional measures such as signage, curb extensions, and parking restrictions are recommended to improve visibility for both pedestrians and motorists. Particular attention should be given to roadways with two or more traffic lanes in one direction as a pedestrian may be hidden from view by a vehicle yielding the right-of-way to a pedestrian.

Mid-block crosswalks should only be considered if the following conditions apply:

- There is a demonstrated need for marking the mid-block crossing based on demand and/or the need for channelizing crossing pedestrians.
- The location is serving a trail or pedestrian trip generator (schools, parks, senior centers, hospitals, commercial areas, etc.) on both sides of the street between controlled intersections.

Treatment requirements and recommendations for mid-block crossings can be found in **Section 4.2**.



2.5 Crosswalks at Trail Crossings

At locations where a trail or a shared-use path crosses a street, the appropriate guidance for controlled intersection crossings, uncontrolled intersection crossings, and mid-block locations should be used to determine whether or not to mark a crosswalk, and to select the appropriate crossing treatments. Ramp receiving areas should be considered at all evaluation locations to determine the most appropriate crossing location. The City Traffic Engineer may consider, on a case-by-case basis, exceptions in regard to the following while determining whether to mark the trail/shared-use path crossing at uncontrolled locations:

- Crossing demand
- Distance to the nearest crosswalk



2.6 Prohibiting Pedestrian Crossings

Legal crosswalks exist at most roadway intersections, even if they are not marked. An unmarked crosswalk is a legal crossing unless local authorities place signs indicating otherwise. The CVC allows local authorities to prohibit pedestrian crossing with signage. Guidance based on the CVC and best practice is provided below.

GUIDANCE:

Signs may be installed at or adjacent to an intersection directing that pedestrians shall not cross in a marked or unmarked crosswalk at the intersection. It is unlawful for any pedestrian to cross at the crosswalk prohibited by a sign. Closures of existing crosswalks should be avoided, and existing closed crosswalks should be evaluated for opening in combination with any necessary safety measures such as signal timing or signage changes. Where required, only one leg of an intersection should be closed. The impact on pedestrian convenience and accessibility should be considered in these decisions.

The City Traffic Engineer may restrict certain pedestrian movements at any intersection. The following are examples where pedestrian crossing prohibition may be considered:

- Heavy right- or left-turn volumes cross the path of the pedestrian crossing and protected signal phasing to separate the movements is infeasible due to cost, lack of infrastructure, or other safety considerations.
- Physical environment or geometric conditions provide inadequate visibility.

3.0 EXISTING UNCONTROLLED MARKED CROSSWALKS

This chapter addresses the following aspects of existing uncontrolled marked crosswalk locations:

- When should City staff evaluate existing uncontrolled marked crosswalks?
- How to evaluate, and enhance or upgrade existing marked crosswalks where there is an opportunity to align the location with the most current guidelines?
- What if the enhancement/upgrade of an existing marked crosswalk is not feasible?
- Removal of existing marked crosswalk(s).



3.1 When Should The City Evaluate Existing Crosswalks?

These guidelines recognize that some existing marked crosswalks and associated inventories of traffic control devices may not comply with the guidelines, and/or applicable standards. The City of Sacramento is 170 years old and has developed a street network based on engineering standards that have evolved over time. The City has also inherited many streets and street designs developed by agencies other than the City of Sacramento.

Unless mandated by the pertinent regulatory/governing documents, such non-conforming pedestrian crossing facilities may remain in service through the end of their useful service life and/or until the inventories are depleted (See CA MUTCD, Introduction and Caltrans HDM, Chapter 80, Topic 82 for more information). As such, these guidelines do not suggest that the existing non-conforming pedestrian crossing facilities become obsolete upon adoption of these or any future updates/revisions to the guidelines, policies, procedures, and practices.

GUIDANCE:

As part of a proactive safety management process, it is recommended to consider evaluating and enhancing, when feasible, existing marked uncontrolled crosswalks and associated traffic control devices under one or more of the following conditions:

- As part of a project involving change in land use (e.g., school closure, development project, etc.).
- As part of a project involving a change in roadway characteristics (e.g., roadway widening, lane reduction, etc.).
- As part of a roadway resurfacing project.
- Based on pedestrian safety related concerns identified during the course of any traffic investigation.

3.2 Evaluation And Enhancement Approach

The approach for evaluation of an existing uncontrolled marked crosswalk, and enhancement of the same is suggested below.

GUIDANCE:

1. The existing crosswalk location should be documented and added to the City's crosswalk inventory database. At a minimum, the crosswalk documentation will include:
   - Marked crosswalk location
   - Site characteristics per the guidelines data collection form
   - Five-year pedestrian-crossing related crash history for the site
   - Potential for enhancement consistent with the guidance
2. Using the guidance presented in **Section 2** (page 3), determine the applicable roadway context classification of the crossing site and the recommended treatments for consideration.
3. Determine the appropriate additional treatment(s), if any, for the site using the treatment guidance in **Section 4** (page 23).
4. Compare the existing crosswalk and associated treatments with the recommended treatments. Determine if additional treatments are preferred for the crosswalk based on the guidelines.
5. If the evaluation of an existing uncontrolled marked crosswalk indicates that there is an opportunity for enhancements at the subject crosswalk based on the guidelines, take necessary measures, if feasible, to install the remaining components to enhance the crosswalk consistent with the guidelines.
6. The marked crosswalk characteristics and the enhancements made as part of the improvement should be added to the crosswalk inventory database to maintain a citywide inventory of known existing crosswalks. This update to the database entry should include the treatments, signage, or devices installed, the date of the most recent improvement(s), the reason for the improvement, and any additional relevant observations or data from the crosswalk site.

3.3 What If Enhancement Of An Existing Crosswalk Is Not Feasible?

These guidelines recognize that it may not be feasible to enhance every existing uncontrolled marked crosswalk based on these guidelines due to the financial constraints of public funds, extensive treatment requirements, the need for right-of-way acquisition, or other considerations.

GENERAL GUIDANCE

The CA MUTCD Section 3B.18 provides the following guidance in regard to new marked crosswalks at uncontrolled locations:

New marked crosswalks alone, without other measures designed to reduce traffic speeds, shorten crossing distances, enhance driver awareness of the crossing, and/or provide active warning of pedestrian presence, should not be installed across uncontrolled roadways where the speed limit exceeds 40 mph and either:

A. The roadway has four or more lanes of travel without a raised median or pedestrian refuge island and an ADT of 12,000 vehicles per day or greater; or

B. The roadway has four or more lanes of travel with a raised median or pedestrian refuge island and an ADT of 15,000 vehicles per day or greater.

In addition, Caltrans' Directive on Crosswalk Enhancements Policy (30) provides the following directions for minimum safety enhancements to existing marked crosswalks that cross uncontrolled roadways on the State Highway System with roadway characteristics that are similar to those addressed above:

Stage 1: Minimum Enhancements:

If a marked crosswalk exists across an uncontrolled intersection or mid-block location on the State Highway System where the speed limit exceeds 40 mph and the roadway has four or more lanes of travel and an ADT of 12,000 vehicles per day or greater, advanced yield lines with associated Yield Here to Pedestrian (R1-5, R1-5a) signs should be placed 20 to 50 feet in advance of the crosswalk, pedestrian crossing (W11-2) warning signs with diagonal downward pointing arrow (W16-7p) plaques should be installed at the crosswalk, and a high visibility crosswalk marking pattern should be used.

Stage 2: Additional Enhancements:

Other enhancements may be considered in conjunction with the minimum enhancements, based on engineering judgement or an engineering study (taking into account roadway characteristics, collision history, and pedestrian volumes) such as curb extensions, raised medians or pedestrian refuge islands, lighting, additional signing and marking, pedestrian actuated flashing beacons, pedestrian hybrid beacons or signalized control.

See the above referenced Policy Directive for further information.

Guidance for Enhancing Existing Uncontrolled Marked Crosswalks

This section documents the recommended approach to enhancing existing uncontrolled marked crosswalks where it may not be feasible to improve them to be consistent with the recommendations of these guidelines. These recommendations expand on the general guidance from the CA MUTCD and Caltrans' Directive on Crosswalks Enhancement Policy. Use of engineering judgement, as appropriate, is emphasized as an integral part of the entire process.

The recommended approach depends on roadway and traffic characteristics at the marked crosswalk site. The guidance has been separated into two different location types:

- Location Type 1 – Multi-Lane Roadways with Speed Limits ≥ 40 mph and ADT ≥ 12,000; and,
- Location Type 2 – All Other Crossing Locations

The two location types are based off the Caltrans' Directive on Crosswalk Enhancements Policy definition of when a marked crosswalk requires minimum enhancements on the State Highway System. Locations meeting the Caltrans Policy Directive criteria, Location Type 1, are not recommended to remain marked without interim improvements. Location Type 2 marked crosswalk locations may remain marked until enhancements can be provided on a case-by-case basis determined by the City Traffic Engineer.

GUIDANCE

Location Type 1 – Multi-Lane Roadways with Speed Limits ≥40 mph and ADT ≥ 12,000:

For roadways where pedestrians must cross three lanes or more in one direction, or four or more lanes in both directions, **and** the posted speed limit is at or above 40 mph and volumes are greater than or equal to 12,000 ADT, the following approach should be taken:

1. Review pedestrian crossing volumes, transit stop locations, surrounding land uses, and reported pedestrian crash history at or near the crossing within the last five years.
2. Evaluate the feasibility of providing interim improvements based on the data collected above and roadway configuration, vehicle volumes, vehicle speeds, and visibility.
3. If interim improvements are feasible at the site, implement appropriate interim improvements to reduce the risk of pedestrian involved crashes until such time when the recommended pedestrian crossing enhancements are in place.
4. If, based on the location, interim improvements are deemed insufficient to reduce the risk of pedestrian-involved crashes, and recommended improvements are not feasible due to cost or constructability, remove the crosswalk per the crosswalk removal guidance in the following subsection.
5. It is recommended to prohibit the crossing by removing traffic control devices associated with the crossing and implementing measures to prevent pedestrian crossings. Crosswalk prohibition should only be implemented as a last resort when interim enhancements are infeasible at the site or there are overriding safety considerations arising from the site conditions. Enhancements may be determined to be infeasible due to a number of considerations, such as cost, lack of infrastructure, or right of way limitations.
6. The evaluations and recommendations should be based on an engineering study before presenting for approval to the City Traffic Engineer. The City Traffic Engineer may consider an exception to this guidance on a case-by-case basis.

Location Type 2 – All Other Crossing Locations:

For other crossing locations, the following approach should be taken:

1. Review pedestrian crossing volumes, transit stop locations, surrounding land uses, and reported pedestrian crash history at or near the crossing within the last five years.
2. Evaluate the roadway configuration, vehicle volumes, vehicle speeds, and visibility for safety concerns related to the crossing location.
3. If there have been no pedestrian crashes at or near the crossing (within 250 feet) in the last five years and there are no visibility or other safety concerns determine if appropriate interim improvements can provide reduced crash risk to the pedestrians until such time when all the recommended pedestrian crossing enhancements are in place. Interim improvements should provide as enhanced a crossing experience as possible for pedestrians within the available resources.
4. The evaluations and recommendations should be based on an engineering study before presenting for approval to the City Traffic Engineer. The City Traffic Engineer may consider an exception to this guidance on a case-by-case basis.

Documentation

Evaluations and recommendations for the interim enhancement or, as a last resort, removal of an existing uncontrolled marked crosswalk should be documented to provide the justification for the crosswalk interim enhancements or removal. The documentation should include:

- existing roadway configuration, vehicle volumes, vehicle speeds, and visibility;
- pedestrian crossing volumes, transit stop locations, surrounding land uses, and reported pedestrian crash history at or near the crossing within the last five years;
- treatments recommended based on these guidelines;
- justification of interim improvements or crosswalk removal; and,
- potential funding sources and estimated timeline to improve the site.

3.4 Uncontrolled Marked Crosswalk Removal

Although, it may be necessary to remove an uncontrolled marked crosswalk due to the risk of crashes involving pedestrians at the location, it is important to note that such a removal does not prevent pedestrians from crossing the street at an intersection unless the crosswalk is prohibited. If there is a desire or need for pedestrians to cross at that location, based on the adjacent land uses, pedestrians may continue to cross at the location.

If a determination is made to remove an existing uncontrolled marked crosswalk, the removal of the crosswalk shall be accomplished in a manner consistent with the CA MUTCD and CVC Section 21950.5. The recommended approach for uncontrolled marked crosswalk removal is provided below.

GUIDANCE:

Marked crosswalk removal should be an exceptional case and crosswalk markings can be recommended for removal while leaving an unmarked crosswalk legally available when:

- an engineering evaluation determines that other measures have not been effective;
- there are overriding safety considerations arising from the site conditions; or,
- interim improvements are not feasible, and the recommended improvements are not feasible to implement in a reasonable timeline.

If it is determined to be necessary to remove an uncontrolled marked crosswalk for safety reasons, the removal should be consistent with CA MUTCD and CVC noticing requirements and City of Sacramento Crosswalk Removal Outreach Policy (see **Appendix B**). Consistent with CVC 21950.5 notification will be posted at the crosswalk identified for removal for not less than 30 days from the scheduled date of removal. Notices will also be posted at transit stops within 500-feet of the proposed crosswalk removal.

Marked crosswalk removal may be accomplished by repaving or surface treatment per the City of Sacramento Standard Specifications. A marked crosswalk should not be eliminated by allowing it to fade out or be worn away. Surface treatment for crosswalk removal should not give the appearance of a faded or worn away marked crosswalk to avoid the appearance of a marked crossing to a pedestrian at the curb. The City Traffic Engineer should confirm with Signs and Markings staff after crosswalk removal to determine the need for repaving or resurfacing based on whether the grinding of the removed crosswalk markings give the appearance of a faded or worn crosswalk. If this condition is not met, the crosswalk location should be resurfaced or repaved.

If a marked crosswalk is removed and prohibited, the crosswalk prohibition shall include signs installed at the location directing that pedestrians shall not cross consistent with CA MUTCD Section 3B.18 and CVC 21106(b). The City Traffic Engineer may approve additional treatments to reinforce the crosswalk prohibition such as barricades or pedestrian fencing on a case-by-case basis, as needed.

3.5 Prioritizing Enhancements for Existing Uncontrolled Marked Crosswalks

Given the potentially large number of existing marked crosswalks that may need enhancement treatments based on these guidelines and limits to available funding for enhancements, a prioritization methodology has been developed to allow the City to address enhancements to existing marked crosswalks. This approach creates a systematic process for identifying and prioritizing those locations for enhancements based on the locations that are most likely beneficial to people walking.

The recommended prioritization process considers site characteristics, crash history, the surrounding land use context of the site, and equity considerations to prioritize existing marked crosswalk locations for enhancements. The recommended prioritization process is described in the guidance below.

GUIDANCE

1. Begin the prioritization process by obtaining the latest version of the potential enhancement crosswalk inventory as described in **Section 3.2**.
2. Use the following scoring criteria to score each crosswalk where enhancements are being considered:
   - **Crash History:** If the site has a pedestrian crossing-related fatal or serious injury crash within the past five years, the site receives 3 points. If the site has a history of non-fatal or serious injury pedestrian crossing-related crashes, the location receives 2 points. If pedestrian crossing-related safety issues are observed at the site, but there is no pedestrian crossing-related crash history, the location receives 1 point.
   - **Demand:** If the site has pedestrian crossings volumes of at least 20 pedestrians per hour, or directly serves a pedestrian generator (as defined in **Section 2.2** above) the location receives 2 points. If the site indirectly serves a pedestrian generator, the location receives 1 point.
   - **Transit Stop:** If the site directly serves a transit stop or station, the location receives 2 points. If the location does not directly serve a transit stop or station but is within 500 feet of a transit stop or station, the location receives 1 point.
   - **Vision Zero High Injury Network:** If the site is on the Vision Zero High Injury Network as designated by the City, the location receives 1 point.
   - **School Zone:** If the site is within a school zone, the location receives 1 point.
   - **Equity:** If the site is within a disadvantaged community (as defined per Senate Bill 535 as within a Census Tract that is in the top 25% of CalEnviroScreen scores), the location receives 1 point.
3. Rank the crosswalk locations by score from highest to lowest.
4. Use the top 20% of the sites as the pool of locations for consideration, develop a short-list of projects for planning level evaluation based on available funding, geographic balance, implementation feasibility, upcoming resurfacing, repaving, or other maintenance activities, and engineering judgement.
5. Develop planning level cost estimates for the recommended improvements and interim improvements at each location for the selected sites.
6. Implement recommended or interim improvements in order of priority. Where recommended improvements are not able to be funded, implement interim improvements.
7. For sites where recommended or interim improvements are not able to be funded given current funding, identify potential funding sources.
8. If a site with an opportunity for enhancement consistent with the guidelines remains unfunded, the City Traffic Engineer may consider removing the marked crosswalk based on engineering judgement.
9. After a site has been enhanced consistent with the guidelines, remove the site from the potential enhancement crosswalk inventory database. Locations with interim improvements should remain in the database until no additional enhancements are recommended by the guidelines.

4.0 PEDESTRIAN CROSSING TREATMENT GUIDANCE

This chapter provides engineering guidance on designing marked pedestrian crossing facilities for uncontrolled and controlled crossing locations.

4.1 Treatments for Marked Crosswalks at Uncontrolled Locations

The design of marked pedestrian crossing facilities at uncontrolled locations in the City of Sacramento entails two major components:

- The 'basic' treatment as outlined in the subsection below; and
- pedestrian crossing facility enhancement(s) treatments to reduce the risk of pedestrian involved crashes and/or enhance the ability of pedestrians to cross the street.

BASIC TREATMENT FOR MARKED CROSSWALKS AT UNCONTROLLED LOCATIONS

The 'basic' treatment as outlined below, and as depicted in **FIGURE 3** is to be provided at marked crosswalks at uncontrolled locations. The City Traffic Engineer may consider variations/exceptions on a case-by-case basis. Exercising engineering judgement is important in such cases, as it is impractical to address every possible scenario of site conditions at different crossing locations.

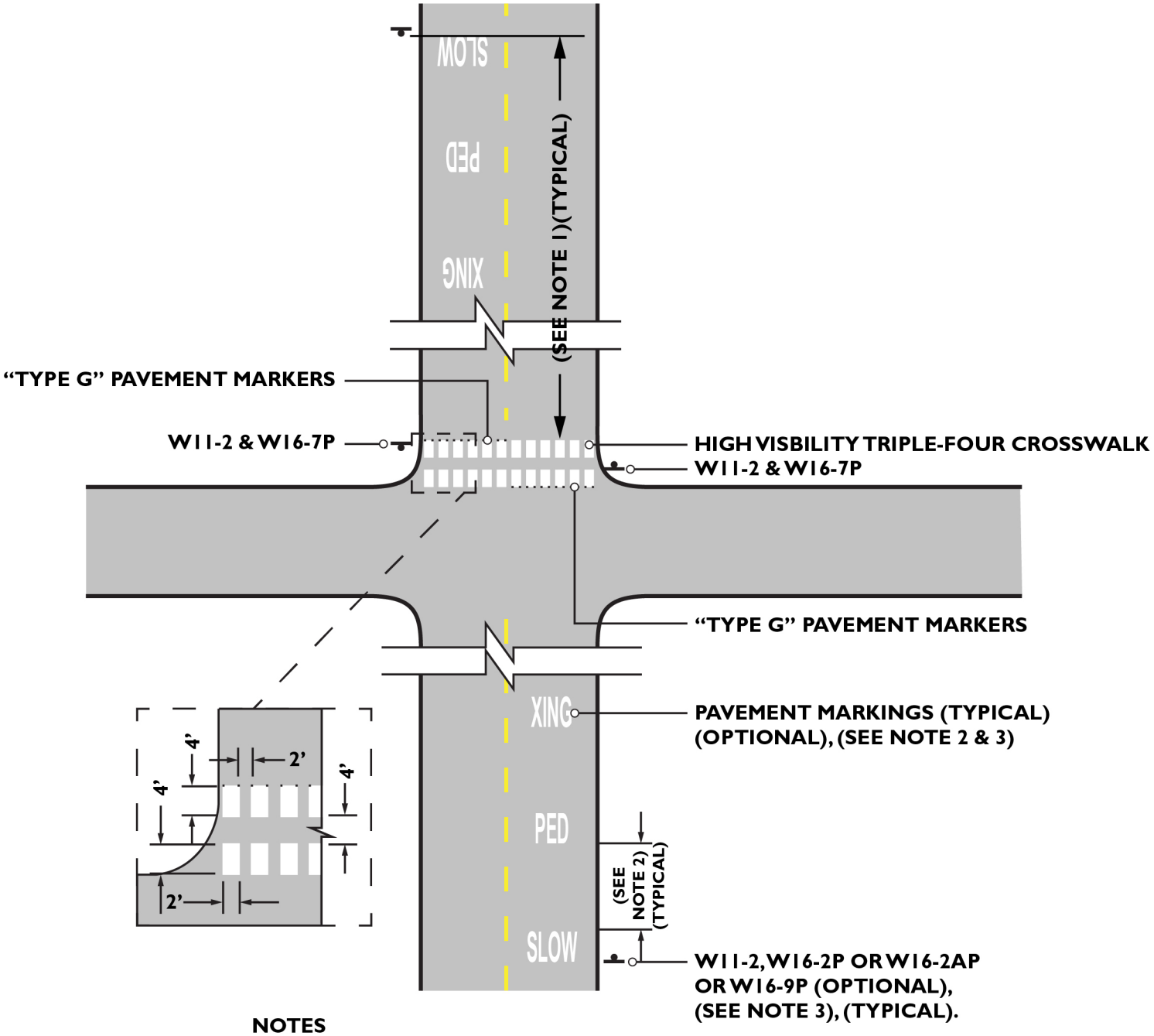


GUIDANCE

The 'basic' treatment for marked crosswalks at uncontrolled locations consists of:

- City's standard high visibility triple four crosswalk markings; and
- Warning signs W11-2 at the crossing location(s). If a W11-2 sign at the location of the crossing point is post-mounted, a diagonal downward pointing arrow (W16-7P) plaque shall be mounted below the W11-2 sign. If the W11-2 sign is mounted overhead, the (W16-7P) plaque shall not be used. Refer to CA MUTCD Section 2C.50 for further information.
- If the crosswalk location is across a roadway where the speed limit exceeds 40 mph and the roadway has four or more lanes of travel and an ADT of 12,000 vehicles per day or greater, advanced yield lines with associated Yield Here to Pedestrians (R1-5, R1-5a) signs should be placed 20 to 50 feet in advance of the crosswalk and adequate visibility should be provided by parking prohibitions. For parking restrictions, parking should be restricted to one stall or within the distance required to provide adequate stopping sight distance for approaching vehicles to stop for a pedestrian intending to cross, as well as one parking stall on the departure side.
- For all other locations, warning signs (W11-2) may be provided in advance of an uncontrolled marked crosswalks if an engineering judgement indicates that either there is a need for alerting road users in advance of where unexpected entries of pedestrian into the roadway might occur, **OR** where visibility of the crossing treatments or pedestrians is obstructed. Obstructions may include near side transit stops, trees, visual clutter, roadway geometry that limits sight distance, a large volume of heavy vehicles, etc.
- If the warning sign (W11-2) is used in advance of a pedestrian crossing (see above), it should be supplemented with plaques with the legend "AHEAD" or "XX FEET".
- "SLOW PED XING" pavement word markings should be provided in conjunction with W11-2 warning signs if the W11-2 signs are provided in advance of the uncontrolled marked crosswalk to supplement the signs and provide additional emphasis for the warning messages. For trail crossings, "SLOW TRAIL XING" pavement markings should be used instead of "SLOW PED XING".
- For streets with multiple uncontrolled marked crossings in series, excessive use of the signs and pavement markings should be avoided in order to ensure the effectiveness as well as the conservative use of these traffic control devices. Depending on site conditions, select appropriate locations to consolidate/minimize the locations of advanced warning signs (W11-2) and associated "SLOW PED XING" pavement word markings.

FIGURE 3 Uncontrolled Marked Crosswalk 'Basic' Treatment



NOTES

1. SELECT THE ADVANCE PLACEMENT DISTANCE BASED ON DESIGN SPEEDS.
2. REFER TO 2014 CA MUTCD (OR LATEST EDITION), SECTION 3B.20 FOR LETTER SIZE AND LONGITUDINAL SPACE BETWEEN PAVEMENT MARKINGS.
3. FOR WARNING SIGNS (W11-2) AND "SLOW PED XING' PAVEMENT MARKINGS IN ADVANCE OF UNCONTROLLED MARKED CROSSINGS, REFER TO SECTION 4.2 FOR GUIDANCE ON:
   (A) APPLICABILITY; AND
   (B) CONSOLIDATION OF LOCATIONS OF THESE SIGNS AND PAVEMENT MARKINGS FOR STREETS WITH MULTIPLE UNCONTROLLED MARKED CROSSINGS IN SERIES.



W11-2



W16-2AP



W16-7P



W16-9P

Source: City of Sacramento, 2014.

Enhancement Treatments for Marked Crosswalks at Uncontrolled Locations

Marked crosswalks at uncontrolled locations may need to be enhanced with appropriate treatments (depending on the roadway and traffic characteristics of the crossing location) to reduce the risk of crashes involving pedestrians and/or enhance the ability of pedestrians to cross the street. To achieve those two outcomes, pedestrian crossings often use several traffic control devices or design elements to meet the information and control needs of both motorists and pedestrians. The following characteristics are desirable for a pedestrian crossing:

- The street crossing task is simple and convenient for pedestrians.
- Waiting or crossing pedestrians are visible to motorists and pedestrians can see approaching vehicles.
- Vehicle speeds are slowed or controlled in the area of the pedestrian crossing.
- Vehicle drivers are aware of the presence of the crosswalk.
- Vehicle drivers yield the right-of-way to pedestrians.
- Pedestrians use designated crossing locations and obey applicable state and local traffic laws.

In a complex (e.g., multi-lane, high-speed, high-volume) street environment, it can be difficult to provide these characteristics with a single treatment, and these environments may require several treatments intended to serve different purposes. Streets with lower speeds or traffic volumes may not require multiple treatments to achieve the desirable characteristics above.

The guidance in this section for selecting enhancement treatments for marked crosswalks at uncontrolled locations is based on the 2018 *FHWA Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations*. The FHWA document provides guidance on specific aspects such as the effectiveness and/or applicability of various treatments under different combinations of roadway and traffic conditions based on the latest research and best practices of 2021. The City of Sacramento guidance uses the FHWA guide as its basis, while tailoring the guidance to fit the unique context of the City.

GUIDANCE:

These guidelines are intended to provide a balance between engineering judgement and prescriptiveness. Although the recommendations presented in this section provide guidance in selecting appropriate pedestrian crossing treatments, engineering judgement should be exercised in selecting a specific treatment(s) for installation.

PRIMARY ENHANCEMENTS

Nine primary treatments are recommended for pedestrian crossing enhancements based on FHWA's 2018 guidance for marked uncontrolled crossing locations. The primary enhancements include:

1. High-visibility crosswalk markings with parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2. Raised crosswalks
3. Advance Yield Here to Pedestrians signs and yield lines
4. In-street Pedestrian Crossing signs
5. Curb extensions
6. Pedestrian refuge islands
7. Rectangular Rapid-Flashing Beacons (RRFBs)
8. Road diets
9. Pedestrian Hybrid Beacons (PHBs)

Recommended primary enhancement treatments by roadway configuration, posted speed, and average daily traffic are presented in **TABLE 3.** (see page 28). The recommended treatments are determined by the roadway and traffic characteristics of the crossing site.

The primary treatment recommendations are provided in three categories for each matrix cell:

- Treatments that are **candidates** for the location type;
- Treatments that should **always be considered**, but are not mandated or required (shown as a **bolded number in a darkened box**);
- Crosswalk visibility enhancements that should always occur in conjunction with other identified treatments (shown as a **bolded number in a darkened box with a black outline**)

Where a treatment is not represented in a matrix cell, it is not recommended for use at sites meeting those conditions.

Not all of the treatments listed in a matrix cell should necessarily be installed at the crossing. The observations and results from the location screening and data collection phases should be used to help determine which treatments seem most likely to be effective at reducing risk of crashes involving pedestrians.

Additionally, the surrounding land use context, pedestrian volumes and activity patterns, and treatment effectiveness and cost should be considered when selecting the treatment most suitable for the crossing.

For multi-lane roadway crossings where vehicle ADT exceeds 10,000, FHWA guidance has established that **a marked crosswalk alone is typically not sufficient**[1]. When these conditions are met, more substantial crossing treatments should be used to prevent an increase in pedestrian crash potential. Treatments such as a pedestrian refuge island, RRFB, or PHB may be considered. Refer to the **TABLE 3** matrix for when a marked crosswalk (Treatment #1) should be paired with one or more of the other treatments (shown in **bold with a darker background**). Additionally, substantial crossing treatments such as traffic signals or pedestrian signals should also be considered at these locations when warranted and could help reduce the risk of crashes involving pedestrians.

To improve the visibility of the marked crossing and pedestrians, multiple treatments may be combined. Roadway geometry and CA MUTCD requirements should be considered when considering installing multiple treatments.

The companion Pedestrian Crossing Treatments Application Guide provides more information on the primary treatments.

SUPPLEMENTAL TREATMENTS

Supplemental treatments may be potentially useful as supplements or add-ons to the City's basic treatment and/or primary treatments. The companion document City of Sacramento Pedestrian Crossing Treatment Applications Guide provides guidance on the primary and supplemental treatments including pertinent requirements.

NEW TREATMENTS

The treatments recommended in these guidelines reflect the more common treatments being used and may not include every treatment available. Furthermore, the City of Sacramento's practice is to use only those traffic control devices that are approved for use in California. Accordingly, only those treatments and devices that are either included in the CA MUTCD or approved for their use by the CTCDC at the time of development of these guidelines are included as the recommended treatments. With advancements in technology, new treatments and devices may become available in the future. The City Traffic Engineer may approve the use of such treatments and devices if they meet the requirement above consistent with the powers and duties defined in the Sacramento City Code, Section 10.80.040.

1 FHWA Guide to Improving Pedestrian Safety at Uncontrolled Locations, 2018.

TABLE 3 Application of Pedestrian Crossing Treatments by Location Type

Roadway Configuration	Posted Speed Limit and ADT																								
	Vehicle ADT <9,000									Vehicle ADT 9,000-15,000									Vehicle ADT >15,000						
	≤30 mph			35 mph			≥40mph			≤30 mph			35 mph			≥40mph			≤30 mph			35 mph			≥40mph		
2 lanes	**1**	2		**1**		3	**1**		3	**1**			1		3	**1**		3	**1**			**1**		3	**1**		3
	4	5	6		5	6		5	6	4	5	6		5	6		5	6	4	5	6		5	6		5	6
				7		9	**7**		**9**				7		9	**7**		**9**	7		9	7		9			**9**
2 lanes one-way	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
		5			**5**			**5**			**5**			**5**			**5**			**5**			**5**			**5**	
	7		9	7		9	7		**9**	7		9	**7**		**9**	**7**		**9**	**7**		9	7		**9**			**9**
3 lanes with raised median	**1**	2	3	**1**		**3**	**1**		**3**	**1**		3	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
	4	5			5			5		4	5			5			5		4	5			5			5	
				7		9	**7**		**9**	7		9	**7**		**9**	**7**		**9**	7		9	**7**		**9**			**9**
3 lanes without raised median	**1**	2	3	**1**		**3**	**1**		**3**	**1**		3	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
	4	5	6		5	6		5	6	4	**5**	6		5	6		5	6	4	5	6		5	6		5	6
	7		9	7		9	7		**9**	7		9	**7**		**9**	7		**9**	7		9			**9**			**9**
3 lanes one-way	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
		5			**5**			**5**			**5**			**5**			**5**			5			**5**			**5**	
	7	8	9	7	8	9	7	8	**9**	7	8	9	**7**	8	**9**	7	8	**9**	**7**	8	**9**		8	**9**		8	**9**
4+ lanes with raised median	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
		5			**5**			**5**			**5**			**5**			**5**			**5**			**5**			**5**	
	7	8	9	7	8	**9**	7	8	**9**		8	9	**7**	8	**9**		8	**9**	**7**	8	**9**		8	**9**		8	**9**
4+ lanes without raised median	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**	**1**		**3**
		5	6		5	**6**		5	**6**		5	**6**		5	**6**		5	**6**		5	**6**		5	**6**		5	**6**
	7	8	9	7	8	9		8	**9**		8	9	**7**	8	**9**		8	**9**	**7**	8	**9**		8	**9**		8	**9**

Treatments:

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)**

Selection Guidance:

#: treatments that are candidates for the location type

#: treatments shown as a bold number within a darkened box should always be considered, but are not mandated or required.

: treatments shown as a bolded number in a darkened box with a black outline are crosswalk visibility enhancements that should always occur in conjunction with other identified treatments.

** Note: The PHB and RRFB are not installed at the same crossing location

Source: Adapted from FHWA Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations (July 2018)

4.2 Crosswalks at Mid-Block

Guidance for the design of marked pedestrian crossing facilities at uncontrolled mid-block locations is provided below.

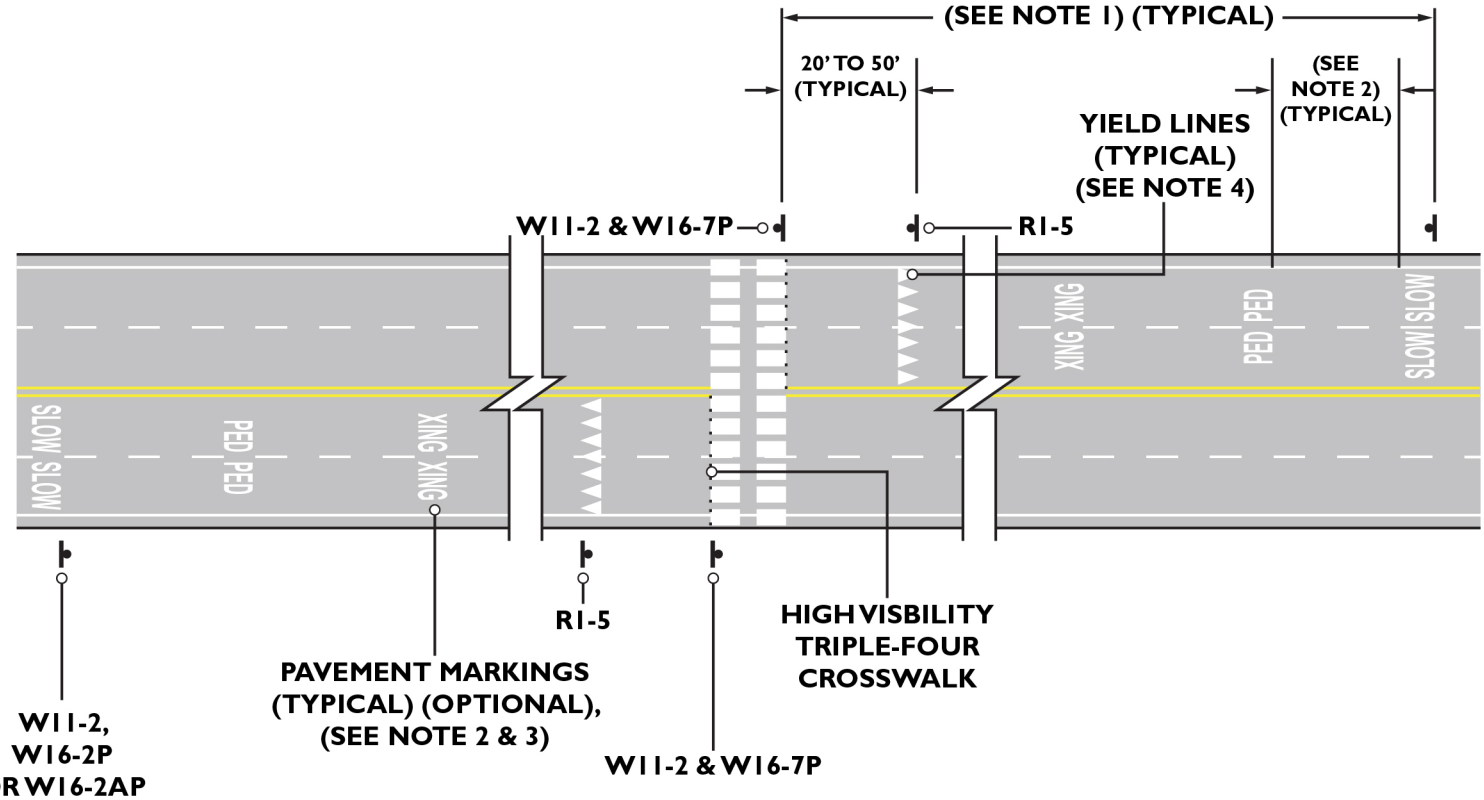
GUIDANCE:

If an uncontrolled mid-block location is selected for a marked crosswalk in accordance with the guidelines in **Section 2**, the location should be provided with the following treatments (see **FIGURE 4** for details):

- City's standard high visibility triple four crosswalk markings;
- Advanced yield lines with associated "Yield Here to Pedestrians" (R1-5, R1-5a) signs should be placed 20 to 50 feet in advance of the crosswalk for mid-block crossings and parking should be prohibited between the yield lines and the crosswalk. Additionally, parking should be restricted to one stall or within the distance required to provide adequate stopping sight distance for approaching vehicles to stop for a pedestrian intending to cross, as well as one parking stall on the departure side.
- Warning signs W11-2 at the crossing location(s). If a W11-2 sign at the location of the crossing point is post-mounted, a diagonal downward pointing arrow (W16-7P) plaque shall be mounted below the W11-2 sign. If the W11-2 sign is mounted overhead, the (W16-7P) plaque shall not be used. Refer to CA MUTCD Section 2C.50 for further information.
- Warning signs (W11-2) may be provided in advance of an uncontrolled marked crosswalk if engineering judgement indicates that either there is a need for alerting road users in advance of where unexpected entries of pedestrians into the roadway might occur, **OR** where visibility of the crossing treatments or pedestrians is obstructed. Obstructions may include near side transit stops, trees, visual clutter, roadway geometry that limits sight distance, a large volume of heavy vehicles, etc.
- If the warning sign (W11-2) is used in advance of a pedestrian crossing (see above), it should be supplemented with plaques with the legend "AHEAD" or "XX FEET".
- "SLOW PED XING" pavement word markings should be provided in conjunction with W11-2 warning signs if the W11-2 signs are provided in advance of the uncontrolled marked crosswalk to supplement the signs and provide additional emphasis for the warning messages. For trail crossings, "SLOW TRAIL XING" pavement markings should be used instead of "SLOW PED XING".
- Pedestrian crossing enhancement treatments as recommended in **TABLE 3** (page 28).



FIGURE 4 Uncontrolled Marked Crosswalk 'Basic' Treatment at Mid-Block Locations





W11-2 W16-2AP



W16-7P W16-9P



R1-5

NOTES

1. SELECT THE ADVANCE PLACEMENT DISTANCE BASED ON DESIGN SPEEDS.
2. REFER TO 2014 CA MUTCD (OR LATEST EDITION), SECTION 3B.20 FOR LETTER SIZE AND LONGITUDINAL SPACE BETWEEN PAVEMENT MARKINGS.
3. FOR WARNING SIGNS (W11-2) AND "SLOW PED XING' PAVEMENT MARKINGS IN ADVANCE OF UNCONTROLLED MARKED CROSSINGS, REFER TO SECTION 4.2 FOR GUIDANCE ON:
   (A) APPLICABILITY; AND
   (B) CONSOLIDATION OF LOCATIONS OF THESE SIGNS AND PAVEMENT MARKINGS FOR STREETS WITH MULTIPLE UNCONTROLLED MARKED CROSSINGS IN SERIES.
4. (A) PARKING SHOULD BE PROHIBITED BETWEEN YIELD LINES AND MARKED CROSSWALK.
   (B) FOR STREETS WITH ONLY ONE LANE IN DIRECTION, THE USE OF ADVANCE YIELD LINE AND PROHIBITION OF PARKING BETWEEN YIELD LINE AND CROSS WALK IS NOT REQUIRED.

Source: City of Sacramento, 2014.

4.3 Crosswalks at Trails or Shared-Use Paths

Guidance for the design of marked crosswalks at a trail or shared-use path at an uncontrolled location is provided below.

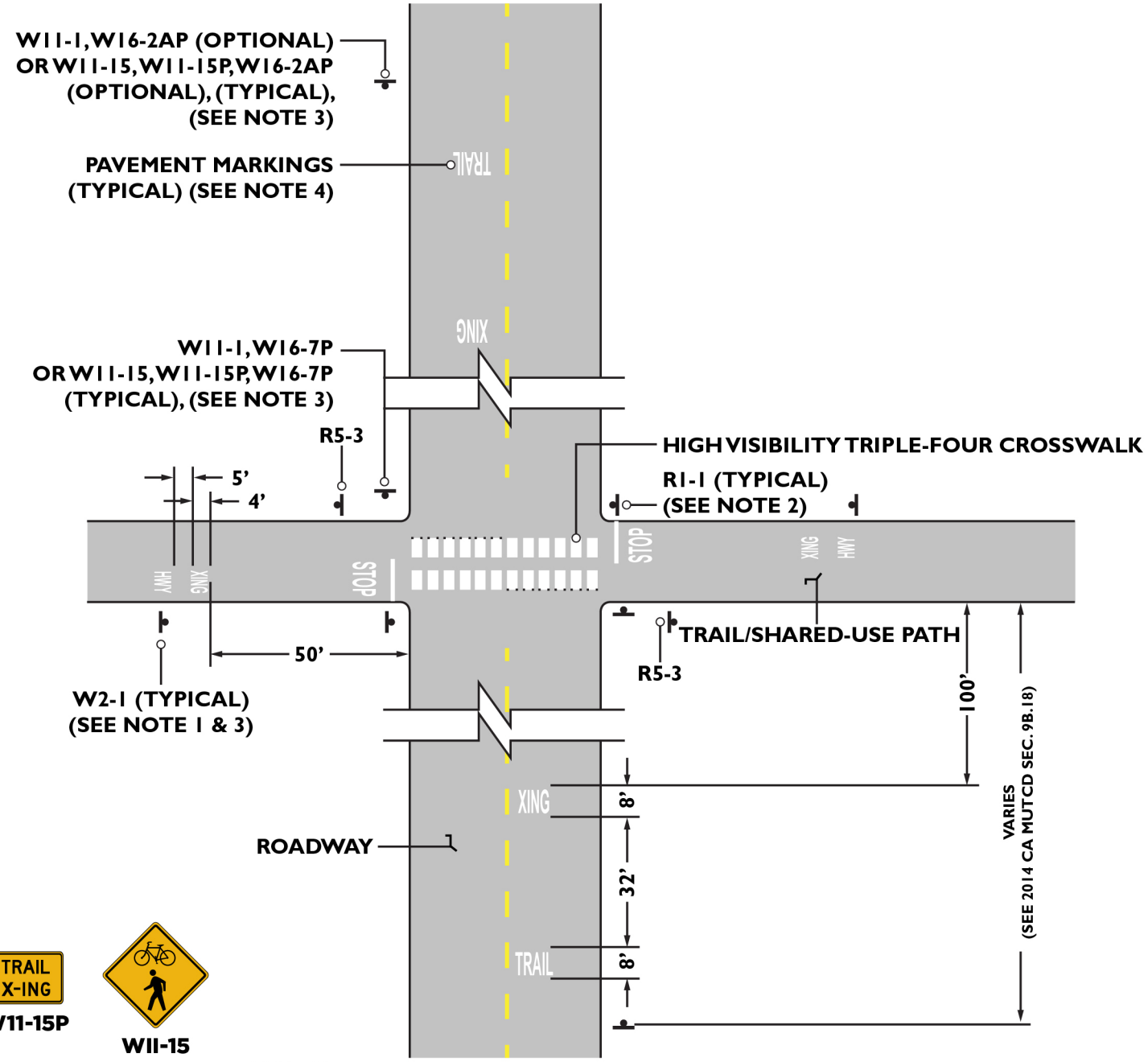
GUIDANCE:

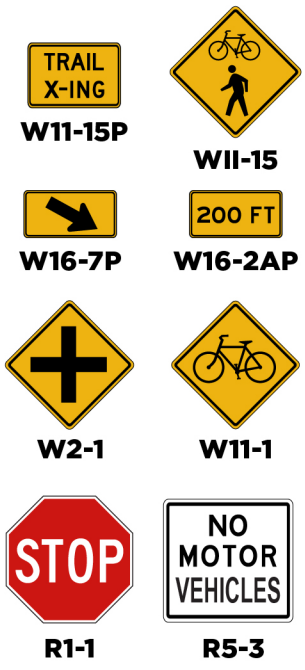
If a determination is made to provide a marked crossing for a trail or a shared-use path at an uncontrolled location, the crossing location should be provided with the following treatments (see Figure 5 for details):

- City's 'basic' treatment as outlined above with the following additional considerations. CA MUTCD Section 9B.16 should be consulted for guidance on the use and applicability of intersection warning signs (W2-1 through W2-5) in advance of a shared- use path / roadway intersection. CA MUTCD Section 9B.18 should be consulted for guidance on the use and applicability of Bicycle Warning sign (W11-1), and combination Bicycle / Pedestrian (W11-15) signs in advance of, and at a path crossing including the use of applicable supplemental plaques. See **FIGURE 5** for details.
- Pedestrian crossing enhancement treatments as recommended in **TABLE 3** (page 28). Refer to the previous subsection for more detailed guidance on selecting pedestrian crossing enhancement treatments.



FIGURE 5 Uncontrolled Marked Crosswalk 'Basic' Treatment at Trail or Shared-Use Path Locations





NOTES

1. INSTALL W2-1 SIGN IF NO STOP, YIELD, OR SIGNAL CONTROL ON PATH.
2. INTERSECTION TRAFFIC CONTROL DEVICES MIGHT BE STOP OR YIELD SIGNS FACING SHARED-USE PATH APPROACHES, ROADWAY APPROACHES, OR BOTH, DEPENDING ON CONDITIONS (SEE 2014 CA MUTCD (OR LATEST EDITION), SEC. 9B.03)
3. FOR GUIDANCE ON WARNING SIGNS W2 SERIES, AND W11-1 / W11-15 INCLUDING APPLICABLE SUPPLEMENTAL PLAQUES, REFER TO 2014 CA MUTCD (OR LATEST EDITION), SECTION 9B.16, AND 9B.18 RESPECTIVELY.
4. FOR GUIDANCE ON PAVEMENT WORD, AND SYMBOL MARKINGS, REFER TO 2014 CA MUTCD (OR LATEST EDITION), SECTION 3B.20.

Source: City of Sacramento, 2014.

4.4 Crosswalks at Controlled Locations

The recommended guidelines for marking crosswalks at signalized and stop or yield controlled locations are presented in the two subsections below, respectively.

Signalized Intersections

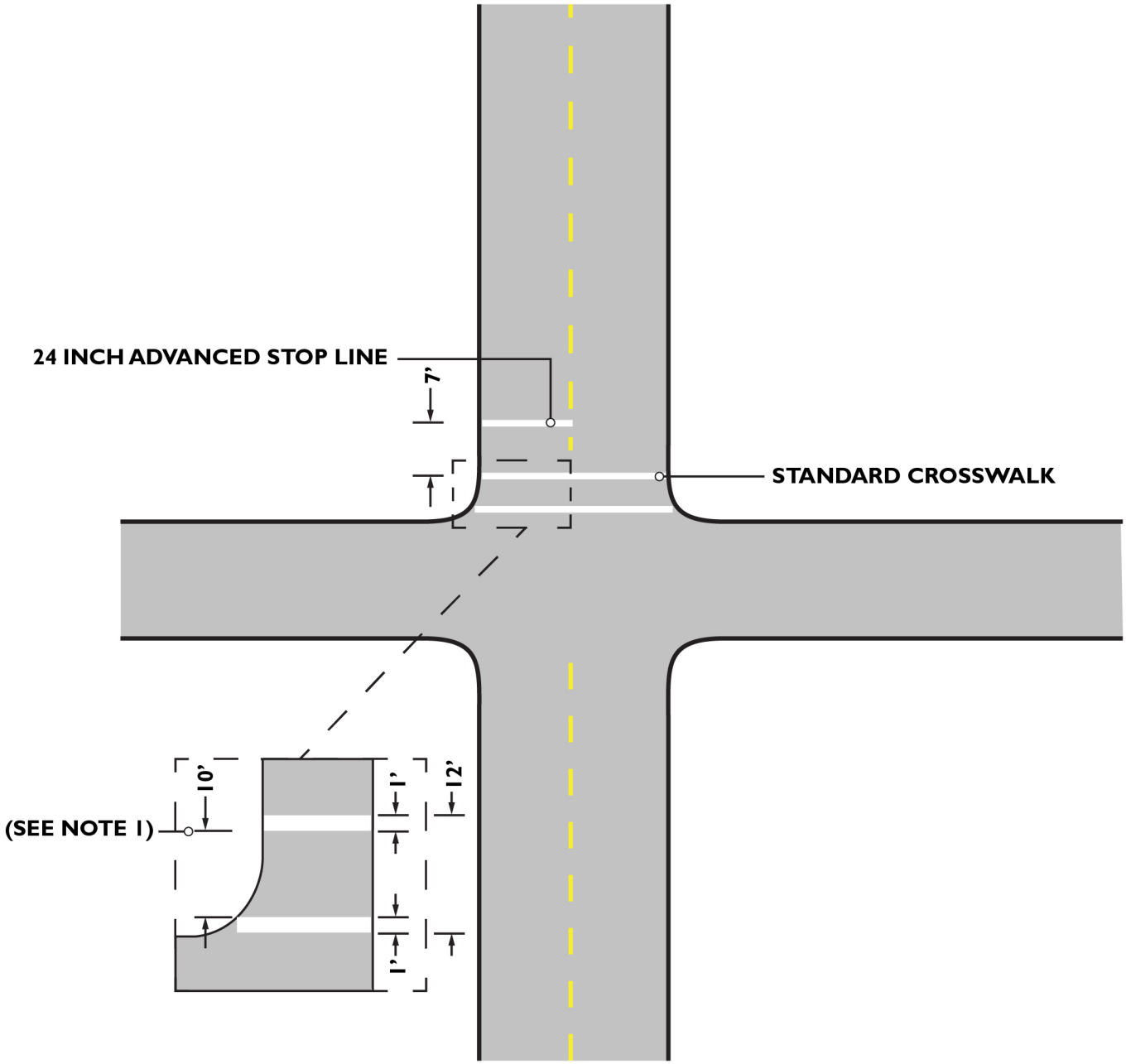
These guidelines recommend the following approach for marking crosswalks at signalized intersections (see **FIGURE 6** for details).

GUIDANCE:

- Provide marked crosswalks on each approach of the signalized intersection unless a pedestrian crossing is prohibited. See **Section 2.6** for more detailed guidance on crossing prohibitions.
- The marked crosswalks should be 12 feet wide with a 10 feet inside clear space. The City Traffic Engineer may consider approving lesser space on a case-by-case basis, provided it is not less than 6 feet. See CA MUTCD Section 3B.18 for more information.
- It is recommended to install a 24-inch advanced stop line seven feet in advance of the crosswalk on each approach to a signalized intersection.
- High visibility crossing markings, including the City's standard high visibility triple four crosswalk markings, should be considered on a case-by-case basis at signalized crossings serving a school zone, transit stops and stations, a corridor on the Vision Zero High-Injury Network, and locations with heavy pedestrian volumes as determined by engineering judgement. Different high visibility markings may be used to differentiate controlled crossing types or contexts.
- Supplemental hardware and operational treatments may be considered for signalized crossing locations. Information on the supplemental hardware and operational treatments to help achieve optimal pedestrian crossing service is covered in this guidance's companion document *Pedestrian Crossing Guidelines Treatments Application Guide*.



FIGURE 6 Marked Crosswalk Treatment at a Signalized Crossing Location



NOTES

1. MARKED CROSSWALKS SHOULD BE 12 FEET WIDE WITH A 10 FEET INSIDE CLEAR SPACE. THE CITY TRAFFIC ENGINEER MAY CONSIDER USING A LESSER SPACE PROVIDED IT IS NOT LESS THAN 6 FEET.

Stop- or Yield-Controlled Locations

These guidelines recommend the following approach for marking crosswalks at stop- or yield-controlled intersections (see **FIGURE 7** and **FIGURE 8** for details, respectively).

GUIDANCE:

Stop-Controlled Locations

- Install marked crosswalks if recommended by the City Traffic Engineer, otherwise, install only a 12-inch wide limit line with associated traffic control devices (e.g. signs, pavement markings, etc.) consistent with CA MUTCD. The City may consider marking the crosswalks at stop-controlled locations based on engineering judgement.
- The marked crosswalks (if provided) should be 12 feet wide with a 10 foot inside clear space and be provided with associated traffic control devices (e.g., signs, pavement markings, etc.) consistent with CA MUTCD. The City Traffic Engineer may consider approving less clear space on a case-by-case basis, provided it is not less than 6 feet.
- If a marked crosswalk is to be provided, the City's standard high visibility triple four crosswalk markings should be considered on a case-by-case basis at stop-controlled crossings serving school walking routes, transit stops and stations, and based on pedestrian volumes. Use of these markings will be determined by engineering judgement.
- A limit line at a stop-controlled approach is not required where a marked crosswalk exists but may be considered on a case-by-case basis as determined by engineering judgement.

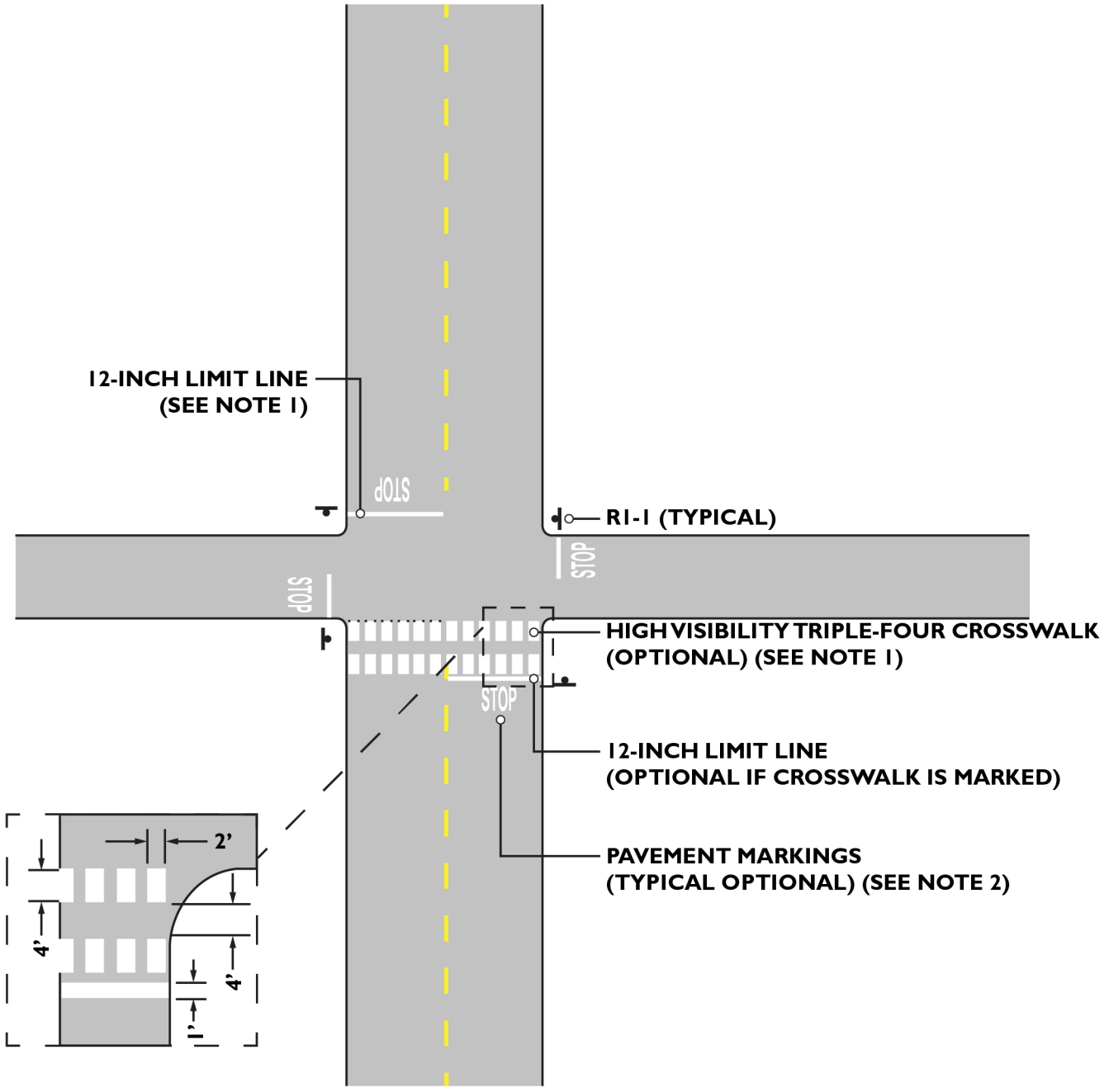
Yield-Controlled Locations

- Install marked crosswalks if recommended by the City Traffic Engineer, otherwise, install a yield line with associated traffic control devices (e.g. signs, pavement markings, etc.) consistent with CA MUTCD. The City may consider marking the crosswalks at yield-controlled locations based on engineering judgement.
- Marked crosswalks (if provided) should be 12 feet wide with a 10 feet inside clear space and the yield-controlled approach be provided with associated traffic control devices (e.g., signs, pavement markings, etc.) consistent with CA MUTCD. The City Traffic Engineer may consider approving less clear space on a case-by-case basis, provided it is not less than 6 feet.
- Yield-controlled pedestrian crossings may exist under a wide range of site conditions, and the City Traffic Engineer may need to consider modifications to the crossing treatments recommended above based on engineering judgement on a case-by-case basis.

Additional Guidance for Stop- or Yield-Controlled Locations

- The treatments presented above cover the basic information on marking the crosswalks at the stop or yield controlled intersections. Refer to the following sections of the CA MUTCD for guidance related to crossing facilities at these locations, as needed: Section 3B.16 (Stop and Yield Lines), Section 3B.18 (Crosswalk Markings) and Section 3B.20 (Pavement Word, Symbol, and Arrow Markings).

FIGURE 7 Marked Crosswalk Treatment at a Stop-Controlled Crossing Location



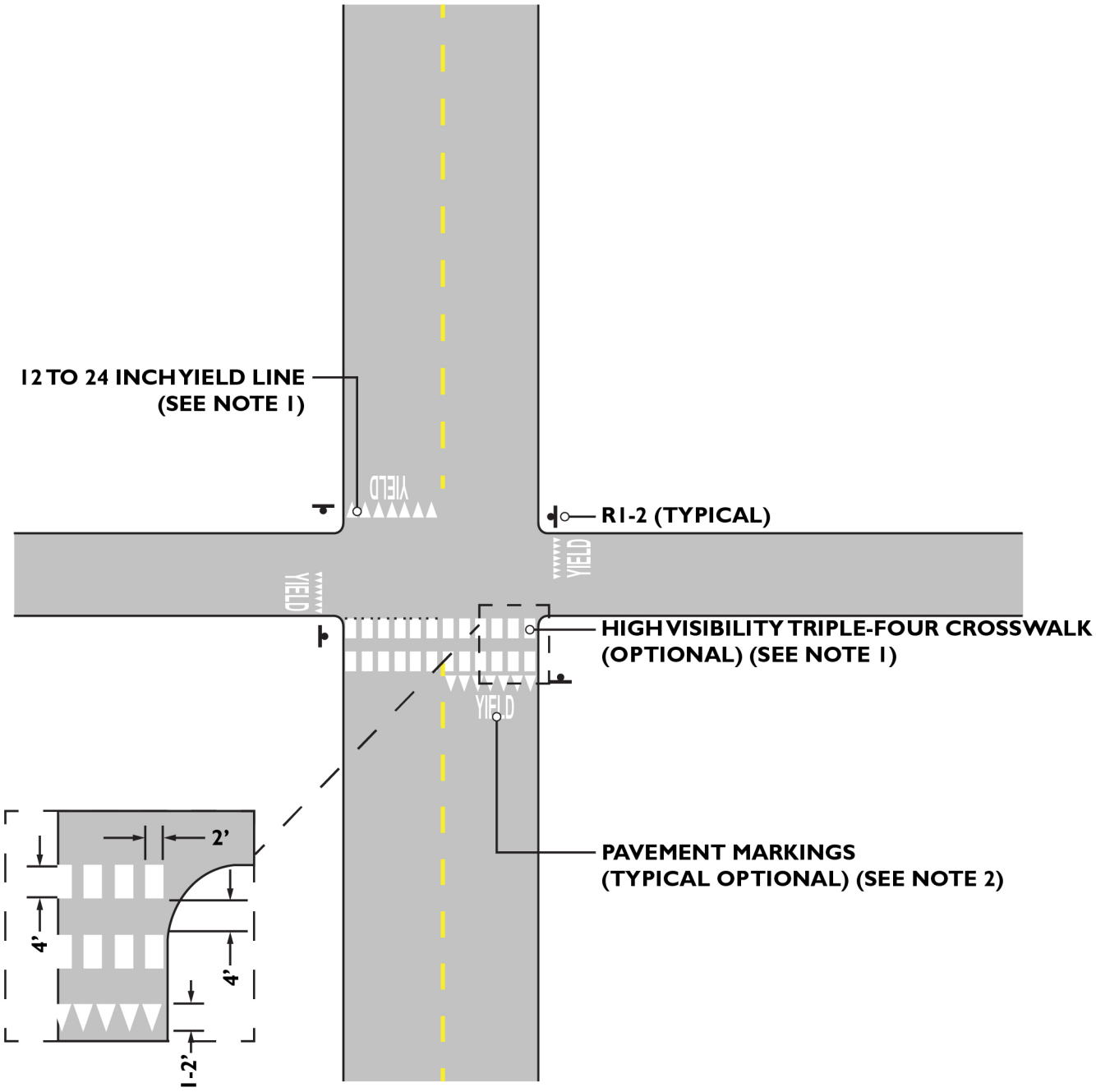


R1-1

NOTES

1. CROSSWALKS MAY BE MARKED AT A STOP-CONTROLLED LOCATION USING THE CITY'S STANDARD HIGH VISIBILITY CROSSWALK MARKINGS.
2. REFER TO 2014 CA MUTCD (OR LATEST EDITION), SECTION 3B.20 FOR LETTER SIZE AND LONGITUDINAL SPACE BETWEEN PAVEMENT MARKINGS

FIGURE 8 Marked Crosswalk Treatment at a Yield-Controlled Crossing Location





R1-2

NOTES

1. CROSSWALKS MAY BE MARKED AT A YIELD-CONTROLLED LOCATION USING THE CITY'S STANDARD HIGH VISIBILITY CROSSWALK MARKINGS.
2. REFER TO 2014 CA MUTCD (OR LATEST EDITION), SECTION 3B.20 FOR LETTER SIZE AND LONGITUDINAL SPACE BETWEEN PAVEMENT MARKINGS


ONE WAY

APPENDICES

Appendix A – Crosswalk Basics and Key Definitions

Function of Crosswalks

Marked crosswalks serve multiple purposes; they:

- provide guidance for pedestrians who are crossing roadways by defining and delineating paths to and within the controlled intersections;
- alert road users (in conjunction with signs and other traffic control devices) of a designated pedestrian crossing point across roadways at locations that are uncontrolled; and,
- legally establish the crosswalk at non-intersection locations (adapted from CA MUTCD, Section 3B.18.).

The following relevant legal statutes are contained in the CVC.

Section 275 defines a crosswalk as:

275 "Crosswalk" is either:

(a) That portion of a roadway included within the prolongation or connection of the boundary lines of sidewalks at intersections where the intersecting roadways meet at approximately right angles, except the prolongation of such lines from an alley across a street.

(b) Any portion of a roadway distinctly indicated for pedestrian crossing by lines or other markings on the surface.

Notwithstanding the foregoing provisions of this section, there shall not be a crosswalk where local authorities have placed signs indicating no crossing.

Section 21950 describes right-of-way at a crosswalk:

(a) The driver of a vehicle shall yield the right-of-way to a pedestrian crossing the roadway within any marked crosswalk or within any unmarked crosswalk at an intersection.

(b) This section does not relieve a pedestrian from the duty of using due care for his or her safety. No pedestrian may suddenly leave a curb or other place of safety and walk or run into the path of a vehicle which is so close as to constitute an immediate hazard. No pedestrian may unnecessarily stop or delay traffic while in a marked or unmarked crosswalk.

(c) The driver of a vehicle approaching a pedestrian within any marked or unmarked crosswalk shall exercise all due care and shall reduce the speed of the vehicle or take any other action relating to the operation of the vehicle as necessary to safeguard the safety of the pedestrian.

(d) Subdivision (b) does not relieve a driver of a vehicle from the duty of exercising due care for the safety of any pedestrian within any marked crosswalk or within any unmarked crosswalk at an intersection.

Section 21955 pertains to crossing between controlled intersections:

Between adjacent intersections controlled by traffic control signal devices or by police officers, pedestrians shall not cross the roadway at any place except in a crosswalk.

Key Definitions

The meanings of following words and phrases when used in this document are explained below:

AVERAGE DAILY TRAFFIC (ADT)
The average 24-hour volume, being the total volume during a stated period divided by the number of days in that period. Normally, this would be periodic daily traffic volumes over several days, not adjusted for days of the week or seasons of the year. (CA MUTCD Section 1A.13)

CONTROLLED INTERSECTION
A controlled intersection is one where each approach to the intersection is regulated by a traffic signal, stop, or yield traffic control device.

CRITICAL GAP
The time in seconds below which a pedestrian will not attempt to begin crossing the street.

CROSSWALK LINES
White or yellow (in school areas per CVC 21368) pavement marking lines that identify a crosswalk. (CA MUTCD Section 1A.13)

LIMIT LINE
A solid white line not less than 12 nor more than 24 inches wide, extending across a roadway or any portion thereof to indicate the point at which traffic is required to stop in compliance with legal requirements. (CA MUTCD Section 1A.13)

MARKED CROSSWALK
A pedestrian crossing delineated by crosswalk lines.

MEDIAN
The area between two roadways of a divided highway measured from edge of traveled way to edge of traveled way. The median excludes turn lanes. The median width might be different between intersections, interchanges, and at opposite approaches of the same intersection. (CA MUTCD Section 1A.13)

MOTORIST COMPLIANCE
Percent of motorists yielding or stopping for pedestrians.

MULTI-LANE
More than one lane moving in the same direction. A multi-lane street, highway, or roadway has a basic cross-section comprised of two or more through lanes in one or both directions. A multi-lane approach has two or more lanes moving toward the intersection, including turning lanes. (CA MUTCD Section 1A.13)

MULTIPLE THREAT CRASHES
A multiple-threat crash involves a driver stopping in one lane of a multilane road to permit pedestrians to cross, and an oncoming vehicle (in the same direction) strikes the pedestrian who is crossing in front of the stopped vehicle. This crash type involves both the pedestrian and driver failing to see each other in time to avoid the collision.

PEDESTRIAN
A person on foot, in a wheelchair, on a non-motorized scooter, on skates, or on a skateboard. As per CVC 467, (a) A "pedestrian" is a person who is afoot or who is using any of the following: (1) A means of conveyance propelled by human power other than a bicycle. (2) An electric personal assistive mobility device. (b) "Pedestrian" includes a person who is operating a self-propelled wheelchair, motorized tricycle, or motorized quadricycle and, by reason of physical disability, is otherwise unable to move about as a pedestrian, as specified in subdivision(a). (CA MUTCD Section 1A.13)

STOP LINE
A solid white pavement marking line extending across approach lanes to indicate the point at which a stop is intended or required to be made. For all purposes, limit line(s) as defined per CVC 377 shall mean stop line(s). (CA MUTCD Section 1A.13)

TRAFFIC CONTROL DEVICE
A sign, signal, marking, or other device used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, private road open to public travel, pedestrian facility, or shared-use path by authority of a public agency or official having jurisdiction, or, in the case of a private road open to public travel, by authority of the private owner or private official having jurisdiction. (CA MUTCD Section 1A.13)

YIELD LINE
A row of solid white isosceles triangles pointing toward approaching vehicles extending across approach lanes to indicate the point at which the yield is intended or required to be made. (CA MUTCD section 1A.13)

85TH PERCENTILE SPEED
The speed at or below which 85 percent of the motor vehicles travel. (CA MUTCD section 1A.13)

Appendix B – City of Sacramento Crosswalk Removal Outreach Policy

City of SACRAMENTO
Department of Public Works

Transportation Division
915 I Street, RM 2000
Sacramento, CA 95814
Phone: 916-808-5307

MEMORANDUM

TO: Transportation Division

FROM: Ryan Moore, PE, TE, City Traffic Engineer RTM

SUBJECT: Crosswalk Removal Outreach Policy

DATE: June 8, 2018

Purpose:

To establish Transportation Division policy and procedures related to informing the public about proposed marked crosswalk removal.

Policy:

Public Works Transportation Division staff will conduct the following actions when noticing of a proposed marked crosswalk removal.

A. Conform with CVC 21950.5 by posting of proposed removal at the crosswalk identified for removal for not less than 30 days from the scheduled date of removal.

B. Provide noticing in multiple languages, languages to be determined through input from the Council District Office, the City Manager's Public Information Office, and Neighborhood Services.

C. Post noticing at transit stops within 500-feet of crosswalk proposed for removal not less than 30 days from the scheduled date of removal.

D. Communicate with Council District Office, the City Manager's Public Information Office, and Neighborhood Services prior to removal to identify appropriate community organizations to provide notice via electronic communications, including but not limited to:

   a. Community and neighborhood associations;

   b. Property business improvement districts; and

   c. Schools.

   Notice to be made not less than 30 days from the scheduled date of crosswalk removal.

July 2018, Updated

U.S. Department of Transportation
Federal Highway Administration

EDC

Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations



Photo: VHB

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U.S. Department of Transportation
Federal Highway Administration





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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	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

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.

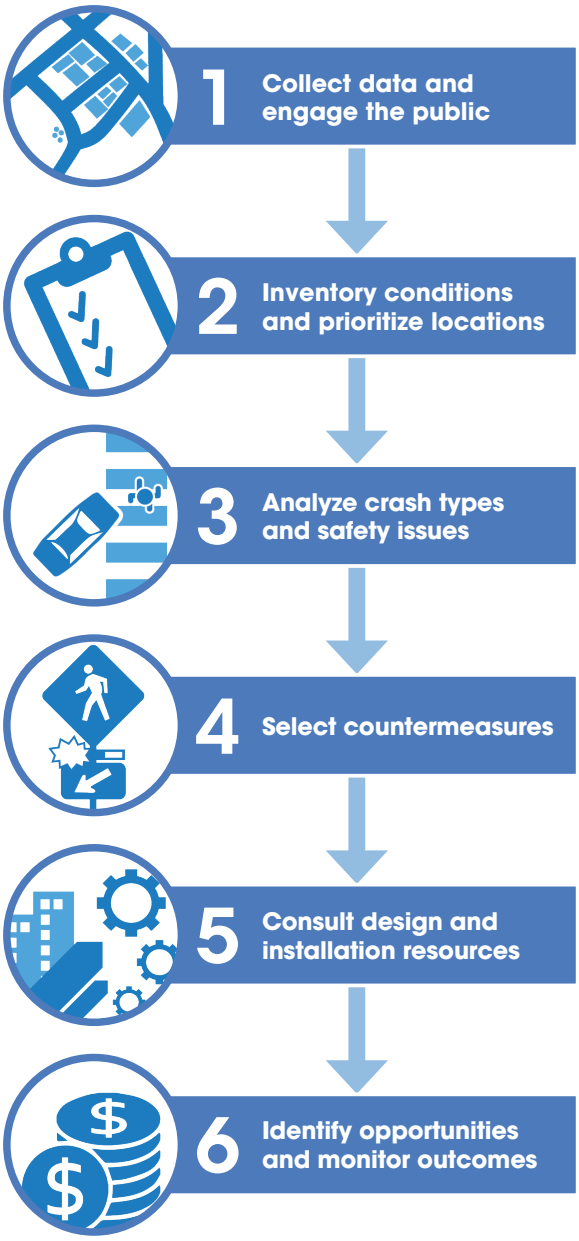


Figure 1. Process diagram for selecting countermeasures at uncontrolled pedestrian crossing locations.

[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.

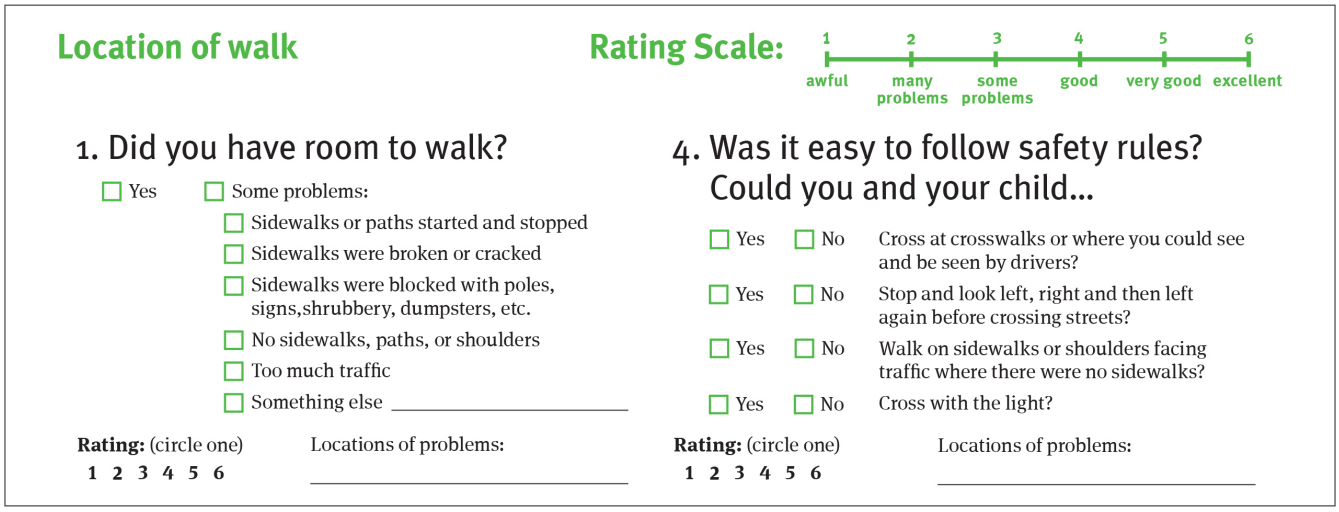


Figure 2. Excerpt from "Walkability Checklist."

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.

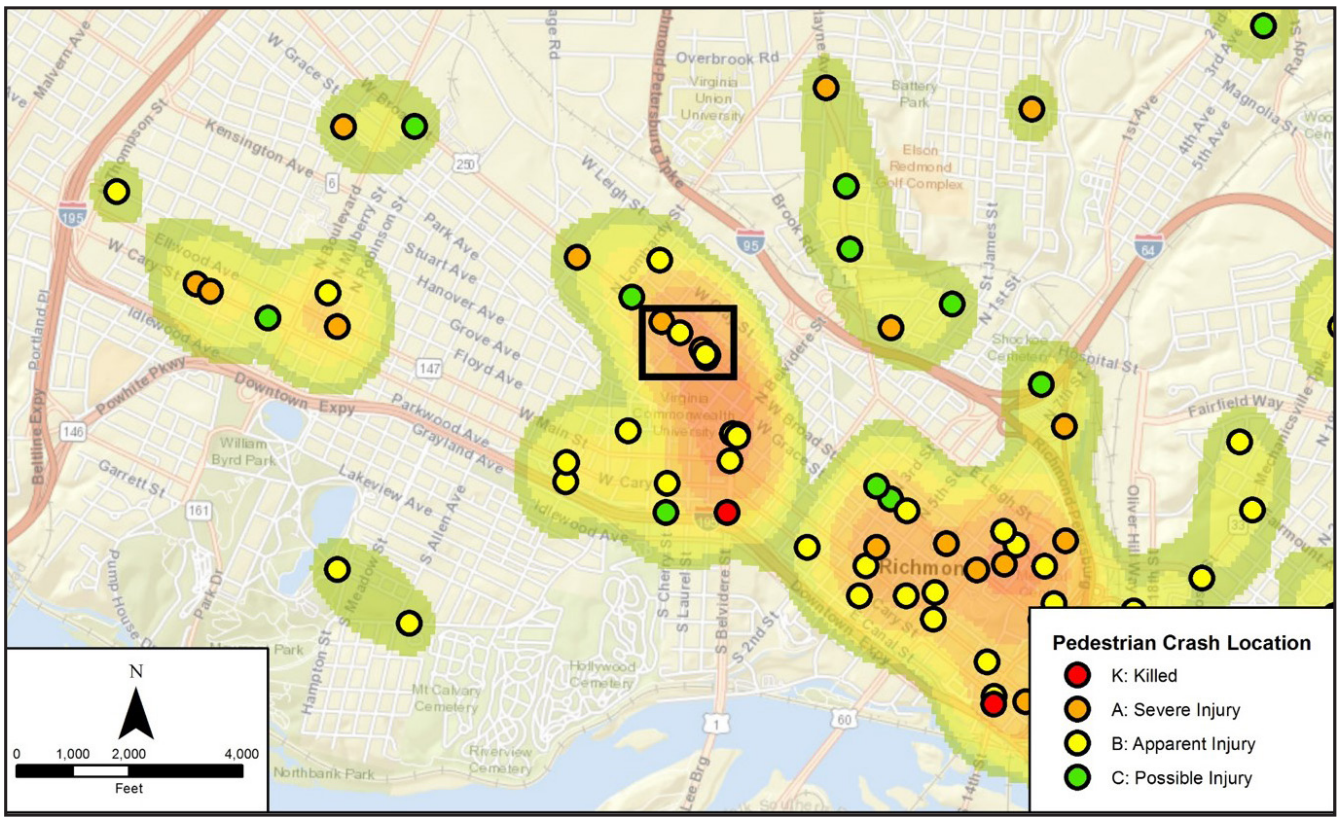
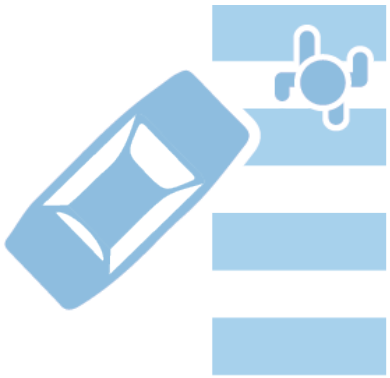


Figure 4. Crash cluster analysis map: Richmond, VA.

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.

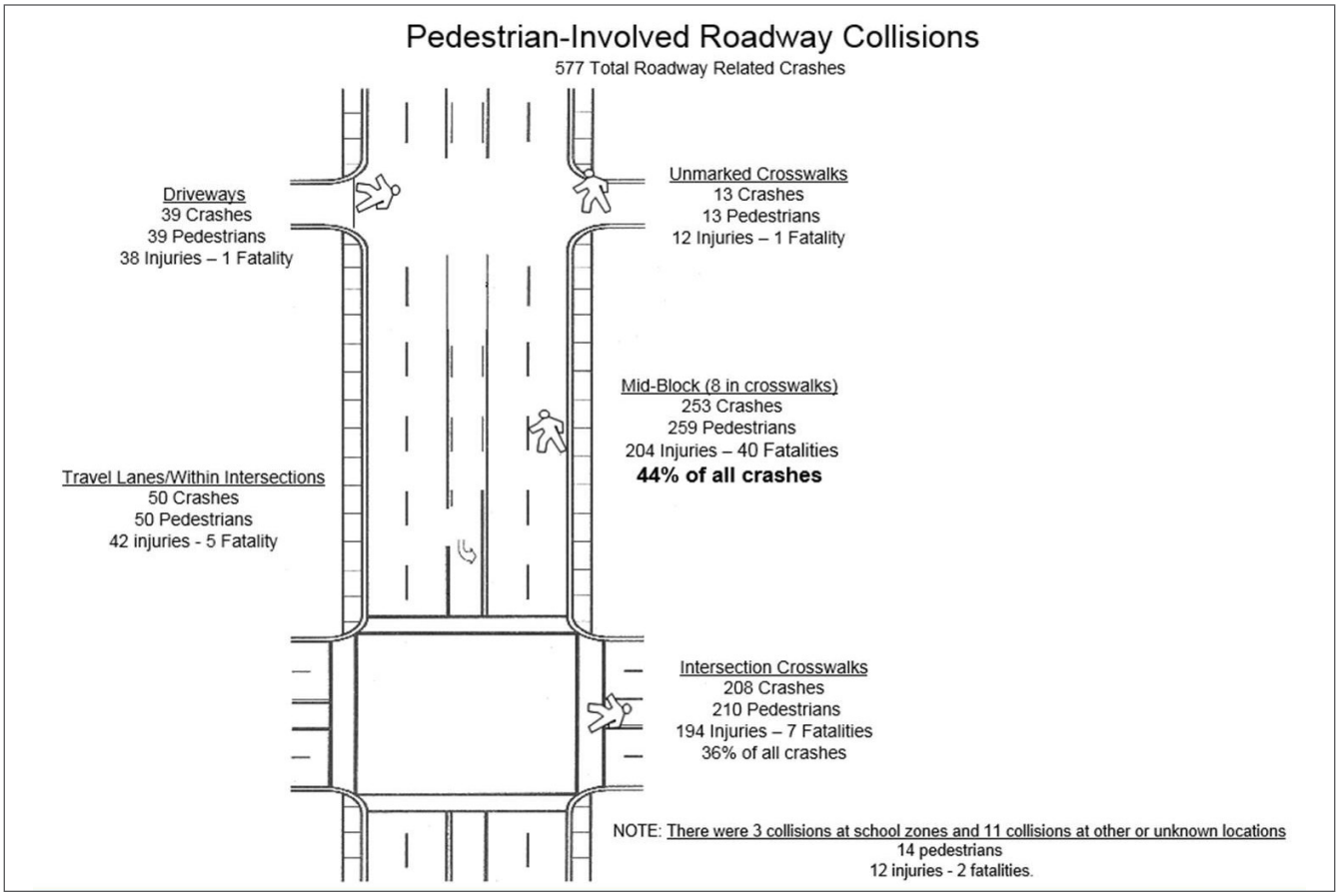


Figure 5. Pedestrian collision summary.

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 ❼ ❾	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 ❾	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 ❾	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.

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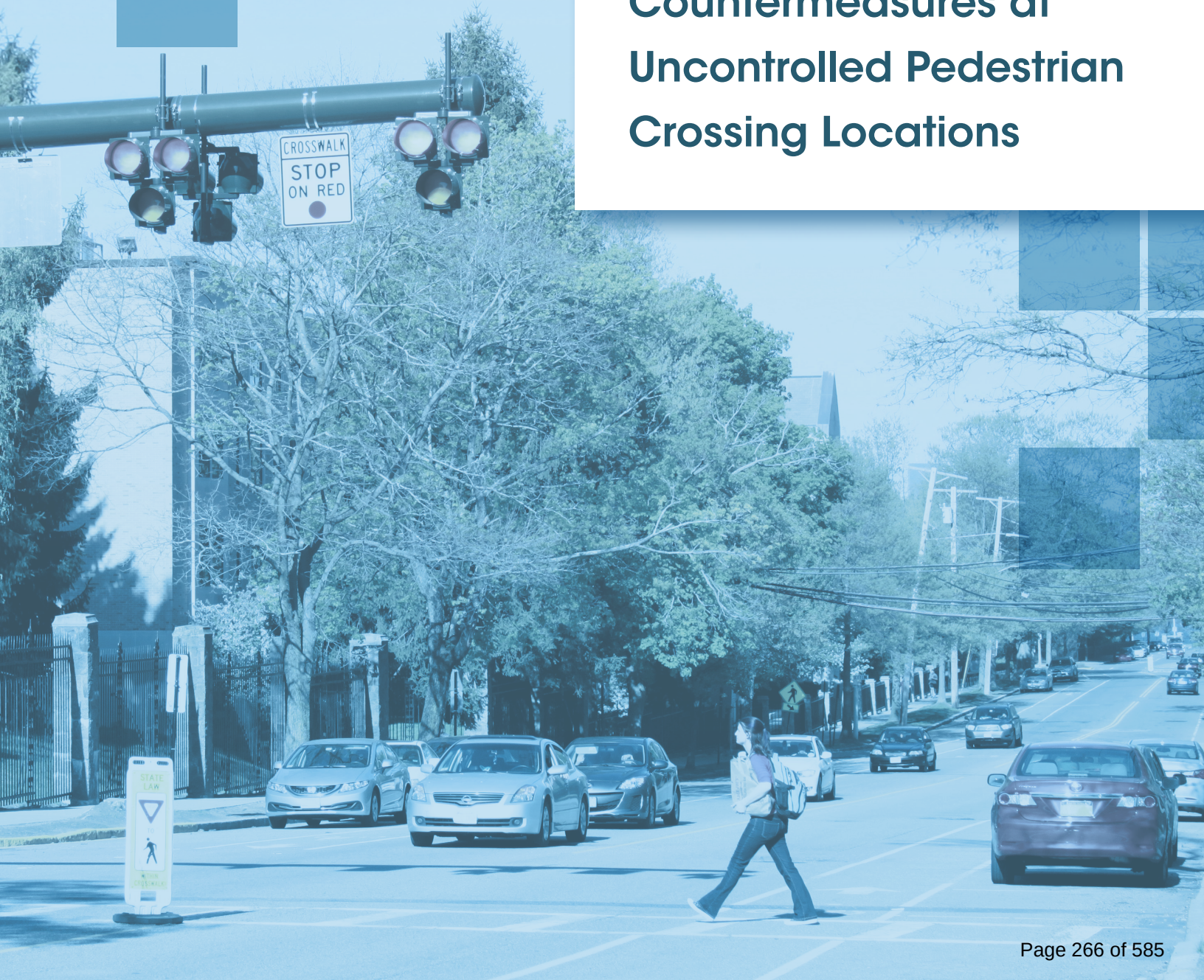
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Field Guide for Selecting Countermeasures at Uncontrolled Pedestrian Crossing Locations



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16. ABSTRACT

This field guide helps agencies select pedestrian crash countermeasures based on criteria established in published literature, best practices, and national guidance. This guide includes a form that the agency may use to document roadway characteristics and pedestrian safety issues. It also includes tables that relate these documented conditions to a specific set of countermeasure options. A series of descriptions lead the agency through additional installation considerations for each countermeasure.

The January 2018 version of this document 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.

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Table of Contents

Introduction 1

Sample Inventory Form 2

Table 1 Instructions 3

Table 1: Application of Pedestrian Crash Countermeasures by Roadway Feature 4

Table 2 Instructions 5

Table 2: Safety Issues Addressed per Countermeasure 6

Countermeasure: Crosswalk Visibility Enhancements 7

Countermeasure: Raised Crosswalk 10

Countermeasure: Pedestrian Refuge Island 12

Countermeasure: Pedestrian Hybrid Beacon (PHB) 14

Countermeasure: Road Diet 16

Countermeasure: Rectangular Rapid-Flashing Beacon (RRFB) 18

Introduction

This field guide helps agencies select pedestrian crash countermeasures based on criteria established in published literature, best practices, and national guidance. This guide includes a form that the agency may use to document roadway characteristics and pedestrian safety issues. It also includes tables that relate these documented conditions to a specific set of countermeasure options. A series of descriptions lead the agency through additional installation considerations for each countermeasure. Practitioners should reference additional resources issued through the FHWA Safe Transportation for Every Pedestrian (STEP) program that further describe these countermeasures. Resources include a series of "tech sheets" including additional illustrations, crash reduction factors, and general construction costs.

Countermeasure Selection Tables

The information in this field guide relates to the information in the *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* (FHWA-SA-17-072). That guide describes a comprehensive decision-making process for the installation of pedestrian crossing countermeasures and leads the agency through the following steps in the process:

1. Collect Data and Engage the Public
2. Inventory Conditions and Prioritize Locations
3. Analyze Crash Types and Safety Issues
4. Select Countermeasure(s)
5. Consult Design and Installation Resources
6. Identify Opportunities and Monitor Outcomes

This field guide expands upon the fourth step, Select Countermeasures, for agencies who have an established process for identifying priority locations for countermeasure installation. This step presents two tables for the agency to review to identify potential countermeasures. Table 1, "Application of pedestrian crash countermeasures by roadway feature," compares roadway and vehicle speed characteristics to appropriate options. Table 2, "Safety issues addressed per countermeasure," compares crash types and other observed safety issues to the countermeasures. This field guide contains both tables and instructions for their use.

Countermeasure Descriptions

The field guide focuses on uncontrolled crossing types—where sidewalks or designated walkways intersect a roadway at a location where no traffic control (i.e., traffic signal or STOP sign) is present. The countermeasures described in the guide include the following:

- Crosswalk Visibility Enhancements, including:
  - High-visibility crosswalk markings
  - Parking restriction on crosswalk approach
  - Overhead lighting
  - Advance Yield Here To (Stop Here For) Pedestrians sign and stop or yield line
  - In-Street Pedestrian Crossing sign
  - Curb extension
- Raised crosswalk
- Pedestrian refuge island
- Pedestrian Hybrid Beacon (PHB)
- Road Diet
- Rectangular Rapid-Flashing Beacon (RRFB)

The field guide includes a description for each of the countermeasures. The descriptions present additional design and installation considerations, such as references to the Manual on Uniform Traffic Control Devices (MUTCD).

Sample Inventory Form

On this example inventory form, the agency records information about roadway conditions and safety issues important to selecting countermeasures for uncontrolled crossing locations. The information added to this form is applied in Tables 1 and 2. Some information, such as pedestrian volume data, is used when reviewing MUTCD guidance for countermeasures such as the PHB.

Roadway Conditions Inventory

Speed Limit

☐ ≤ 30 mph ☐ 35 mph ☐ ≥ 40 mph

Total Vehicles per Day

Annual Average Daily Traffic (AADT): _____

Approximate Vehicles per Hour (VPH): _____

☐ AADT < 9,000
☐ AADT 9,000–15,000
☐ AADT > 15,000

Travel Lane Configuration

☐ 2 lanes without raised median
☐ 3 lanes without raised median
☐ 3 lanes with raised median
☐ 4+ lanes without raised median
☐ 4+ lanes with raised median

Crosswalk Length (feet): _____

Approximate Total Pedestrians per Hour (PPH) Crossing the Roadway: _____

Pedestrian Safety Issues Inventory

Noted conflicts at crossing locations ☐ Yes ☐ No

» History of turning movement crashes
» Observed conflicts at permitted crossings

Excessive vehicle speed ☐ Yes ☐ No

» 85th percentile speeds, per speed study
» History of speed-related crashes

Inadequate conspicuity/visibility ☐ Yes ☐ No

» Dim or dark conditions for pedestrians in the crosswalk
» Limited visibility of crosswalk due to roadway curvature or topography
» Obstructions, such as on-street parking, vegetation, and signage

Drivers not yielding to pedestrians in crosswalks ☐ Yes ☐ No

» Crash history in marked crosswalks

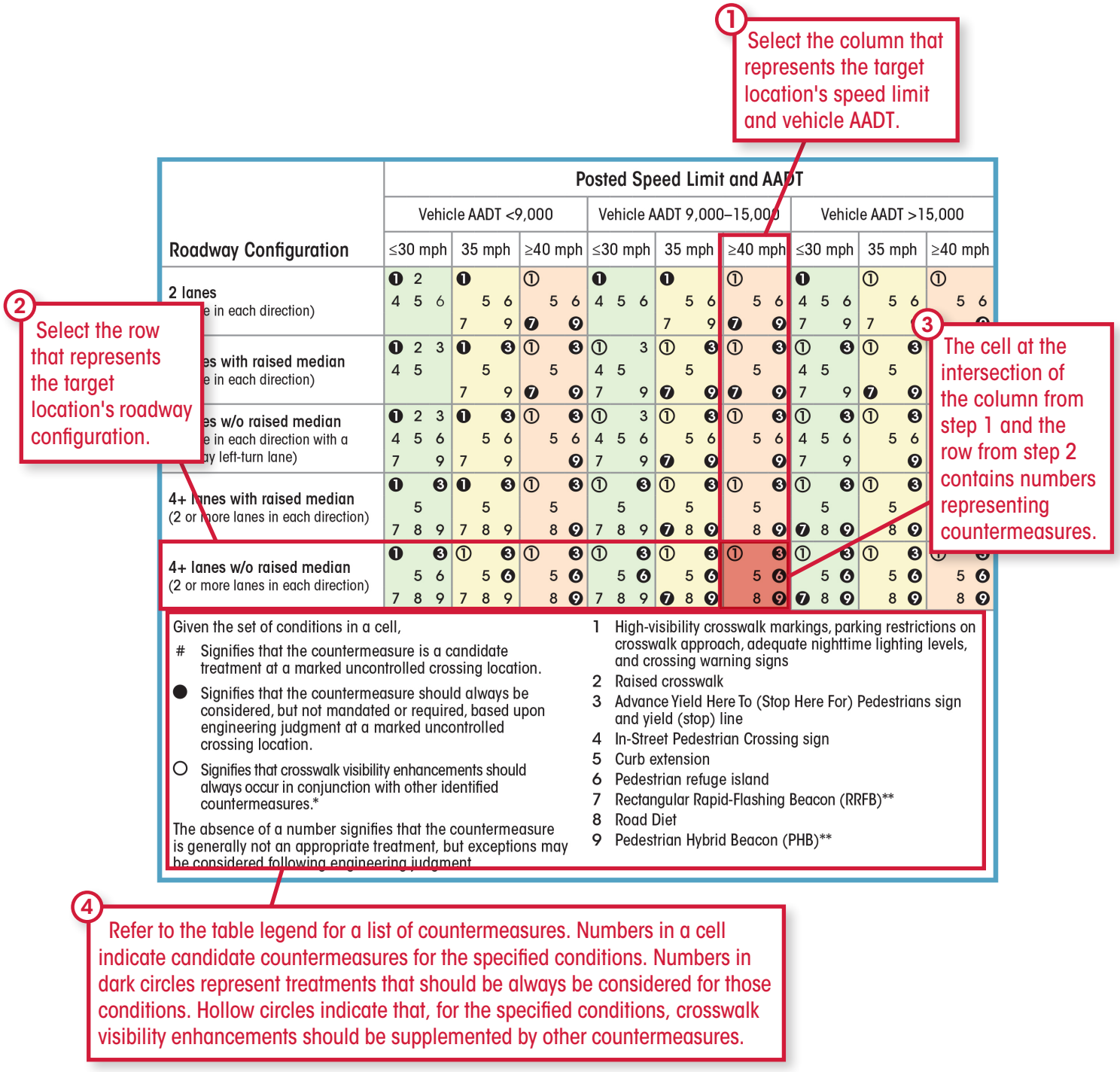
Insufficient separation between pedestrians and traffic ☐ Yes ☐ No

» Long crossing distance
» No buffer (e.g., landscape buffer, on-street parking, bike lanes)

Table 1 Instructions

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.



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 (e 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	① 5 6
es with raised median (e in each direction)	❶ 2 3 4 5	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	
es w/o raised median (e in each direction with a ay left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 9	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 9	① ❸ 4 5 6 7 9	① ❸ 5 6 9	
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 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 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 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	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)**

Table 1: Application of Pedestrian Crash Countermeasures by Roadway Feature

Table 1 identifies suggested countermeasures for uncontrolled crossing locations according to roadway and traffic features. Review the corresponding worksheets for countermeasures considered for the site. The worksheets describe additional design and installation considerations for the countermeasures.

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 ❾	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 ❾	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.

Table 2 Instructions

1. Select the columns representing the priority safety issues at the location.

2. Use the rows to identify pedestrian crash countermeasures that address these safety issues at uncontrolled crossings.

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	✓		✓	✓	✓

Table 2: Safety Issues Addressed per Countermeasure

Table 2 identifies the safety issues that may be addressed by suggested countermeasures for uncontrolled crossing locations. Review the corresponding worksheets for countermeasures considered for the site. The worksheets describe additional design and installation considerations for the countermeasures.

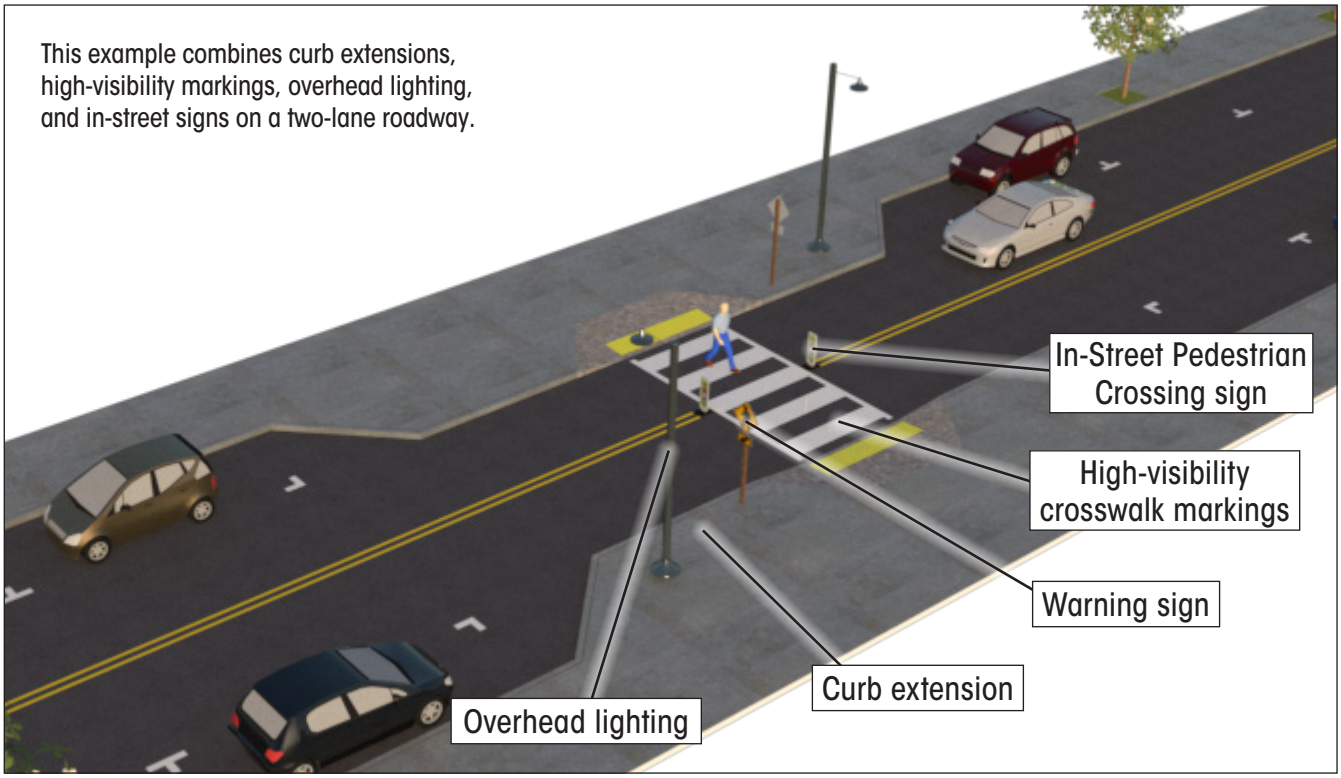
Table 2. Safety issues addressed per countermeasure.

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	✓		✓	✓	✓

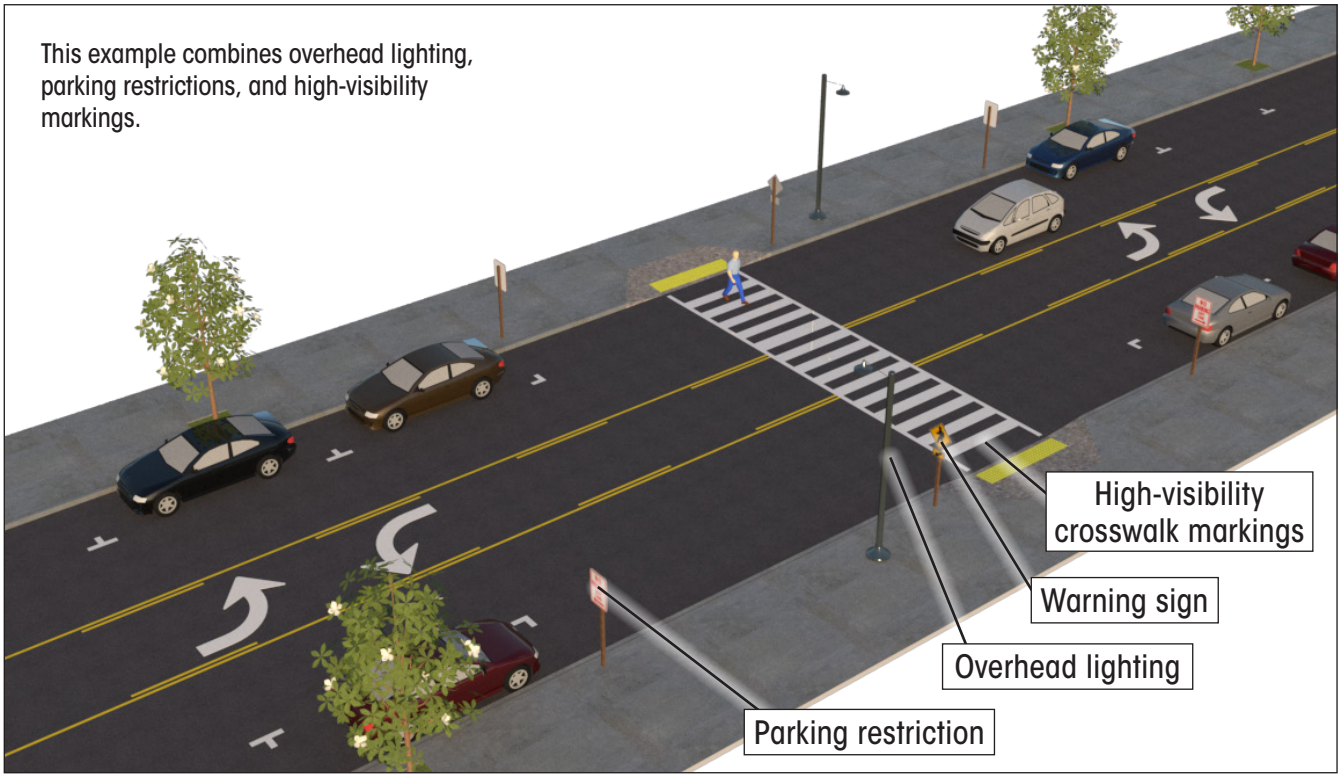
*These countermeasures make up the STEP countermeasure "crosswalk visibility enhancements." Multiple countermeasures may be implemented at a location as part of crosswalk visibility enhancements.

Countermeasure: Crosswalk Visibility Enhancements

This example combines curb extensions, high-visibility markings, overhead lighting, and in-street signs on a two-lane roadway.



This example combines overhead lighting, parking restrictions, and high-visibility markings.



Definition

This group of countermeasures includes high-visibility crosswalk markings, improved nighttime lighting, advance or in-street warning signage, curb extensions, and parking restrictions. These features may be used in combination to indicate preferred locations for people to cross, to increase visibility of the crossing location, and to help reinforce the driver requirement to yield the right-of-way to pedestrians at crossing locations. Refer to the Crosswalk Visibility Enhancements Tech Sheet for more information about this set of countermeasures.

Roadway and Site Information

Strongly consider the following countermeasures at all established midblock or intersection uncontrolled crossing locations:

- High-visibility crosswalk markings
- Overhead lighting
- On-street parking restrictions or curb extensions

  Note: On roadways with 4 or more lanes and more than 9,000 vehicles per day, the risk for pedestrian crashes could increase if marked crosswalks are not combined with other treatments, such as refuge islands or Pedestrian Hybrid Beacons.

Strongly consider adding advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line if the roadway(s) are described by one of the following sets of conditions:

- ☐ Any AADT + 4 or more lanes (with or without a raised median) + any speed limit
- ☐ Any AADT + any number of lanes + ≥ 35 mph speed limit

Safety Issues and Behaviors

This countermeasure may help address most traffic behaviors or safety issues but are most needed when the following are observed at the site:

- ☐ Drivers not yielding to pedestrians in crosswalks
- ☐ Inadequate conspicuity/visibility of the crosswalk and pedestrian
- ☐ Noted conflicts at crossing locations

Additional Installation and Design Guidelines

Crosswalk Markings

- High-visibility crosswalks may include a variety of crosswalk striping designs, such as ladder, continental, or bar pairs.
- High-visibility markings may be supplemented with the pedestrian crossing warning signs (sign W11-2 in the MUTCD) on each approach to the crosswalk.
- See MUTCD Section 2C.50 for more information about Non-Vehicular Warning Signs and Section 3B.18 for more information about crosswalk markings.
- Adjacent bus stops should be placed downstream of the crosswalk and not on the crosswalk approach.

Overhead Lighting

- Overhead lights placed in advance of uncontrolled crossings on both approaches illuminate the front of the pedestrian and avoid creating a silhouette.
- Consider placing the light fixtures 10 to 15 feet in advance of the crosswalk on both sides of the street.

Parking Restrictions and Curb Extensions

- Parking restrictions can include the removal of parking space markings or the installation of "no parking" signs or pavement markings.
- The minimum setback for parking restrictions is 20 feet in advance of the crosswalk where speeds are 25 mph or less, and 30 feet in advance of the crosswalk where speeds are between 26 and 35 mph.
- Curb extensions must not extend into travel lanes and should not block bicycle lanes.

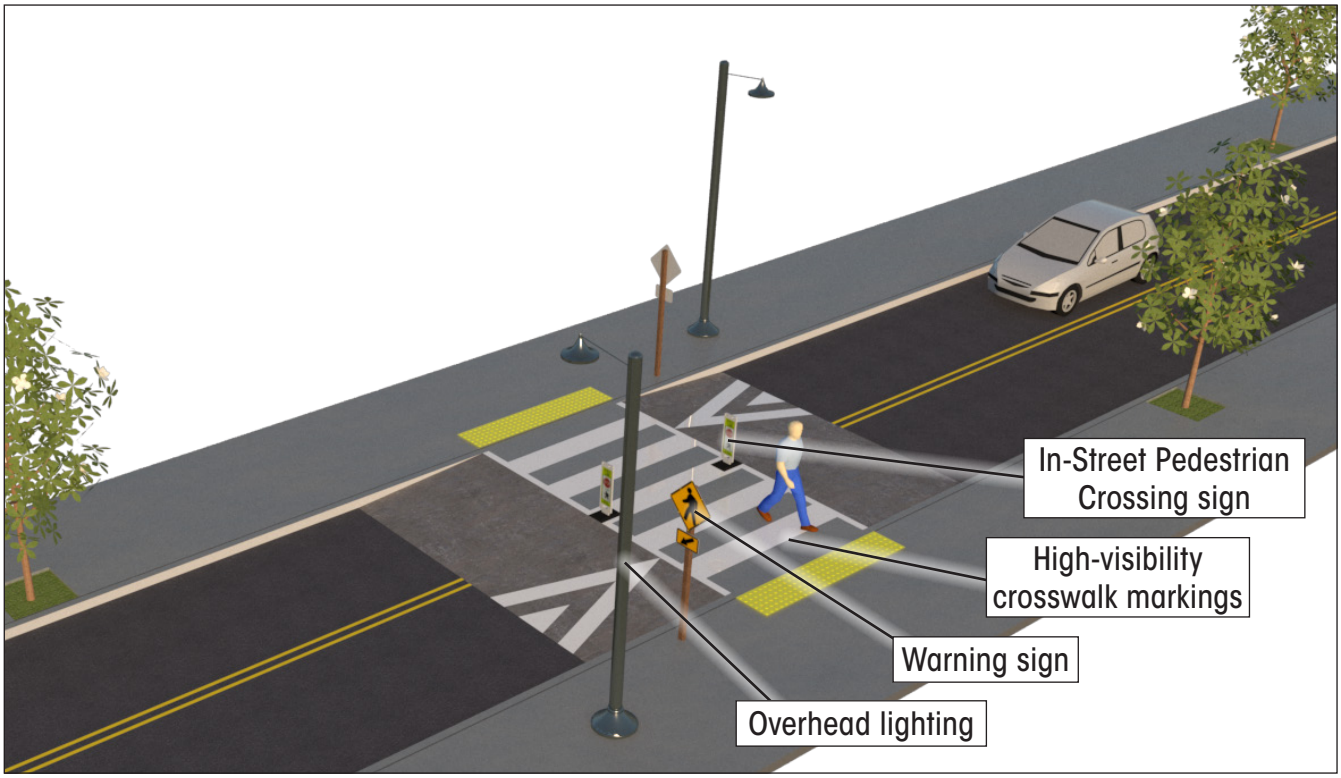
Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line

- The stop line or "shark's teeth" yield line is placed 20 to 50 feet in advance of a marked crosswalk to indicate where vehicles are required to stop or yield in compliance with the accompanying Yield Here To (Stop Here For) Pedestrians sign.
- 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. Otherwise, Yield Here for Pedestrians signs should be used with shark's teeth pavement markings.
- See MUTCD Section 2B.11 for more information about Yield Here To (Stop Here For) Pedestrians signs and Section 3B.16 for more information about stop and yield lines.

In-Street Pedestrian Crossing Sign

- The In-Street Pedestrian Crossing sign can be placed in between travel lanes or in conjunction with a refuge island or raised median.
- Consider maintenance and prompt replacement of damaged in-street (and all other) signs.
- See MUTCD Section 2B.12 for more information about In-Street Pedestrian Crossing signs.

Countermeasure: Raised Crosswalk



Definition

Raised crosswalks are ramped speed tables spanning the entire width of the roadway, often placed at midblock crossing locations. Refer to the Raised Crosswalks Tech Sheet for more information about this countermeasure.

Roadway and Site Information

Consider this countermeasure for 2 or 3 lane roadways also described by the following conditions:

- ☐ AADT < 9,000 + ≤ 30 mph speed limit

Safety Issues and Behaviors

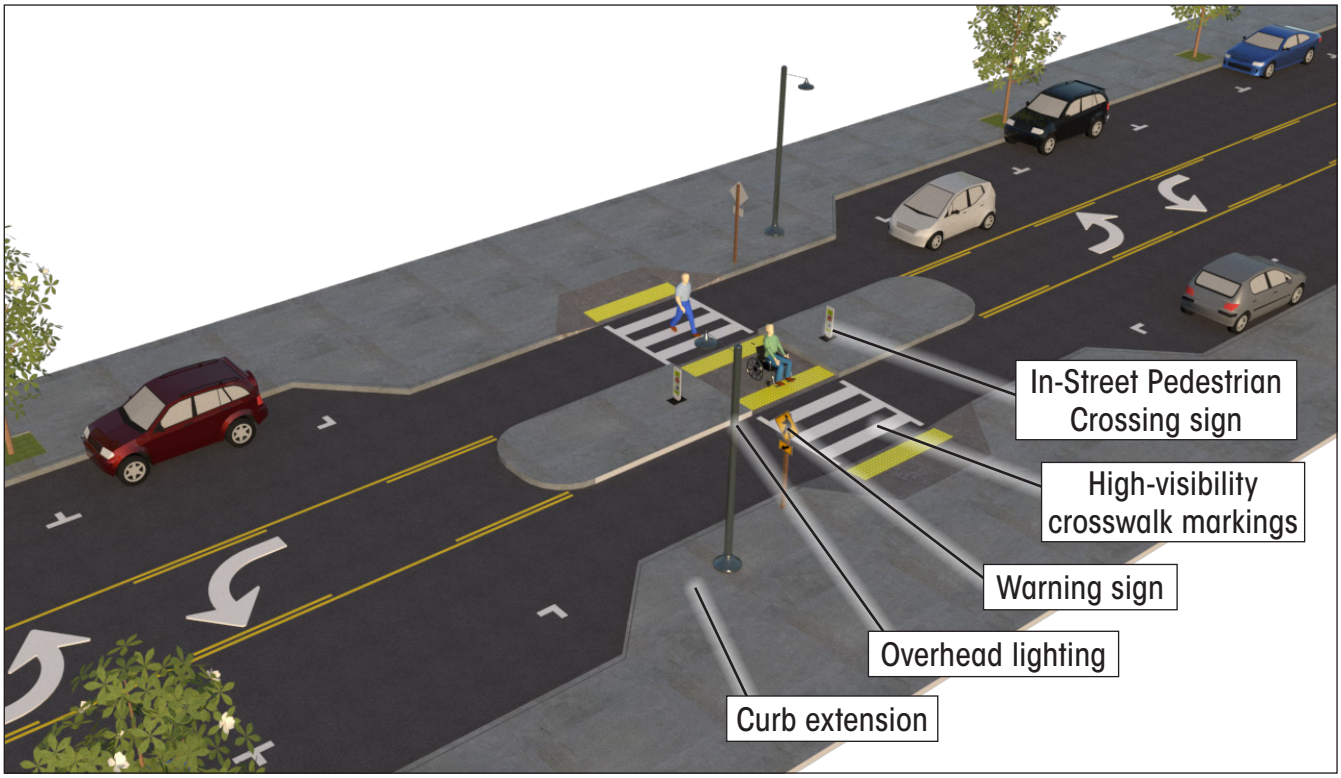
This countermeasure may help address the following traffic behaviors or safety issues observed at the site:

- ☐ Inadequate conspicuity/visibility
- ☐ Excessive vehicle speed

Installation and Design Guidelines

- Raised crosswalks may be installed with curb extensions and on-street parking.
- Raised crosswalks may also be used at intersections, particularly at the entrance of the minor street.
- Raised crosswalks should be flush with the height of the sidewalk.
- The crosswalk table is typically at least 10 feet wide and designed to allow the front and rear wheels of a passenger vehicle to be on top of the table at the same time.
- Detectable warnings (truncated domes) and curb ramps should be installed at the street edge for pedestrians with impaired vision.
- Raised crossings are generally avoided on arterial streets and primary routes for heavy trucks, bus transit, and emergency response vehicles.
- Consider storm water drainage and snowplowing in the design of the raised crosswalk.
- See MUTCD Section 3B.25 for information about Speed Hump Markings and other markings that can be used with raised crosswalks.

Countermeasure: Pedestrian Refuge Island



Definition

A pedestrian refuge island is 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. Refer to the Pedestrian Refuge Island Tech Sheet for more information about this countermeasure.

Roadway and Site Information

Consider this countermeasure for established pedestrian crossings at all 2 or 3 lane roadways without a raised median.

Strongly consider this countermeasure if the roadway(s) are described by one of the following sets of conditions:

- ☐ AADT ≥ 9,000 + 4 or more lanes without a raised median + any speed limit
- ☐ Any AADT + 4 or more lanes without a raised median + ≥ 35 mph speed limit

Safety Issues and Behaviors

This countermeasure may help address all traffic behaviors or safety issues but is most effective where the following are observed at the site:

- ☐ Inadequate conspicuity/visibility
- ☐ Excessive vehicle speed
- ☐ Insufficient pedstrian separation from traffic

Installation and Design Guidelines

» Consideration should be given to creating a two-stage crossing. The island can encourage pedestrians to cross one direction of traffic at a time and look towards oncoming traffic before completing the second part of the crossing.

» Pedestrian refuge islands should be at least 4 feet wide (preferably 8 feet) and of adequate length to allow the anticipated number of pedestrians to stand and wait for gaps in traffic before crossing.

» The cut-through of the island must include detectable warnings if island width is at least 6 feet.

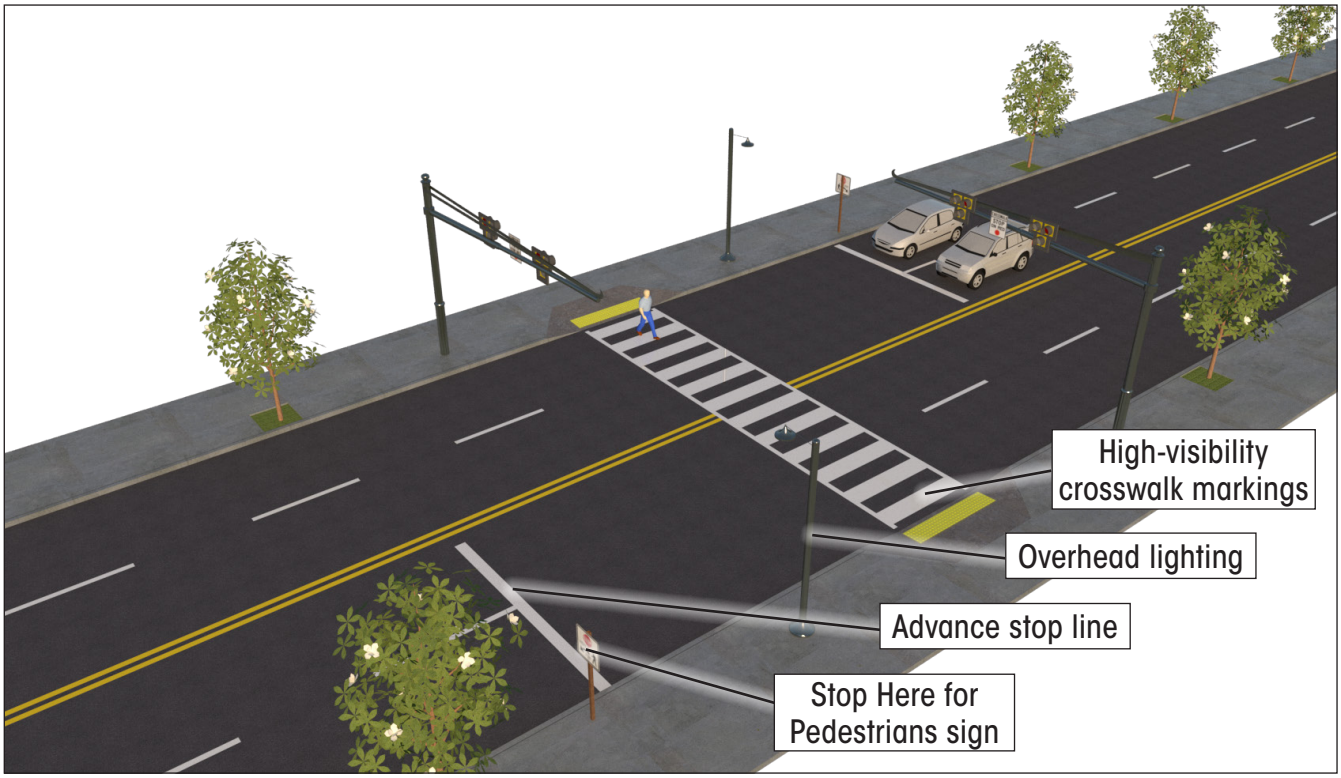
» Refuge islands should be illuminated or highlighted with street lights, signs, and/or reflectors to ensure that they are visible to motorists.

» See MUTCD Section 3B for more information about the following for refuge islands:

- Section 3B.10 - Approach Markings for Obstructions
- Section 3B.18 - Crosswalk Markings
- Section 3B.23 - Curb Markings

» If applicable, evaluate the impact of the island on bicycle facility design.

Countermeasure: Pedestrian Hybrid Beacon (PHB)



Definition

A PHB is a hybrid beacon used to control traffic and 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 indicate when pedestrians should cross and when it is safe for drivers to proceed. Refer to the PHB Tech Sheet for more information about this countermeasure.

Roadway and Site Information

Strongly consider this countermeasure if the roadway(s) are described by one of the following sets of conditions:

- ☐ AADT ≥ 15,000 + 4 or more lanes + any speed limit
- ☐ AADT ≥ 9,000 + 3 or more lanes (with or without median) + ≥ 35 mph speed limit
- ☐ Any AADT + any number of lanes + ≥ 40 mph speed limit

Safety Issues and Behaviors

This countermeasure may help address the following traffic behaviors or safety issues observed at the site:

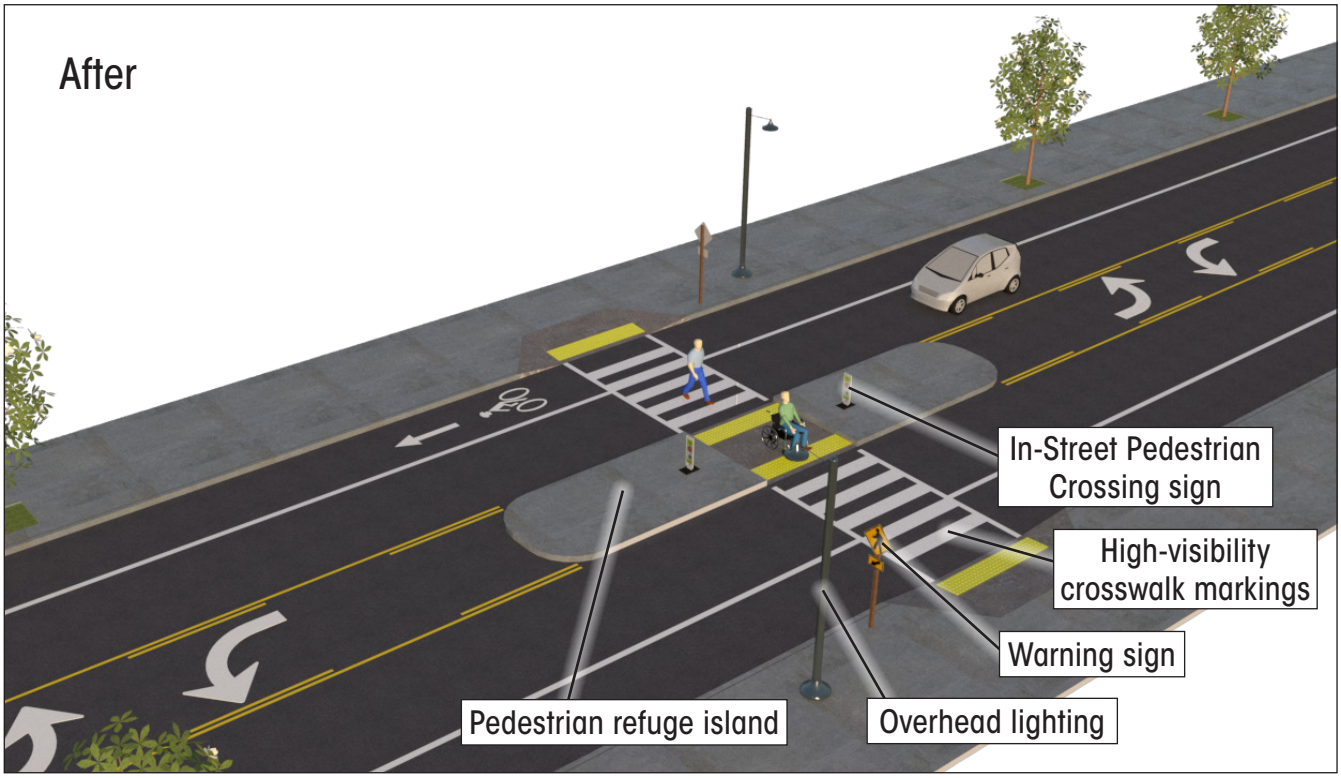
- ☐ Drivers not yielding to pedestrians in crosswalks
- ☐ Noted conflicts at crossing locations

Additional Installation and Design Guidelines

- Use in conjunction with signs and pavement markings at locations where pedestrians enter or cross the roadway.
- Only install a PHB at a marked crosswalk.
- For roadways with speeds of 35 mph or less, see *MUTCD Figure 4F-1*. For roadways speeds greater than 35 mph, see *MUTCD Figure 4F-2*. These charts compare crosswalk length, approximate vehicles per hour (VPH, including both approaches), and pedestrians per hour (PPH). The MUTCD recommends installation of a PHB where these conditions meet minimum criteria.
- The PHB should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs.
- Parking should be prohibited and other sight obstructions should be removed at least 100 feet in advance of and at least 20 feet beyond the marked crosswalk and PHB.
- The PHB should be coordinated if within a signal system.
- Review the MUTCD Part 4F for more information about the design and operation of the beacon face and the installation of optional signage.

Countermeasure: Road Diet





Definition

A Road Diet is a roadway reconfiguration resulting in a reduction in the number of travel lanes, which is usually achieved by converting a four-lane undivided road to three lanes. The space gained by eliminating lanes is typically used for other uses and travel modes. Refer to the Road Diet Tech Sheet for more information about this countermeasure.

Roadway and Site Information

Consider this countermeasure for all roadways with four or more lanes without a raised median.

Typically, Road Diets are considered for roadways with current and future average daily traffic (ADT) equal to or less than about 20,000.

Safety Issues and Behaviors

This countermeasure may help address the following traffic behaviors or safety issues observed at the site:

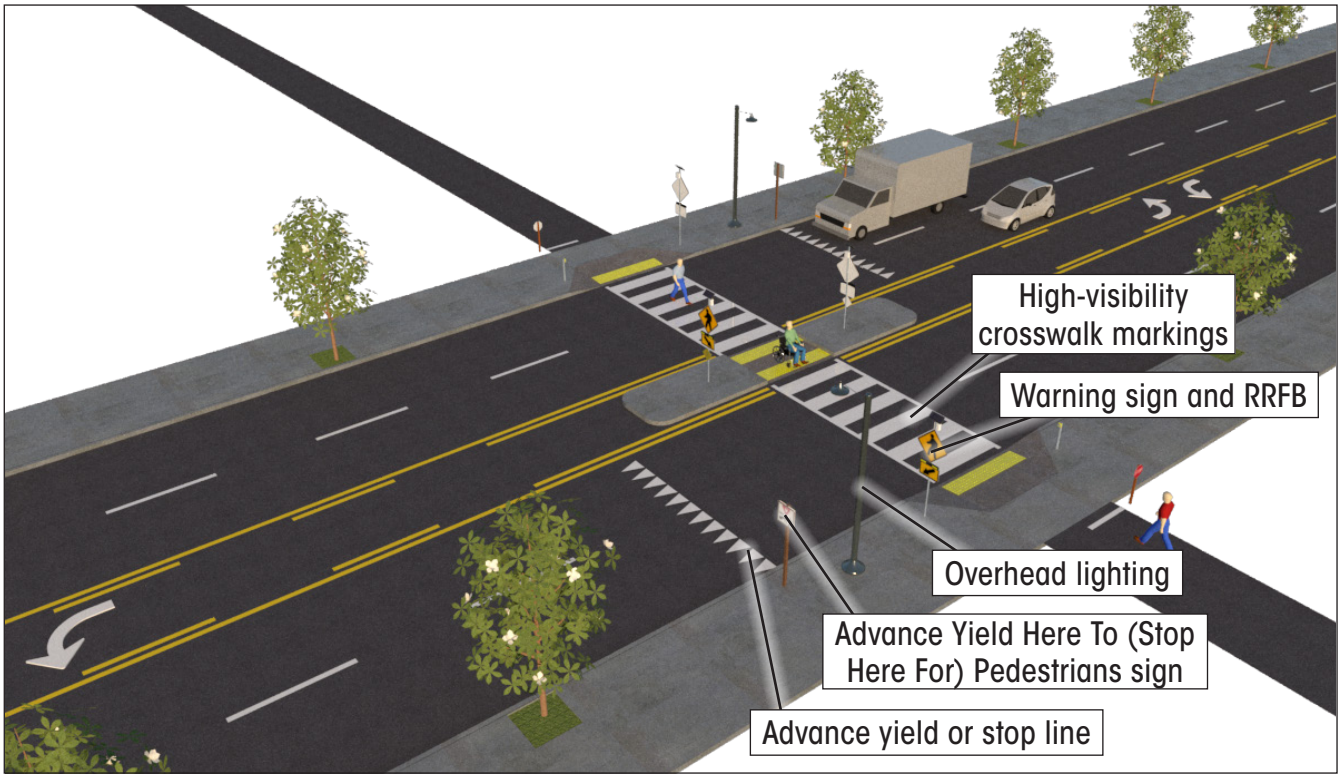
- ☐ Conflicts at crossing locations
- ☐ Excessive vehicle speeds
- ☐ Insufficient pedestrian separation from traffic

Additional Installation and Design Guidelines

Refer to the FHWA's Road Diet Informational Guide for a range of additional design considerations, including:

- » Vehicle speed
- » Level of Service (LOS)
- » Quality of Service
- » Operation and volume of pedestrians, bicyclists, transit, and freight
- » Peak hour and peak direction traffic flow
- » Vehicle turning volumes and patterns
- » Frequency of stopping and slow-moving vehicles
- » Presence of parallel roadways

Countermeasure: Rectangular Rapid-Flashing Beacon (RRFB)



Definition

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.

Roadway and Site Information

Strongly consider this countermeasure if the roadway(s) are described by one of the following sets of conditions:

- ☐ AADT ≤ 15,000 + 2 lanes or 3 lanes (with a raised median) + ≥ 40 mph speed limit
- ☐ AADT 9,000–15,000 + 3 or more lanes (with or without median) + ≥ 35 mph speed limit

In the following exceptions, strongly consider a PHB instead of the RRFB:

- ☐ AADT 9,000–15,000 + 3 lanes (without raised median) or more lanes + ≥ 40 mph speed limit

Safety Issues and Behaviors

This countermeasure may help address the following traffic behaviors or safety issues observed at the site:

- ☐ Noted conflicts at crossing locations
- ☐ Inadequate conspicuity/visibility of the crosswalk and pedestrian
- ☐ Insufficient pedestrian separation from traffic

Additional Installation and Design Guidelines

The RRFB is not currently included in the MUTCD. FHWA has issued interim approval for the optional use of the RRFB (Interim Approval 21 or IA-21). 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, accessibility features, and flashing requirements. IA-21 does not provide guidance or criteria based on number of lanes, speed, or traffic volumes.

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).

An RRFB shall only be used to supplement the following warning signs, located at or immediately adjacent to an uncontrolled marked crosswalk:

- » Post-mounted W11-2, S1-1, or W11-15 crossing warning sign with a (W16-7P) plaque *OR*
- » An overhead-mounted W11-2, S1-1, or W11-15 crossing warning sign.

See MUTCD Section 2C.50 Non-Vehicular Warning Signs and Section 7B.08 School Sign (S1-1) for more information about signs that may be used with an RRFB.


U.S. Department of Transportation
Federal Highway Administration


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


EDC



MAKING OUR ROADS SAFER

One Countermeasure at a Time

28 Proven Safety Countermeasures that offer significant and measurable impacts to improving safety

U.S. Department of Transportation
Federal Highway Administration

ZERO IS OUR GOAL
A SAFE SYSTEM IS HOW WE GET THERE

https://safety.fhwa.dot.gov/

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16. ABSTRACT

The Proven Safety Countermeasure Initiative (PSCi) is a collection of 28 countermeasures and strategieseffective in reducing roadway fatalities and serious injuries on our Nation's highways. Transportationagencies are strongly encouraged to consider widespread implementation of PSCs to accelerate theachievement of local, State, and National safety goals. This booklet provides 1-page handouts for all 28PSCs, broken into the focus areas of speed management, roadway departure, intersections,pedestrians/bicyclists, and crosscutting for countermeasures that apply across categories.

17. KEY WORDS	18. DISTRIBUTION STATEMENT		
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OFFICE OF SAFETY

Proven Safety Countermeasures

SPEED MANAGEMENT


Speed Safety Cameras



Variable Speed Limits



Appropriate Speed Limits for All Road Users

ROADWAY DEPARTURE


Wider Edge Lines


Enhanced Delineation for Horizontal Curves


Longitudinal Rumble Strips and Stripes on Two-Lane Roads


SafetyEdge℠


Roadside Design Improvements at Curves


Median Barriers

INTERSECTIONS


Backplates with Retroreflective Borders


Corridor Access Management


Dedicated Left- and Right-Turn Lanes at Intersections


Reduced Left-Turn Conflict Intersections


Roundabouts


Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections


Yellow Change Intervals

PEDESTRIANS/BICYCLES


Crosswalk Visibility Enhancements


Bicycle Lanes


Rectangular Rapid Flashing Beacons (RRFB)


Leading Pedestrian Interval


Medians and Pedestrian Refuge Islands in Urban and Suburban Areas


Pedestrian Hybrid Beacons


Road Diets (Roadway Reconfiguration)


Walkways

Crosscutting


Pavement Friction Management


Lighting


Local Road Safety Plans


Road Safety Audit

Introduction

Widespread use of the 28 Proven Safety Countermeasures (PSCs) identified in this booklet can offer significant, measurable impacts as part of any agency's approach to improving safety. These strategies are designed for all road users and all kinds of roads—from rural to urban, from high-volume freeways to less traveled two-lane State and county roads, from signalized crossings to horizontal curves, and everything in between. Each countermeasure addresses at least one safety focus area – speed management, intersections, roadway departures, or pedestrians/bicyclists – while others are crosscutting strategies that address multiple safety focus areas.

Between 2016 and 2020, 85 percent[1] of all public highway fatalities occurred on Federal-aid highways, which represent 25 percent[2] of the entire public highway network. FHWA's partner agencies have invested in highway safety through the Highway Safety Improvement Program (HSIP), which provides targeted safety funding that is eligible for use on all public roads. However, this dedicated funding source represents only about 6 percent of the total Federal-aid program.[3] Every transportation project, whether or not the specific project purpose is safety related, is a new opportunity to save lives on our roadways. The FHWA's Proven Safety Countermeasures are eligible under most Federal-aid highway funding programs, and can support state, local, and tribal agency efforts to effectively accomplish goals to reduce fatalities and serious injuries. These countermeasures should serve as the basis for what agencies consider and implement when designing any highway project to improve safety.

To assist practitioners with determining the most appropriate PSC for their location of interest, the PSC webpage includes a filter tool that allows users to obtain a tailored listing of potential PSCs. Users answer questions regarding area types, functional classification, traffic volumes, issue identified, targeted crash types, and other information to receive a list of PSCs meeting thecriteria. This search function is intended to better serve practitioners, including those with limited safety background, when identifying and considering treatments and strategies that can improve safety as part of their program or project.

The PSCs can support agencies with implementation of the Safe System Approach, which seeks to build and reinforce multiple layers of protection to both prevent crashes from happening and minimize the harm caused to those involved when crashes do occur. Implementing a Safe System Approach requires collaborative engagement among a diverse group of stakeholders to increase safety for all road users. Accordingly, agencies should consider how the PSCs and National Highway Traffic Safety Administration's (NHTSA) Countermeasures That Work[4] can create a system with redundancies in place to protect all road users. Reaching our goal of zero deaths and serious injuries requires all of us to take ownership in safety. Together, we can consider the safety needs at every stage of the project development process, the safety impact of every investment decision, and the appropriate safety countermeasures for every Federal-aid project.

1 NHTSA Fatality Analysis Reporting System (FARS) 2016-2020 Final
2 FHWA Highway Statistics 2022 (https://www.fhwa.dot.gov/policyinformation/statistics/2022/hm16.cfm)
3 Federal-aid apportioned programs under the Infrastructure Investment and Jobs Act (IIJA) (https://www.fhwa.dot.gov/bipartisan-infrastructure-law/funding.cfm)
4 Countermeasures That Work (https://www.nhtsa.gov/book/countermeasures/countermeasures-that-work)

Speed Safety Cameras

Safe Speeds is a core principle of the Safe System Approach since humans are less likely to survive high-speed crashes. Enforcing safe speeds has been challenging; however, with more information and tools communities can make progress in reducing speeds. Agencies can use speed safety cameras (SSCs) as an effective and reliable technology to supplement more traditional methods of enforcement, engineering measures, and education to alter the social norms of speeding. SSCs use speed measurement devices to detect speeding and capture photographic or video evidence of vehicles that are violating a set speed threshold.



Safety Benefits:

Fixed units can reduce crashes on urban principal arterials up to:

54% for all crashes.[4]

48% for injury crashes.[4]

P2P units can reduce crashes on urban expressways, freeways, and principal arterials up to:

37% for fatal and injury crashes.[2]

Mobile units can reduce crashes on urban principal arterials up to:

20% for fatal and injury crashes.[5]

In New York City, fixed units reduced speeding in school zones up to 63% during school hours.[6]

For more information on this and other FHWA Proven Safety Countermeasures, please reference the: Speed Safety Camera Program Planning and Operations Guide.

The contents of this Fact Sheet do not have the force and effect of law and are not meant to bind the public in any way. This Fact Sheet is intended only to provide clarity regarding existing requirements under the law or agency policies.

FHWA-SA-21-070

Applications

Agencies should conduct a network analysis of speeding-related crashes to identify locations to implement SSCs. The analysis can include scope (e.g., widespread, localized), location types (e.g., urban/suburban/rural, work zones, residential, school zones), roadway types (e.g., expressways, arterials, local streets), times of day, and road users most affected by speed-related crashes (e.g., pedestrians, bicyclists).

SSCs can be deployed as:

- **Fixed units**—a single, stationary camera targeting one location.
- **Point-to-Point (P2P) units**—multiple cameras to capture average speed over a certain distance.
- **Mobile units**—a portable camera, generally in a vehicle or trailer.

The table below describes suitable circumstances for SSC deployment.[1]

Considerations

- SSCs can produce a crash reduction upstream and downstream, thus generating a spillover effect.[2]
- Public trust is essential for any type of enforcement. With proper controls in place, SSCs can offer fair and equitable enforcement of speeding, regardless of driver age, race, gender, or socio-economic status. SSCs should be planned with community input and equity impacts in mind.
- Using both overt (i.e., highly visible) and covert (i.e., hidden) enforcement may encourage drivers to comply with limits everywhere, not only at sites they are aware are enforced.
- Agencies should conduct evaluations regularly to determine if SSCs are accomplishing safety goals and whether changes in strategy, scheduling, communications, or public engagement are necessary.
- Agencies should conduct a legal and policy review to determine if SSCs are authorized within a jurisdiction and how the authorization and other traffic laws will affect a SSC program.
- Agencies should develop an SSC program plan with consideration of the USDOT SSC guidelines for planning, public involvement, stakeholder coordination, implementation, maintenance, evaluation, etc.[3]

Considerations for Selection	Fixed	P2P	Mobile
Problems are long-term and site-specific.	X	X	—
Problems are network-wide, and shift based on enforcement efforts.	—	—	X
Speeds at enforcement site vary largely from downstream sites.	—	X	X
Overt enforcement is legally required.	X	X	X
Sight distance for the enforcement unit is limited.	X	X	—
Enforcement sites are multilane facilities.	X	X	—

1 Speed Safety Camera Program Planning and Operations Guide. FHWA, (2023).
2 (CMF ID: 7718) Montella et al. "Effects on speed and safety of point-to-point speed enforcement systems". Accident Analysis and Prevention, Vol. 75, (2015). Note that this is an international study.
3 Speed Enforcement Camera Systems Operational Guidelines. NHTSA, (2008).
4 (CMF ID: 2915,2921) Shin et al. "Evaluation of the Scottsdale Loop 101 automated speed enforcement demonstration program." Accident Analysis and Prevention, Vol. 41, (2009).
5 (CMF ID: 7582) Li et al. "A Before-and-After Empirical Bayes Evaluation of Automated Mobile Speed Enforcement on Urban Arterial Roads." Presented at the 94th Annual Meeting of the Transportation Research Board, Paper No. 15-1563, Washington, D.C., (2015). Note that this is an international study.
6 Automated Speed Enforcement Program Report 2014-2017. New York City DOT, (2018).



Variable Speed Limits

Selecting appropriate speed limits on roadways is important in maintaining a safe and efficient transportation network. Speed limits are established with an engineering study based on inputs like traffic volumes, operating speeds, roadway characteristics, and crash history. However, conditions on the roadway are susceptible to change in a short amount of time (e.g., congestion, crashes, weather). Drivers typically determine their operating speeds under normal weather conditions on a straight roadway section with good pavement quality and adequate sight distances. If ideal conditions do not exist and the roadway does not meet the driver's expectations, there is a greater chance that a driver error could result in a crash. Providing variable speeds limits (VSLs) capable of adapting to changing circumstances could reduce crash frequency and severity.

Speed management strategies, including VSLs, are integral to the Safe Speeds element of the Safe System Approach. Because humans are unlikely to survive high-speed crashes, VSLs reduce speeds so that human injury tolerances are accommodated in three ways: improving visibility, providing additional time for drivers to stop, and reducing impact forces.

Safety Benefits:

VSLs can reduce crashes on freeways up to:

34%
for total crashes.[1]

65%
for rear-end crashes.[1]

51%
for fatal and injury crashes.[1]

Benefit/Cost Ratios range between[1]

9:1 - 40:1

Applications

VSLs use prevailing information on the roadway, like traffic speed, volumes, weather, and road surface conditions, to determine appropriate speeds and display them to drivers. This strategy improves safety performance and traffic flow by reducing speed variance (i.e., improving speed harmonization). VSLs may also improve driver expectation by providing information in advance of slowdowns and potential lane closures, which could reduce the probability for secondary crashes. VSLs can mitigate adverse weather conditions or to slow faster-moving traffic as it approaches a queue or bottleneck.

Agencies can implement VSLs for the following applications:

CONGESTION

INCIDENTS

WORK ZONES

INCLEMENT WEATHER

Considerations

- Particularly effective on urban and rural freeways and high-speed arterials with posted speed limits greater than 40 mph.
- Often implemented as part of Active Traffic Management (ATM) plans or incorporated into existing Road Weather Information Systems.
- When used with ATM, VSLs can mitigate rear-end, sideswipe, and other crashes on high-speed roadways.
- May be implemented as a regulatory and/or an advisory system.
- Can be applied to an entire roadway segment or individual lanes.



Source: WSDOT

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/speed-management/reference-materials.

1 (CMF ID: 11002,11005,11003) Avelar et al. Developing Crash Modification Factors for Variable Speed Limit. FHWA, (2020).



Appropriate Speed Limits for All Road Users

There is broad consensus among global roadway safety experts that speed control is one of the most important methods for reducing fatalities and serious injuries. Speed is an especially important factor on non-limited access roadways where vehicles and vulnerable road users mix.

A driver may not see or be aware of the conditions within a corridor, and may drive at a speed that feels reasonable for themselves but may not be for all users of the system, especially vulnerable road users, including children and seniors. A driver traveling at 30 miles per hour who hits a pedestrian has a 45 percent chance of killing or seriously injuring them.[1] At 20 miles per hour, that percentage drops to 5 percent.[1] A number of cities across the United States, including New York, Washington, Seattle and Minneapolis, have reduced their local speed limits in recent years in an effort to reduce fatalities and serious injuries, with most having to secure State legislative authorization to do so.

States and local jurisdictions should set appropriate speed limits to reduce the significant risks drivers impose on others—especially vulnerable road users—and on themselves. Addressing speed is fundamental to the Safe System Approach to making streets safer, and a growing body of research shows that speed limit changes alone can lead to measurable declines in speeds and crashes.[2]

Safety Benefits:

Traffic fatalities in the City of Seattle decreased 26 percent after the city implemented comprehensive, city-wide speed management strategies and countermeasures inspired by Vision Zero. This included setting speed limits on all non-arterial streets at 20 mph and 200 miles of arterial streets at 25 mph.[5]

One study found that on rural roads, when considering other relevant factors in the engineering study along with the speed distribution, setting a speed limit no more than 5 mph below the 85th-percentile speed may result in fewer total and fatal plus injury crashes, and lead to drivers complying closely with the posted speed limit.[6]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/speed-management/reference-materials.

Applications

Posted speed limits are often the same as the legislative statutory speed limit. Agencies with designated authorities to set speed limits, which include States, and sometimes local jurisdictions, can establish non-statutory speed limits or designate reduced speed zones, and a growing number are doing so. While non-statutory speed limits must be based on an engineering study, conducted in accordance with the *Manual on Uniform Traffic Control Devices* (MUTCD) involving multiple factors and engineering judgment, FHWA is also encouraging agencies to use the following:[3]

- Expert Systems tools.
  - USLIMITS2.
  - NCHRP 966: Posted Speed Limit Setting Procedure and Tool.
- Safe System approach.

Based on international experience and implementation in the United States, the use of 20 mph speed zones or speed limits in urban core areas where vulnerable users share the road environment with motorists may result in further safety benefits.[4]

Considerations

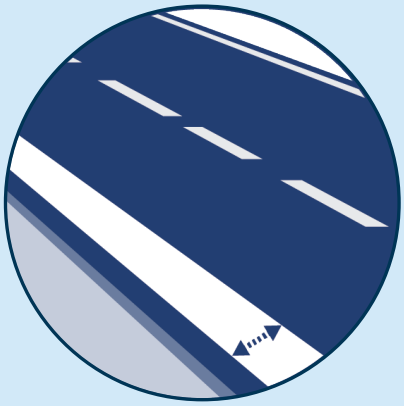
When setting a speed limit, agencies should consider a range of factors such as pedestrian and bicyclist activity, crash history, land use context, intersection spacing, driveway density, roadway geometry, roadside conditions, roadway functional classification, traffic volume, and observed speeds.

To achieve desired speeds, agencies often implement other speed management strategies concurrently with setting speed limits, such as self-enforcing roadways, traffic calming, and speed safety cameras. Additional information is in the following FHWA resources:

- FHWA Speed Management website.
- Self-Enforcing Roadways: A Guidance Report.
- Noteworthy Speed Management Practices.
- Jurisdiction Speed Management Action Plan Development Package.
- Traffic Calming ePrimer.

1 Reducing the speed limit to 20 mph in urban areas: Child deaths and injuries would be decreased.
2 Lowering the speed limit from 30 to 25 mph in Boston: effects on vehicle speeds.
3 FHWA's Methods and Practices for Setting Speed Limits: An Informational Report, (2012).
4 Recommendations of the Academic Expert Group for the 3rd Global Ministerial Conference on Road Safety.
5 https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa20047/sec8.cfm#foot813
6 Safety and Operational Impacts of Setting Speed Limits below Engineering Recommendations.

FHWA-SA-21-034



Safety Benefits:

Wider edge lines can reduce crashes up to:

37%
for non-intersection, fatal and injury crashes on rural, two-lane roads.[2]

22%
for fatal and injury crashes on rural freeways.[3]

Benefit Cost Ratio
25:1
for fatal and serious injury crashes on two-lane rural roads.[4]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/other/visibility/pavement-markings.

FHWA-SA-21-055

Wider Edge Lines

Roadway departures account for over half of all traffic fatalities in the United States. If drivers cannot clearly identify the edge of the travel lanes and see the road alignment ahead, the risk of roadway departure may be greater. Wider edge lines enhance the visibility of travel lane boundaries compared to traditional edge lines. Edge lines are considered "wider" when the marking width is increased from the minimum normal line width of 4 inches to the maximum normal line width of 6 inches.[1]

Applications

Wider edge lines increase drivers' perception of the edge of the travel lane and can provide a safety benefit to all facility types (e.g., freeways, multilane divided and undivided highways, two-lane highways) in both urban and rural areas.[2] Wider edge lines are most effective in reducing crashes on rural two-lane highways, especially for single-vehicle crashes.[3] Agencies should also consider implementing a systemic approach to wider edge line installation based roadway departure crash risk factors. Potential risk factors for two-lane rural roads include:

- Pavement and shoulder widths.
- Presence of curves.
- Traffic volumes.
- History of nighttime crashes.

Considerations

- Wider edge lines are relatively low cost.
- Wider edge lines can be implemented using existing equipment during maintenance procedures like re-striping and resurfacing, with the only cost increase being the additional material.
- Paint may have a lower initial cost, but more durable materials (e.g., thermoplastic) may result in a lower life cycle cost based on their longer service life.
- As the number of automated vehicles increases on roadways, wider edge lines may provide better guidance for these vehicles' sensors.



Source: Texas Transportation Institute

1 Manual on Uniform Traffic Control Devices (MUTCD), Section 3A.04. FHWA, (2023).
2 (CMF ID: 4737) Park et al. "Safety effects of wider edge lines on rural, two-lane highways." Accident Analysis and Prevention Vol. 48, pp.317-325, (2012).
3 Potts et al. Benefit/Cost Evaluation of MoDOT's Total Striping and Delineation Program: Phase II. Missouri Department of Transportation, (2011).
4 Abdel-Rahim et al. Safety Impacts of Using Wider Pavement Markings on Two-Lane Rural Highways in Idaho. Idaho Transportation Department, (2018).

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Safety Benefits:

Chevron Signs

25% reduction in nighttime crashes.[1]

16% reduction in non-intersection fatal and injury crashes.[2]

Oversized Chevron Signs

15% reduction in fatal and injury crashes.[3]

Sequential Dynamic Chevrons

60% reduction in fatal and injury crashes.[4]

In-Lane Curve Warning Pavement Markings

35 - 38% reduction in all crashes.[5]

New Fluorescent Curve Signs or Upgrade Existing Curve Signs to Fluorescent Sheeting

18% reduction in non-intersection, head-on, run-off-road, and sideswipe in rural areas.[1]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/keep-vehicles-road/horizontal-curve-safety.

FHWA-SA-21-035

Enhanced Delineation for Horizontal Curves

Enhanced delineation at horizontal curves includes a variety of potential strategies that can be implemented in advance of or within curves, in combination, or individually.

Potential Strategies	In Advance of Curve	Within Curve
Pavement markings (standard width or wider)	✓	✓
In-lane curve warning pavement markings	✓	
Retroreflective strips on sign posts	✓	✓
Delineators		✓
Chevron signs		✓
Enhanced Conspicuity (larger, fluorescent, and/or retroreflective signs)	✓	✓
Dynamic curve warning signs (including speed radar feedback signs)	✓	
Sequential dynamic chevrons		✓

Enhanced delineation treatments can alert drivers to upcoming curves, the direction and sharpness of the curve, and appropriate operating speed.

Agencies can take the following steps to implement enhanced delineation strategies:

1. Review signing practices and policies to ensure they comply with the Manual on Uniform Traffic Control Devices (MUTCD) principles of traffic control devices. Consistent practice for similar curves sets the appropriate driver expectancy.
2. Use the systemic approach to identify and treat problem curves. For example, Minnesota uses risk factors that include curve radii between 500 and 1,200 ft, traffic volumes between 500 and 1,000 vehicles per day, intersection in the curve, and presence of a visual trap.[1]
3. Match the appropriate strategy to the identified problem(s), considering the full range of enhanced delineation treatments. Once the MUTCD requirements and recommendations have been met, an incremental approach is often beneficial to avoid excessive cost.



Chevron signs with retroreflective strips on sign posts installed along a curve. Source: FHWA

1 (CMF ID: 2439,2431,2432) Albin et al. Low-Cost Treatments for Horizontal Curve Safety 2016. FHWA-SA-15-084, (2016).
2 (CMF ID: 2438) Srinivasan et al. Safety Evaluation of Improved Curve Delineation. FHWA-HRT-09-045, (2009).
3 (CMF ID: 8978) Lyon et al. Safety Evaluation of Two Curve Warning Treatments: In-Lane Curve Warning Pavement Markings and Oversized Chevron Signs. Presented at the 96th TRB Annual Meeting, Paper No. 17-00432, (2017).
4 (CMF ID: 10362) Hallmark, S. Evaluation of Sequential Dynamic Chevrons on Rural Two-lane Highways. FHWA, (2017).
5 (CMF ID: 10312,9167) Donnell et al. Reducing Roadway Departure Crashes at Horizontal Curve Sections on Two-lane Rural Highways. FHWA-SA-19-005, (2019).



Safety Benefits:

Center Line Rumble Strips

44-64%

reduction in head-on fatal and injury crashes on two-lane rural roads.[4]

Shoulder Rumble Strips

13-51%

reduction in single vehicle, run-off-road fatal and injury crashes on two-lane rural roads.[4]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/keep-vehicles-road/rumble-strips.

FHWA-SA-21-036

Longitudinal Rumble Strips and Stripes

Longitudinal rumble strips are milled or raised elements on the pavement intended to alert drivers through vibration and sound that their vehicle has left the travel lane. They can be installed on the shoulder, edge line, or at or near the center line of an undivided roadway.

Rumble stripes are edge line or center line rumble strips where the pavement marking is placed over the rumble strip. This can increase the visibility and durability of the pavement marking during wet, nighttime conditions, and can improve the durability of the marking on roads with snowplowing operations.

With roadway departure crashes accounting for more than half of the fatal roadway crashes annually in the United States, rumble strips and stripes are designed to address these crashes by alerting distracted, drowsy, or otherwise inattentive drivers who drift from their lane. They are most effective when deployed systemically.

Transportation agencies should consider milled center line rumble strips (including in passing zone areas) and milled edge line or shoulder rumble strips with bicycle gaps for systemic safety projects, location-specific corridor safety improvements, as well as reconstruction or resurfacing projects.

Considerations

- Rumble strips are relatively low-cost, and economic analyses have indicated benefit/cost ratios that exceed 100.[1]
- Where rumble strips cannot be placed due to noise concerns, agencies may consider a design using an oscillating sine wave pattern (also known as "mumble strips") that reduces noise outside of the vehicle. However, the safety benefits of this design need more study.[2]
- Maintenance concerns:
  - Where rumble strips are placed along a pavement joint, there are typically no issues with joint stability if the pavement structure and joint was already in good condition.
  - Studies have shown no evidence of issues related to snow, ice, or rain build-up in the rumble strip.[3]



Shoulder rumble strips and center line rumble stripes are installed on this roadway. Source: FHWA



Example of an edge line rumble stripe. Source: Missouri DOT

1 Himes, S., and McGee, H. Decision Support Guide for the Installation of Shoulder and Center Line Rumble Strips on Non-Freeways. Federal Highway Administration Report No. FHWA-SA-16-115. (August 2016).
2 Bedsole et al. *Did You Hear That?* Public Roads Magazine, Volume 80, No. 4. FHWA Publication No. FHWA-HRT-17-002, (2017).
3 NCHRP Synthesis 339: Centerline Rumble Strips – A Synthesis of Highway Practices, (2005
4 (CMF ID: 3358, 3356, 3425, 3648) NCHRP Report 641: Guidance for the Design and Application of Shoulder and Centerline Rumble Strips, (2009).

SafetyEdge^{SM}

The SafetyEdge^{SM} technology shapes the edge of the pavement at approximately 30 degrees from the pavement cross slope during the paving process. This safety practice eliminates the potential for vertical drop-off at the pavement edge, has minimal effect on project cost, and can improve pavement durability by reducing edge raveling of asphalt.

Safety Benefits:

11%
reduction in fatal and injury crashes.[2]

21%
reduction in run-off-road crashes.[2]

19%
reduction in head-on crashes.[2]

Benefit-Cost Ratio Range[3]

700:1 to 1,500:1

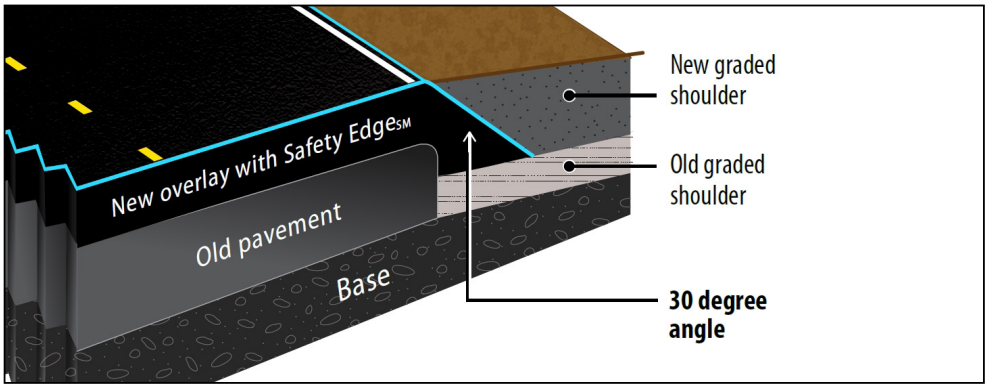
Rural road crashes involving edge drop-offs are 2-4 times more likely to include a fatality than other crashes on similar roads.[1] Vehicles may leave the roadway for various reasons ranging from distracted driver errors to low visibility, or to the presence of an animal on the road. Exposed vertical pavement edges can cause vehicles to become unstable and prevent their safe return to the roadway. The SafetyEdge^{SM} gives drivers the opportunity to return to their travel lane while maintaining control of their vehicle.

The SafetyEdge^{SM} technology only requires adding one of several commercially available devices to the screed or endgate when placing hot-mix asphalt. Forms for shaping the edge of concrete pavement are simpler and can be made on site by the contractor. Some agencies allow the SafetyEdge^{SM} to remain exposed while a segment is under construction, unlike conventional pavement edges. However, before construction ends, agencies should bring the adjacent roadside flush with the top of the pavement for both the SafetyEdge^{SM} and traditional pavement edge. Over time, regardless of the edge type, the edge may become exposed due to settling, erosion, and tire wear. When this occurs, the gentle slope provided by the SafetyEdge^{SM} is preferred versus the traditional vertical pavement edge.

Transportation agencies should develop standards for implementing the SafetyEdge^{SM} systemwide on all new asphalt paving and resurfacing projects where curbs and/or guardrail are not present, while also encouraging standard application for concrete pavements.



Example of the SafetyEdge^{SM} after backfill material settles or erodes. Source: FHWA



Cross-section view of an overlay with the SafetyEdge^{SM}. Source: FHWA-SA-17-044

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/provide-safe-recovery/safetyedge.

FHWA-SA-21-038

1 Hallmark et al. Safety Impacts of Pavement Edge Drop-offs, (Washington, DC: AAA Foundation for Traffic Safety: 2006), p 93.
2 (CMF ID: 9205, 9211, 9217) Donnell et al. Development of Crash Modification Factors for the Application of the SafetyEdge^{SM} on Two-Lane Rural Roads. FHWA-HRT-17-081, (2017).
3 Safety Effects of the SafetyEdge^{SM}, FHWA-SA-17-044, (2017).



Safety Benefits:

Flatten sideslope from 1V:3H to 1V:4H:

8%

reduction for single-vehicle crashes.[2]

Flatten sideslope from 1V:4H to 1V:6H:

12%

reduction for single-vehicle crashes.[2]

Increase the distance to roadside features from 3.3 ft to 16.7 ft:

22%

reduction for all crashes.[3]

Increase the distance to roadside features from 16.7 ft to 30 ft:

44%

reduction for all crashes.[3]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/provide-safe-recovery/clear-zones/clear-zones.

FHWA-SA-21-029

Roadside Design Improvements at Curves

Horizontal curves account for 27 percent of all fatal crashes and 80 percent of all fatal crashes at curves are roadway departure crashes.[1] Roadside design improvements at curves is a strategy encompassing several treatments that target the high-risk roadside environment along the outside of horizontal curves. These treatments can reduce roadway departure fatalities and serious injuries by giving vehicles the opportunity to recover safely and by reducing crash severity.

Roadside design improvements can be implemented alone or in combination, and are particularly recommended at horizontal curves—where data indicates a higher risk for roadway departure fatalities and serious injuries.

Roadside Design Improvements to Provide for a Safe Recovery

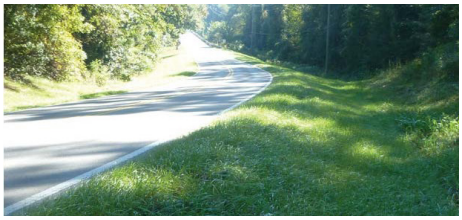
In cases where a vehicle leaves the roadway, having strategic roadside design elements, including an added or widened shoulder, flattened sideslopes, or a widened clear zone can provide drivers with an opportunity to regain control and re-enter the roadway in their lane or come to a safe stop before rolling over or encountering a fixed object.

- A **clear zone** is an unobstructed, traversable roadside area that allows a driver to stop safely or regain control of a vehicle that has left the roadway. Agencies should avoid adding new fixed objects such as trees and utility cabinets or poles in the clear zone. AASHTO's *Roadside Design Guide* details the clear zone width adjustment factors to be applied at horizontal curves.
- **Slope flattening** reduces the steepness of the sideslope to increase drivers' ability to keep the vehicle stable, regain control of the vehicle, and avoid obstacles. Slopes of 1V:4H or flatter are considered recoverable (i.e., drivers can retain control of a vehicle by slowing or stopping). Slopes between 1V:3H and 1V:4H are generally considered traversable, but non-recoverable (i.e., errant vehicle will continue to the bottom of the slope).
- **Adding or widening shoulders** gives drivers more recovery area to regain control in the event of a roadway departure.

Roadside Design Improvements to Reduce Crash Severity

Since not all roadside hazards can be removed, relocated, or redesigned at curves, installing roadside barriers to shield unmovable objects or steep embankments may be an appropriate treatment. Three common types of roadside barriers are:

- **Cable barrier** is a flexible barrier made from steel cables mounted on weak steel posts. Flexible barriers are more forgiving and have the most deflection.
- **Metal-beam guardrail** is a semi-rigid barrier where a W-beam or box-beam is mounted on steel or timber posts. These deflect less than cable barriers, so they can be located closer to objects where space is limited.
- **Concrete barrier** is a rigid barrier that has little to no deflection.



Clear zone provided on the outside of the curve. Source: FHWA.

1 Fatality Analysis Reporting System.
2 (CMF ID: 4627,4632) NCHRP Report 617: Accident Modification Factors for Traffic Engineering and ITS Improvements, (2008).
3 (CMF ID: 35,36) Elvik, R., and Vaa, T. Handbook of Road Safety Measures, (2004).



8%

of all fatalities on divided highways are due to head-on crashes.[1]

Safety Benefits:

Median Barriers Installed on Rural Four-Lane Freeways

97%

reduction in cross-median crashes.[2]

Median Barriers

Median barriers are longitudinal barriers that separate opposing traffic on a divided highway and are designed to redirect vehicles striking either side of the barrier. Median barriers significantly reduce the number of cross-median crashes, which are attributed to the relatively high speeds that are typical on divided highways. AASHTO's ***Roadside Design Guide*** (RDG) recommends guidelines for the use of median barriers on high-speed, fully controlled-access roadways for locations where the median is 30 ft in width or less and the average daily traffic (ADT) is greater than 20,000 vehicles per day (vpd). For locations with median widths greater than 50 ft and where the ADT is less than 20,000 vpd, a median barrier is optional. For locations where the median is between 30 and 50 feet, the RDG suggests an analysis to determine the cost effectiveness of median barrier installation. Median barriers can be cable, metal-beam, or concrete.

- **Cable barriers** are flexible barriers, made from steel cables mounted on weak steel posts, resulting in less occupant impact force as it absorbs energy from the crash, capturing or redirecting the vehicle. Due to larger deflection, median width is an important consideration. These barriers are more adaptable to slopes typically found in medians. Cable barriers tend to require more frequent maintenance and repair than other barrier types.
- **Metal-beam guardrails** are considered semi-rigid barriers, where the W-beam or box-beam is mounted to steel or timber posts. When impacted, they are designed to deform and deflect, absorbing some of the crash energy and redirecting the vehicle. Metal-beam guardrails often do not require maintenance after minor impacts. They deflect less than cable barriers, so they can be located closer to objects where space is limited.
- **Concrete barriers** are usually rigid and result in little to no deflection. They redirect rather than absorb energy from the impact. Rigid concrete barriers seldom require repair or maintenance. Some agencies have used portable concrete barriers as median barriers. These barriers require repositioning after an impact but are typically less maintenance than a post mounted barrier.

To reduce cross-median crashes, transportation agencies should review their head-on crash history on divided highways to identify hot spots. Agencies should also consider implementing a systemic approach to median barrier placement based on cross-median crash risk factors. Potential risk factors include:

- Traffic volumes.
- Vehicle classifications.
- Median crossover history.
- Crash incidents.
- Vertical and horizontal alignment.
- Median terrain configurations.



Median cable barrier prevents a potential head-on crash.
Source: Washington State DOT

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/reduce-crash-severity.

1 Fatality Analysis Reporting System.
2 (CMF ID: 7040) NCHRP Report 794: Median Cross-Section Design for Rural Divided Highways, (2011).

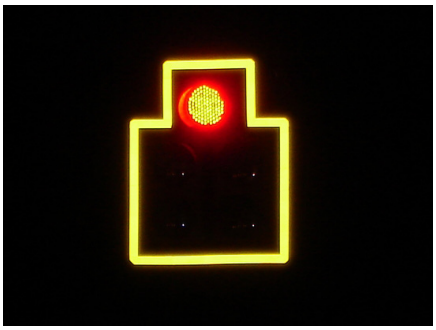
Backplates with Retroreflective Borders

Backplates added to a traffic signal head improve the visibility of the illuminated face of the signal by introducing a controlled-contrast background. The improved visibility of a signal head with a backplate is made even more conspicuous by framing it with a 1- to 3-inch yellow retroreflective border. Signal heads that have backplates equipped with retroreflective borders are more visible and conspicuous in both daytime and nighttime conditions.

Safety Benefits:

15%
reduction in total crashes.[1]

This treatment is recognized as a human factors enhancement of traffic signal visibility, conspicuity, and orientation for both older and color vision deficient drivers. This countermeasure is also advantageous during periods of power outages when the signals would otherwise be dark, providing a visible cue for motorists to stop at the intersection ahead.



Retroreflective borders are highly visible during the night. Source: South Carolina DOT

Considerations

Transportation agencies should consider backplates with retroreflective borders as part of their efforts to systematically improve safety performance at signalized intersections. Adding a retroreflective border to an existing signal backplate is a very low-cost safety treatment. This can be done by either adding retroreflective tape to an existing backplate or purchasing a new backplate with a retroreflective border already incorporated. The most efficient means of implementing this proven safety countermeasure is to adopt it as a standard treatment for signalized intersections across a jurisdiction or State.

Implementation challenges include minimizing installation time, accessing existing signal heads, and structural limitations due to added wind load in instances where an entire backplate is added. Agencies should consider the design of the existing signal support structure to determine if the design is sufficient to support the added wind load.



Signal backplate framed with a retroreflective border. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://rosap.ntl.bts.gov/view/dot/42807.

1 (CMF ID: 1410) Sayed, T., Leur, P., and Pump, J., "Safety Impact of Increased Traffic Signal Backboards Conspicuity." 2005 TRB 84th Annual Meeting: Compendium of Papers CD-ROM, Vol. TRB#05-16, Washington, D.C., (2005).

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Safety Benefits:

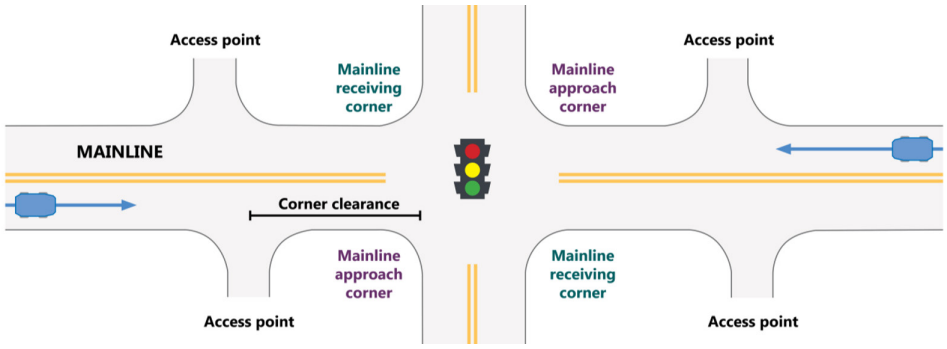
Reducing driveway density

5-23%
reduction in total crashes along 2-lane rural roads.[3]

25-31%
reduction in fatal and injury crashes along urban/ suburban arterials.[4]

Corridor Access Management

Access management refers to the design, application, and control of entry and exit points along a roadway. This includes intersections with other roads and driveways that serve adjacent properties. Thoughtful access management along a corridor can simultaneously enhance safety for all modes, facilitate walking and biking, and reduce trip delay and congestion.



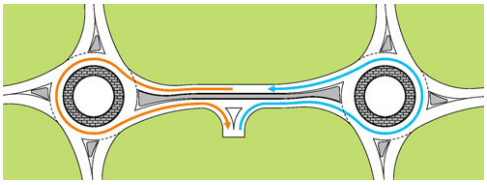
Schematic of an intersection and adjacent access points. Source: FHWA

Every intersection, from a signalized intersection to an unpaved driveway, has the potential for conflicts between vehicles, pedestrians, and bicyclists. The number and types of conflict points—locations where the travel paths of two users intersect—influence the safety performance of the intersection or driveway. FHWA developed corridor-level crash prediction models to estimate and analyze the safety effects of selected access management techniques for different area types, land uses, roadway variables, and traffic volumes.[1]

The following access management strategies can be used individually or in combination with one another:

- Reduce density through driveway closure, consolidation, or relocation.
- Manage spacing of intersection and access points.
- Limit allowable movements at driveways (such as right-in/ right-out only).
- Place driveways on an intersection approach corner rather than a receiving corner, which is expected to have fewer total crashes.[2]
- Implement raised medians that preclude across-roadway movements.
- Utilize designs such as roundabouts or reduced left-turn conflicts (such as restricted crossing U-turn, median U-turns, etc.).
- Provide turn lanes (i.e., left-only, right-only, or interior two-way left).
- Use lower speed one-way or two-way off-arterial circulation roads.

Successful corridor access management involves balancing overall safety and mobility for all users along with the needs of adjacent land uses.



Tandem roundabouts with a continuous raised median eliminates left-turn and across-roadway conflicts. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/intersection-safety/cam.

1 Gross et al. Safety Evaluation of Access Management Policies and Techniques. FHWA-HRT-14-057, (2018).
2 Le et al. Safety Evaluation of Corner Clearance at Signalized Intersections. FHWA-HRT-17-084, (2018).
3 Harwood et al. Prediction of the Expected Safety Performance of Rural Two-Lane Highways. FHWA-RD-99-207, (2000).
4 (CMF ID: 179,178) Elvik, R. and Vaa, T., Handbook of Road Safety Measures. Oxford, United Kingdom, Elsevier, (2004).

FHWA-SA-21-040

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Dedicated Left- and Right-Turn Lanes at Intersections

Auxiliary turn lanes—either for left turns or right turns—provide physical separation between turning traffic that is slowing or stopped and adjacent through traffic at approaches to intersections. Turn lanes can be designed to provide for deceleration prior to a turn, as well as for storage of vehicles that are stopped and waiting for the opportunity to complete a turn.

Safety Benefits:

Left-Turn Lanes

28-48%

reduction in total crashes.[1]

Positive Offset Left-Turn Lanes

36%

reduction in fatal and injury crashes.[2]

Right-Turn Lanes

14-26%

reduction in total crashes.[1]



Left- and right-turn lanes at a two-way stop-controlled intersection. Source: City of Greeley, CO

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://www.fhwa.dot.gov/publications/research/safety/02103/02103techbrief.pdf.

FHWA-SA-21-041

While turn lanes provide measurable safety and operational benefits at many types of intersections, they are particularly helpful at two-way stop-controlled intersections. Crashes occurring at these intersections are often related to turning maneuvers. Since the major route traffic is free flowing and typically travels at higher speeds, crashes that do occur are often severe. The main crash types include collisions of vehicles turning left across opposing through traffic and rear-end collisions of vehicles turning left or right with other vehicles following closely behind. Turn lanes reduce the potential for these types of crashes.

Installing left-turn lanes and/or right-turn lanes should be considered for the major road approaches for improving safety at both three- and four-leg intersections with stop control on the minor road, where significant turning volumes exist, or where there is a history of turn-related crashes. Pedestrian and bicyclist safety and convenience should also be considered when adding turn lanes at an intersection. Specifically, offset left- and right-turn lanes will lengthen crossing distances for pedestrians.

Offset Turn Lanes

Providing offset of left- and right-turn lanes to increase visibility can provide added safety benefits, and is preferable in many situations, particularly at locations with higher speeds, or where free-flow or permissive movements are possible.

At turn lanes with zero or negative offset, turning vehicles can block sightlines. For left-turn lanes, this usually involves opposing left-turning vehicles occupying the turn lanes at the same time. For right-turn lanes, this typically involves right-turning vehicles from the major road and vehicles entering the intersection from the minor road. In both scenarios, adding positive offset to turn lanes enhances the sight distance to approaching vehicles that conflict with the turning movement. Offset turn lanes should be considered when there is a high frequency of these types of conflicts in order to reduce the likelihood of a severe crash.

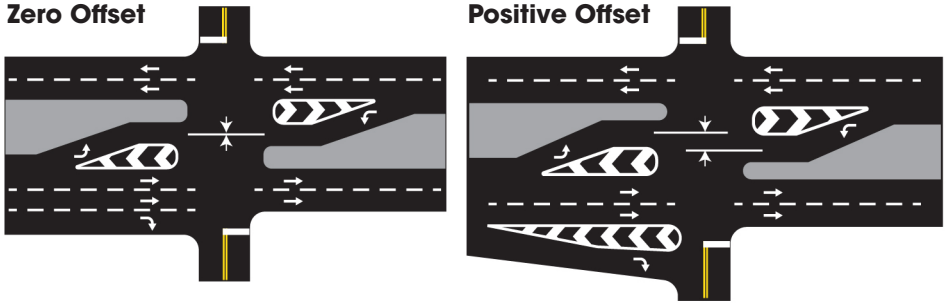


Illustration comparing zero offset to positive offset of left- and right-turn lanes. Source: FHWA

1 (CMF ID: 260, 268, 285, 289) Harwood et al. Safety Effectiveness of Intersection Left- and Right-Turn Lanes. FHWA-HRD-02-089, (2002).
2 (CMF ID: 6096) Persaud et al. Safety Evaluation of Offset Improvements for Left-Turn Lanes. FHWA-HRT-09-035, (2009).

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Safety Benefits:

RCUT

Two-Way Stop-Controlled to RCUT:

54%

reduction in fatal and injury crashes.[2]

Signalized Intersection to Signalized RCUT:

22%

reduction in fatal and injury crashes.[3]

Unsignalized Intersection to Unsignalized RCUT:

63%

reduction in fatal and injury crashes. [4]

MUT

30%

reduction in intersection-related injury crash rate.[5]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/intersection-safety/intersection-types/reduced-left-turn-conflict-intersections.

FHWA-SA-21-030

Reduced Left-Turn Conflict Intersections

Reduced left-turn conflict intersections are geometric designs that alter how left-turn movements occur. These intersections simplify decision-making for drivers and minimize the potential for higher severity crash types, such as head-on and angle. Two highly effective designs that rely on U-turns to complete certain left-turn movements are known as the Restricted Crossing U-turn (RCUT) and the Median U-turn (MUT).

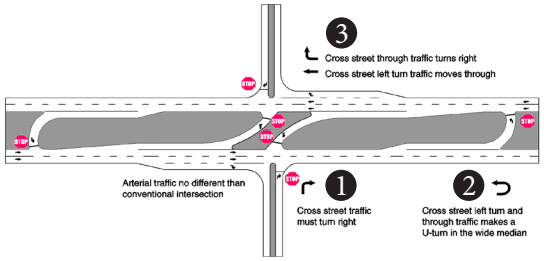
Restricted Crossing U-turn

The RCUT intersection, also known as a J-Turn, Superstreet, or Reduced Conflict Intersection, modifies the direct left-turn and through movements from cross-street approaches. Minor road traffic makes a right turn followed by a U-turn at a designated location—either signalized or unsignalized—to continue in the desired direction. The RCUT is suitable for and adaptable to a wide variety of circumstances, ranging from isolated rural, high-speed locations to urban and suburban high-volume, multimodal corridors. It is a competitive and less costly alternative to constructing an interchange. RCUTs work well when consistently used along a corridor, but also can be used effectively at individual intersections. Studies have shown that installing an RCUT can result in a 30-percent increase in throughput and a 40-percent reduction in network intersection travel time.[1]

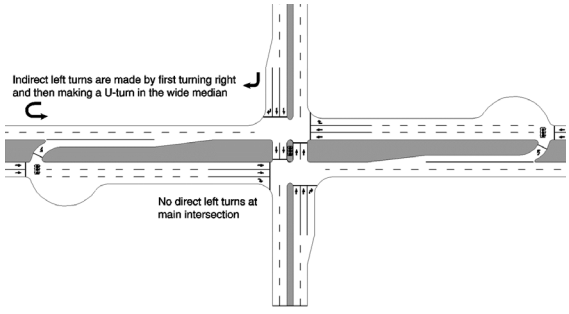
Median U-turn

The MUT intersection modifies direct left turns from the major approaches. Vehicles proceed through the main intersection, make a U-turn a short distance downstream, followed by a right turn at the main intersection. The U-turns can also be used for modifying the cross-street left turns, similar to the RCUT.

The MUT is an excellent choice for intersections with heavy through traffic and moderate left-turn volumes. Studies have shown a 20- to 50-percent improvement in intersection throughput for various lane configurations as a result of implementing the MUT design. When implemented at multiple intersections along a corridor, the efficient two-phase signal operation of the MUT can reduce delay, improve travel times, and create more crossing opportunities for pedestrians and bicyclists.



Example of a unsignalized RCUT intersection. Source: FHWA



Example of a MUT intersection. Source: FHWA

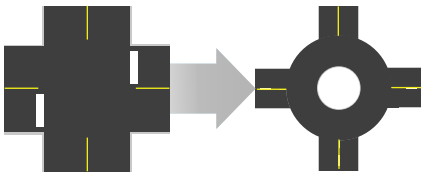
1 Hugher and Jagannathan. Restricted Crossing U-Turn Intersection. FHWA-HRT-09-059, (2009).
2 (CMF ID: 5556) Edara et al. Evaluation of J-turn Intersection Design Performance in Missouri. MoDOT, (2013).
3 (CMF ID: 9985) Hummer and Rao. Safety Evaluation of a Signalized Restricted Crossing U-Turn. FHWA-HRT-17-082, (2017).
4 (CMF ID: 4884) Hummer et al. Superstreet Benefits and Capacities. FHWA/NC/2009-06, NC State University, (2010).
5 (CMF ID: 10867) Synthesis of the Median U-Turn Treatment, Safety, and Operational Benefits, FHWA-HRT-07-033, (2007).

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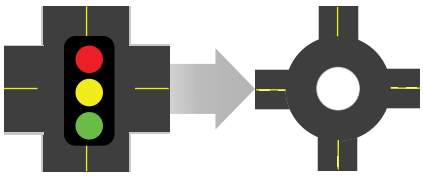
Safety Benefits:

Two-Way Stop-Controlled Intersection to a Roundabout



82%
reduction in fatal and injury crashes.[1]

Signalized Intersection to a Roundabout



78%
reduction in fatal and injury crashes.[1]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/intersection-safety/intersection-types/roundabouts.

FHWA-SA-21-042

Roundabouts

The modern roundabout is an intersection with a circular configuration that safely and efficiently moves traffic. Roundabouts feature channelized, curved approaches that reduce vehicle speed, entry yield control that gives right-of-way to circulating traffic, and counterclockwise flow around a central island that minimizes conflict points. The net result of lower speeds and reduced conflicts at roundabouts is an environment where crashes that cause injury or fatality are substantially reduced.

Roundabouts are not only a safer type of intersection; they are also efficient in terms of keeping people moving. Even while calming traffic, they can reduce delay and queuing when compared to other intersection alternatives. Furthermore, the lower vehicular speeds and reduced conflict environment can create a more suitable environment for walking and bicycling.

Roundabouts can be implemented in both urban and rural areas under a wide range of traffic conditions. They can replace signals, two-way stop controls, and all-way stop controls. Roundabouts are an effective option for managing speed and transitioning traffic from high-speed to low-speed environments, such as freeway interchange ramp terminals, and rural intersections along high-speed roads.

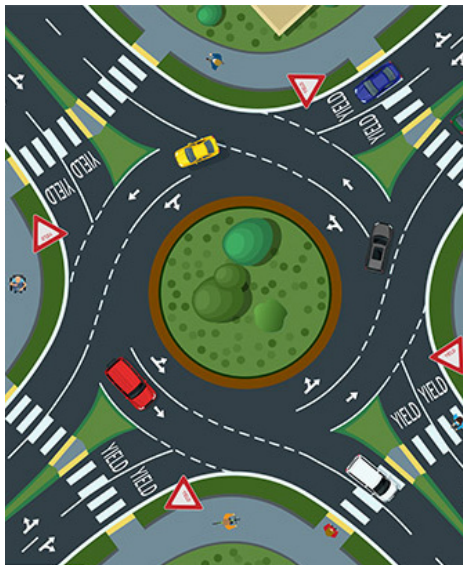


Illustration of a multilane roundabout. Source: FHWA



Example of a single-lane roundabout. Source: FHWA

1 (CMF ID: 211,226) AASHTO. The Highway Safety Manual, American Association of State Highway Transportation Professionals, Washington, D.C., (2010).

U.S. Department of Transportation
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Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

This systemic approach to intersection safety involves deploying a package of multiple low-cost countermeasures, including enhanced signing and pavement markings, at a large number of stop-controlled intersections within a jurisdiction. These countermeasures increase driver awareness and recognition of the intersections and potential conflicts.

Safety Benefits:

10%
reduction of fatal and injury crashes at all locations/types/areas.

15%
reduction of nighttime crashes at all locations/types/areas.

27%
reduction of fatal and injury crashes at rural intersections.

19%
reduction of fatal and injury crashes at 2-lane by 2-lane intersections.

Average Benefit-Cost Ratio

12:1

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa18047.pdf.

FHWA-SA-21-031

There are several benefits to systemically applying multiple low-cost countermeasures at stop-controlled intersections, including,

- Resources are maximized because the treatments are low cost.
- A high number of intersections can receive treatment.
- Improvements are highly cost-effective, with an average benefit-cost ratio of 12:1, even assuming a conservative 3-year service life.



Example of countermeasures on the through approach.
Source: South Carolina DOT



Example of countermeasures on the stop approach.
Source: South Carolina DOT

The low-cost countermeasures for stop-controlled intersections generally consist of the following treatments:

On the Through Approach

- Doubled-up (left and right), oversized advance intersection warning signs, with supplemental street name plaques (can also include flashing beacon).
- Retroreflective sheeting on sign posts.
- Enhanced pavement markings that delineate through lane edge lines.

On the Stop Approach

- Doubled-up (left and right), oversized advance "Stop Ahead" intersection warning signs (can also include flashing beacon).
- Doubled-up (left and right), oversized Stop signs.
- Retroreflective sheeting on sign posts.
- Properly placed stop bar.
- Removal of vegetation, parking, or obstructions that limit sight distance.
- Double arrow warning sign at stem of T-intersections.

Source: (CMF ID: 8867, 8870, 8874, 8893) T. Le et al. "Safety Effects of Low-Cost Systemic Safety Improvements at Signalized and Stop-Controlled Intersections," 96th Annual Meeting of the Transportation Research Board, Paper Number 17-05379, January 2017.



Safety Benefits:

36-50%
reduction in red light running.[3]

8-14%
reduction in total crashes.[3]

12%
reduction in injury crashes.[3]

Yellow Change Intervals

At a signalized intersection, the yellow change interval is the length of time that the yellow signal indication is displayed following a green signal indication. The yellow signal confirms to motorists that the green has ended and that a red will soon follow.

Since red-light running is a leading cause of severe crashes at signalized intersections, it is imperative that the yellow change interval be appropriately timed. Too brief an interval may result in drivers being unable to stop safely and cause unintentional red-light running. Too long of an interval may result in drivers treating the yellow as an extension of the green phase and invite intentional red-light running. Factors such as the speed of approaching and turning vehicles, driver perception-reaction time, vehicle deceleration, and intersection geometry should all be considered in the timing calculation.

Transportation agencies can improve signalized intersection safety and reduce red-light running by reviewing and updating their traffic signal timing policies and procedures concerning the yellow change interval. Agencies should institute regular evaluation and adjustment protocols for existing traffic signal timing. Refer to the *Manual on Uniform Traffic Control Devices* for basic requirements and further recommendations about yellow change interval timing.[1] As part of strategic signal system modernization and updates, incorporating automated traffic signal performance measures (ATSPMs) is a proven approach to improve on traditional retiming processes. ATSPMs provide continuous performance monitoring capability and the ability to modify timing based on actual performance, without requiring expensive modeling or data collection.[2]



Appropriately timed yellow change intervals can reduce red-light running and improve overall intersection safety. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa13027.pdf.

1 Manual on Uniform Traffic Control Devices (MUTCD), Section 4F.17. FHWA, (2023).
2 Federal Highway Administration. "Automated Traffic Signal Performance," (2020).
3 (CMF ID: 380,384) NCHRP Report 731: Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections, (2011).

FHWA-SA-21-043



Safety Benefits:

High-visibility crosswalks can reduce pedestrian injury crashes up to:

40% [1]

Intersection lighting can reduce pedestrian crashes up to:

42% [2]

Advance yield or stop markings and signs can reduce pedestrian crashes up to:

25% [3]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/techSheetVizEnhancemt2018.pdf.

FHWA-SA-21-049

Crosswalk Visibility Enhancements

Poor lighting conditions, obstructions such as parked cars, and horizontal or vertical roadway curvature can reduce visibility at crosswalks, contributing to safety issues. For multilane roadway crossings where vehicle volumes are in excess of 10,000 Average Annual Daily Traffic (AADT), a marked crosswalk alone is typically not sufficient. Under such conditions, more substantial crossing improvements could prevent an increase in pedestrian crash potential.

Three main crosswalk visibility enhancements help make crosswalks and the pedestrians, bicyclists, wheelchair and other mobility device users, and transit users using them more visible to drivers. These include high-visibility crosswalks, lighting, and signing and pavement markings. These enhancements can also assist users in deciding where to cross. Agencies can implement these features as standalone or combination enhancements to indicate the preferred location for users to cross.

High-visibility crosswalks

High-visibility crosswalks use patterns (i.e., bar pairs, continental, ladder) that are visible to both the driver and pedestrian from farther away compared to traditional transverse line crosswalks. They should be considered at all midblock pedestrian crossings and uncontrolled intersections. Agencies should use materials such as inlay or thermoplastic tape, instead of paint or brick, for highly reflective crosswalk markings.

Improved Lighting

The goal of crosswalk lighting should be to illuminate with positive contrast to make it easier for a driver to visually identify the pedestrian. This involves carefully placing the luminaires in forward locations to avoid a silhouette effect of the pedestrian.

Enhanced Signing and Pavement Markings

On multilane roadways, agencies can use "YIELD Here to Pedestrians" or "STOP Here for Pedestrians" signs 20 to 50 feet in advance of a marked crosswalk to indicate where a driver should stop or yield to pedestrians, depending on State law. To supplement the signing, agencies can also install a STOP or YIELD bar (commonly referred to as "shark's teeth") pavement markings.

In-street signing, such as "STOP Here for Pedestrians" or "YIELD Here to Pedestrians" may be appropriate on roads with two- or three-lane roads where speed limits are 30 miles per hour or less.

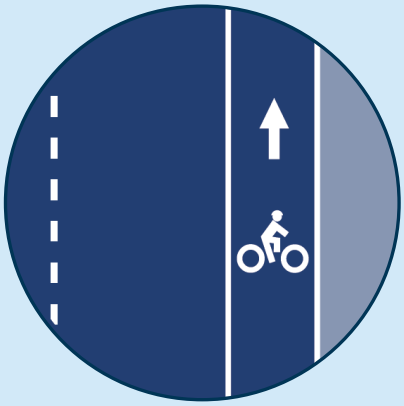


Source: FHWA

1 (CMF ID: 4123) Chen, L., C. Chen, and R. Ewing. The Relative Effectiveness of Pedestrian Safety Countermeasures at Urban Intersections - Lessons from a New York City Experience. (2012).
2 (CMF ID: 436) Elvik, R. and Vaa, T. Handbook of Road Safety Measures. Oxford, United Kingdom, Elsevier, (2004).
3 (CMF ID: 9017) Zeeger et al. Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments, FHWA, (2017).

Transportation agencies should refer to the Manual on Uniform Traffic Control Devices (MUTCD) for information on crosswalk markings (Chapter 3C) and in-street signing (Sections 2B.19 and 2B.20).

U.S. Department of Transportation
Federal Highway Administration



Bicycle Lanes

Most fatal and serious injury bicyclist crashes occur at non-intersection locations. Nearly one-third of these crashes occur when motorists are overtaking bicyclists[1] because the speed and size differential between vehicles and bicycles can lead to severe injury. Many people are not comfortable riding a bicycle because of their fear that this type of crash may occur. To make bicycling safer and more comfortable for most types of bicyclists, State and local agencies should consider installing bicycle lanes. Providing bicycle facilities can mitigate or prevent interactions, conflicts, and crashes between bicyclists and motor vehicles, and create a network of safer roadways for bicycling. Bicycle Lanes align with the Safe System Approach principle of recognizing human vulnerability—where separating users in space can enhance safety for all road users.

Safety Benefits:

Converting traditional or flush buffered bicycle lanes to a separated bicycle lane with flexible delineator posts can reduce crashes up to:

53%

for bicycle/vehicle crashes.[3]

Bicycle Lane Additions can reduce crashes up to:

49%

for total crashes on urban 4-lane undivided collectors and local roads.[7]

30%

for total crashes on urban 2-lane undivided collectors and local roads.[7]



Bicycle lane in Washington, DC. Source: Alex Baca, Washington Area Bicyclist Association.

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-07/fhwasa18077.pdf.

Applications

The FHWA's *Bikeway Selection Guide* and *Incorporating On-Road Bicycle Networks into Resurfacing Projects* assist agencies in determining which facilities provide the most benefit in various contexts. Bicycle lanes can be included on new roadways or created on existing roads by reallocating space in the right-of-way through *Road Diets*. Separated bicycle lanes, which use vertical elements—such as flexible delineator posts, curbs, or vegetation—between the bicycle lane and motorized traffic lanes provide additional safety benefits.[2,3] For a marked bike lane without vertical elements, a lateral offset with marked buffer can help to further separate bicyclists from vehicle traffic.

Considerations

- In order to maximize a roadway's suitability for riders of all ages and abilities, bicycle lane design should vary according to roadway characteristics (number of lanes, motor vehicle and truck volumes, speed, presence of transit), user needs (current and forecasted ridership, types of bicycles and micromobility devices in use within the community, role within the bicycling network), and land-use context (adjacent land uses, types and intensity of conflicting uses, demands from other users for curbside access). Separated bicycle lanes are recommended on roadways with higher vehicle volumes and speeds, such as arterials.
- City and State policies may require minimum bicycle lane widths, although desirable bicycle lane widths can differ by agency and functional classification of the road, current and forecasted bicycle volumes, and contextual attributes such as topography.
- Studies have found that roadways did not experience an increase in crashes or congestion when travel lane widths were decreased to add a bicycle lane.[4]
- Studies and experience in U.S. cities show that bicycle lanes increase ridership and may help jurisdictions better manage roadway capacity.
- In rural areas, rumble strips can negatively impact bicyclists' ability to ride if not properly installed. Agencies should consider the dimensions, placement, and offset of rumble strips when adding a bicycle lane.[5]
- Bicycle lanes should be considered on roadways where adjacent land use suggests that trips could be served by varied modes, particularly to meet the safety and travel needs of low-income populations likely to use bicycles to reach essential destinations.[6]

1 Thomas et al. *Bicyclist Crash Types on National, State, and Local Levels: A New Look*. Transportation Research Record 673(6), 664-676, (2019).
2 Separated Bike Lane Planning and Design Guide. FHWA-HEP-15-025, (2015).
3 (CMF ID: 11296) Developing CMFs for Separated Bicycle Lanes. FHWA-HRT-23-025, (2023).
4 Park and Abdel-Aty. *Evaluation of safety effectiveness of multiple cross sectional features on urban arterials*. Accident Analysis and Prevention, Vol. 92, pp. 245-255, (2016).
5 FHWA Tech Advisory Shoulder and Edge Line Rumble Strips, (2011).
6 Sandt et al. Pursuing Equity in Pedestrian and Bicycle Planning. FHWA, (2016).
7 (CMF ID: 10738, 10742) Development of Crash Modification Factors for Bicycle Lane Additions While Reducing Lane and Shoulder Widths. FHWA-HRT-21-012, (2021).

FHWA-SA-21-051



Safety Benefits:

RRFBs can reduce crashes up to:

47%

for pedestrian crashes.[4]

RRFBs can increase motorist yielding rates up to:

98%

(varies by speed limit, number of lanes, crossing distance, and time of day).[3]



RRFBs used at a trail crossing.
Source: LJB

Rectangular Rapid Flashing Beacons (RRFB)

A marked crosswalk or pedestrian warning sign can improve safety for pedestrians crossing the road, but at times may not be sufficient for drivers to visibly locate crossing locations and yield to pedestrians. To enhance pedestrian conspicuity and increase driver awareness at uncontrolled, marked crosswalks, transportation agencies can install a pedestrian actuated Rectangular Rapid Flashing Beacon (RRFB) to accompany a pedestrian warning sign. RRFBs consist of two, rectangular- shaped yellow indications, each with a light-emitting diode (LED)-array-based light source.[1] RRFBs flash with an alternating high frequency when activated to enhance conspicuity of pedestrians at the crossing to drivers.

Transportation agencies should refer to the *Manual on Uniform Traffic Control Devices (MUTCD)* for information on the application of RRFBs.[1]

Applications

The RRFB is applicable to many types of pedestrian crossings but is particularly effective at multilane crossings with speed limits less than 40 miles per hour.[2] Research suggests RRFBs can result in motorist yielding rates as high at 98 percent at marked crosswalks, but varies depending on the location, posted speed limit, pedestrian crossing distance, one- versus two-way road, and the number of travel lanes.[3] RRFBs can also accompany school or trail crossing warning signs.

RRFBs are placed on both sides of a crosswalk below the pedestrian crossing sign and above the diagonal downward arrow plaque pointing at the crossing.[1] The flashing pattern can be activated with pushbuttons or passive (e.g., video or infrared) pedestrian detection, and should be unlit when not activated.

Considerations

Agencies should:[2]

- Install RRFBs in the median rather than the far-side of the roadway if there is a pedestrian refuge or other type of median.
- Use solar-power panels to eliminate the need for a power source.
- Reserve the use of RRFBs for locations with significant pedestrian safety issues, as over-use of RRFB treatments may diminish their effectiveness.

Agencies shall not:[2]

- Use RRFBs without the presence of a pedestrian, school or trail crossing warning sign.
- Use RRFBs for crosswalks across approaches controlled by YIELD signs, STOP signs, traffic control signals, or pedestrian hybrid beacons, except for the approach or egress from a roundabout.

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/techSheet_RRFB_2018.pdf.

FHWA-SA-21-053

1 Manual on Uniform Traffic Control Devices (MUTCD), Chapter 4L. FHWA, (2023).
2 "Rectangular Rapid Flash Beacon" in PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System. FHWA, (2013).
3 Fitzpatrick et al. "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, (2016).
4 (CMF ID: 9024) NCHRP Research Report 841 Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments, (2017).



Safety Benefits:

13%

reduction in pedestrian-vehicle crashes at intersections.[2]

Leading Pedestrian Interval

A leading pedestrian interval (LPI) gives pedestrians the opportunity to enter the crosswalk at an intersection 3-7 seconds before vehicles are given a green indication. Pedestrians can better establish their presence in the crosswalk before vehicles have priority to turn right or left.

LPIs provide the following benefits:

- Increased visibility of crossing pedestrians.
- Reduced conflicts between pedestrians and vehicles.
- Increased likelihood of motorists yielding to pedestrians.
- Enhanced safety for pedestrians who may be slower to start into the intersection.

FHWA's Handbook for ***Designing Roadways for the Aging Population*** recommends the use of the LPI at intersections with high turning vehicle volumes. Transportation agencies should refer to the ***Manual on Uniform Traffic Control Devices*** for guidance on LPI timing and ensure that pedestrian signals are accessible for all users.[1] Costs for implementing LPIs are very low when only signal timing alteration is required.



An LPI allows a pedestrian to establish a presence in the crosswalk before vehicles are given a green indication. Source: FHWA



LPIs reduce potential conflicts between pedestrians and turning vehicles. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa19040.pdf.

1 Manual on Uniform Traffic Control Devices (MUTCD), Section 4I.06. FHWA, (2023).
2 (CMF ID: 9918) Goughnour, E., D. Carter, C. Lyon, B. Persaud, B. Lan, P. Chun, I. Hamilton, and K. Signor. "Safety Evaluation of Protected Left-Turn Phasing and Leading Pedestrian Intervals on Pedestrian Safety." Report No. FHWA-HRT-18-044. Federal Highway Administration. (October 2018)



Safety Benefits:

Median with Marked Crosswalk

46%

reduction in pedestrian crashes.[2]

Pedestrian Refuge Island

56%

reduction in pedestrian crashes.[2]

Medians and Pedestrian Refuge Islands in Urban and Suburban Areas

A **median** is the area between opposing lanes of traffic, excluding turn lanes. Medians in urban and suburban areas can be defined by pavement markings, raised medians, or islands to separate motorized and non-motorized road users.

A **pedestrian refuge island** (or crossing area) is a median with a refuge area that is intended to help protect pedestrians who are crossing a road.

Pedestrian crashes account for approximately 17 percent of all traffic fatalities annually, and 74 percent of these occur at non-intersection locations.[1] For pedestrians to safely cross a roadway, they must estimate vehicle speeds, determine acceptable gaps in traffic based on their walking speed, and predict vehicle paths. Installing a median or pedestrian refuge island can help improve safety by allowing pedestrians to cross one direction of traffic at a time.

Transportation agencies should consider medians or pedestrian refuge islands in curbed sections of urban and suburban multilane roadways, particularly in areas with a significant mix of pedestrian and vehicle traffic, traffic volumes over 9,000 vehicles per day, and travel speeds 35 mph or greater. Medians/refuge islands should be at least 4-ft wide, but preferably 8 ft for pedestrian comfort. Some example locations that may benefit from medians or pedestrian refuge islands include:

- Mid-block crossings.
- Approaches to multilane intersections.
- Areas near transit stops or other pedestrian-focused sites.



Example of a road with a median and pedestrian refuge islands. Source: City of Charlotte, NC



Median and pedestrian refuge island near a roundabout. Source: www.pedbikeimages.org / Dan Burden

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-08/techSheet_PedRefugeIsland2018.pdf.

1 National Center for Statistics and Analysis. (2020, March). Pedestrians: 2018 data (Traffic Safety Facts. Report No. DOT HS 812 850). National Highway Traffic Safety Administration

2 (CMF ID: 175) Desktop Reference for Crash Reduction Factors, FHWA-SA-08-011, September 2008, Table 11.

FHWA-SA-21-044



Safety Benefits:

55%
reduction in pedestrian crashes.[3]

29%
reduction in total crashes.[4]

15%
reduction in fatal and serious injury crashes.[4]



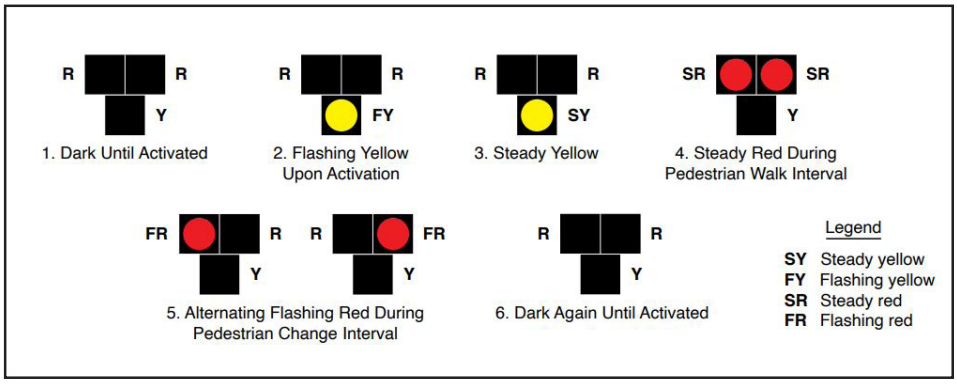
Example of PHBs mounted on a mast arm. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa18064.pdf.

FHWA-SA-21-045

Pedestrian Hybrid Beacons

The pedestrian hybrid beacon (PHB) is a traffic control device designed to help pedestrians safely cross higher-speed roadways at midblock crossings and uncontrolled intersections. The beacon head consists of two red lenses above a single yellow lens. The lenses remain "dark" until a pedestrian desiring to cross the street pushes the call button to activate the beacon, which then initiates a yellow to red lighting sequence consisting of flashing and steady lights that directs motorists to slow and come to a stop, and provides the right-of-way to the pedestrian to safely cross the roadway before going dark again.



Sequence for a PHB. Source: MUTCD 2023 Edition, Chapter 4J, FHWA

Nearly 74 percent of pedestrian fatalities occur at non-intersection locations, and vehicle speeds are often a major contributing factor.[1] As a safety strategy to address this pedestrian crash risk, the PHB is an intermediate option between a flashing beacon and a full pedestrian signal because it assigns right of way and provides positive stop control. It also allows motorists to proceed once the pedestrian has cleared their side of the travel lane(s), reducing vehicle delay.

Transportation agencies should refer to the *Manual on Uniform Traffic Control Devices* (MUTCD) for information on the application of PHBs.[2] Transportation agencies should locate pedestrian signals to be accessible for all users.

In general, PHBs are used where it is difficult for pedestrians to cross a roadway, such as when gaps in traffic are not sufficient or speed limits exceed 35 miles per hour. They are very effective at locations where three or more lanes will be crossed or traffic volumes are above 9,000 annual average daily traffic. Installation of a PHB must also include a marked crosswalk and pedestrian countdown signal. If PHBs are not already familiar to a community, agencies should conduct appropriate education and outreach as part of implementation.

1 National Center for Statistics and Analysis. (2020, March). Pedestrians: 2018 data (Traffic Safety Facts. Report No. DOT HS 812 850). National Highway Traffic Safety Administration
2 Manual on Uniform Traffic Control Devices, Chapter 4J. FHWA, (2023).
3 (CMF ID: 9020) Zegeer et al. NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. TRB, (2017).
4 (CMF ID: 2911,2917) Fitzpatrick, K. and Park, E.S. Safety Effectiveness of the HAWK Pedestrian Crossing Treatment, FHWA-HRT-10-042, (2010).



Safety Benefits:

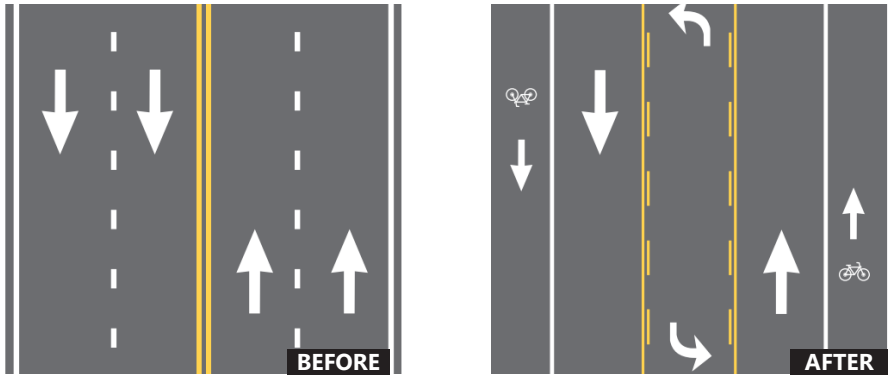
4-Lane to 3-Lane Road Diet Conversions

19-47%

reduction in total crashes.[1]

Road Diets (Roadway Reconfiguration)

A Road Diet, or roadway reconfiguration, can improve safety, calm traffic, provide better mobility and access for all road users, and enhance overall quality of life. A Road Diet typically involves converting an existing four-lane undivided roadway to a three-lane roadway consisting of two through lanes and a center two-way left-turn lane (TWLTL).



Before and after example of a Road Diet. Source: FHWA

Benefits of Road Diet installations may include:

- Reduction of rear-end and left-turn crashes due to the dedicated left-turn lane.
- Reduced right-angle crashes as side street motorists cross three versus four travel lanes.
- Fewer lanes for pedestrians to cross.
- Opportunity to install pedestrian refuge islands, bicycle lanes, on-street parking, or transit stops.
- Traffic calming and more consistent speeds.
- A more community-focused, Complete Streets environment that better accommodates the needs of all road users.

A Road Diet can be a low-cost safety solution when planned in conjunction with a simple pavement overlay, and the reconfiguration can be accomplished at no additional cost. Typically, a Road Diet is implemented on a roadway with a current and future average daily traffic of 25,000 or less.



Road Diet project in Honolulu, Hawaii. Source: Leidos

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/other/road-diets.

1 (CMF ID: 5554,2841) *Evaluation of Lane Reduction "Road Diet" Measures on Crashes*, FHWA-HRT-10-053, (2010).



Safety Benefits:

Sidewalks

65-89%

reduction in crashes involving pedestrians walking along roadways.[3]

Paved Shoulders

71%

reduction in crashes involving pedestrians walking along roadways.[3]

Walkways

A walkway is any type of defined space or pathway for use by a person traveling by foot or using a wheelchair. These may be pedestrian walkways, shared use paths, sidewalks, or roadway shoulders.

With more than 6,200 pedestrian fatalities and 75,000 pedestrian injuries occurring in roadway crashes annually,[1] it is important for transportation agencies to improve conditions and safety for pedestrians and to integrate walkways more fully into the transportation system. Research shows people living in low-income communities are less likely to encounter walkways and other pedestrian-friendly features.[2]

Well-designed pedestrian walkways, shared use paths, and sidewalks improve the safety and mobility of pedestrians. Pedestrians should have direct and connected network of walking routes to desired destinations without gaps or abrupt changes. In some rural or suburban areas, where these types of walkways are not feasible, roadway shoulders provide an area for pedestrians to walk next to the roadway, although these are not preferable.

Transportation agencies should work towards incorporating pedestrian facilities into all roadway projects unless exceptional circumstances exist. It is important to provide and maintain accessible walkways along both sides of the road in urban areas, particularly near school zones and transit locations, and where there is a large amount of pedestrian activity. Walkable shoulders should also be considered along both sides of rural highways when routinely used by pedestrians.



Example of a sidewalk in a residential area. Source: pedbikeimages.org / Burden



Paved shoulder used as a walkway. Source: pedbikeimages.org / Burden

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=1.

FHWA-SA-21-047

1 National Center for Statistics and Analysis. (2020, March). Pedestrians: 2018 data (Traffic Safety Facts. Report No. DOT HS 812 850). National Highway Traffic Safety Administration.
2 Gibbs, et all. Income Disparities in Street Features that Encourage Walking. Bridging the Gap, (2012, March).
3 Gan et al. Update of Florida Crash Reduction Factors and Countermeasures to Improve the Development of District Safety Improvement Projects. Florida DOT, (2005).



Safety Benefits:

HFST can reduce crashes up to:

63%
for injury crashes at ramps.[2]

48%
for injury crashes at horizontal curves.[2]

20%
for total crashes at intersections.[3]



Automated application of HFST.
Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/rwd/keep-vehicles-road/pavement-friction/hfst.

FHWA-SA-21-052

Pavement Friction Management

Friction is a critical characteristic of a pavement that affects how vehicles interact with the roadway, including the frequency of crashes. Measuring, monitoring, and maintaining pavement friction—especially at locations where vehicles are frequently turning, slowing, and stopping—can prevent many roadway departure, intersection, and pedestrian-related crashes.

Pavement friction treatments, such as High Friction Surface Treatment (HFST), can be better targeted and result in more efficient and effective installations when using continuous pavement friction data along with crash and roadway data.

Continuous Pavement Friction Measurement

Friction data for safety performance is best measured with Continuous Pavement Friction Measurement (CPFM) equipment. Spot friction measurement devices, like locked-wheel skid trailers, cannot safely and accurately collect friction data in curves or intersections, where the pavement polishes more quickly and adequate friction is so much more critical. Without CPFM equipment, agencies will assume the same friction over a mile or more.

CPFM technology measures friction continuously at highway speeds and provides both network and segment level data. Practitioners can analyze the friction, crash, and roadway data to better understand and predict where friction-related crashes will occur to better target locations and more effectively install treatments.[1]

High Friction Surface Treatment

HFST consists of a layer of durable, anti-abrasion, and polish-resistant aggregate over a thermosetting polymer resin binder that locks the aggregate in place to restore or enhance friction and skid resistance. Calcined bauxite is the aggregate shown to yield the best results and should be used with HFST applications.

Applications

HFST should be applied in locations with increased friction demand, including:

- Horizontal curves.
- Interchange ramps.
- Intersection approaches.
  - Higher-speed signalized and stop-controlled intersections.
  - Steep downward grades.
- Locations with a history of rear-end, failure to yield, wet-weather, or red-light-running crashes.
- Crosswalk approaches.

Considerations

- HFST is applied on existing pavement, so no new pavement is added.
- If the underlying pavement structure is unstable, then the HFST life cycle may be shortened, resulting in pre-mature failure.
- The automated installation method is preferred as it minimizes issues often associated with manual installation: human error due to fatigue, inadequate binder mixing, improper and uneven binder thickness, delayed aggregate placement, and inadequate aggregate coverage.
- The cost can be reduced when bundling installations at multiple locations.

1 Izeppi et al. Continuous Friction Measurement Equipment as a Tool for Improving Crash Rate Prediction: A Pilot Study. Virginia Department of Transportation, (2016).
2 (CMF ID: 10342, 10333) Merritt et al. Development of Crash Modification Factors for High Friction Surface Treatments. FHWA, (2020).
3 (CMF ID: 2259) NCHRP Report 617: Accident Modification Factors for Traffic Engineering and ITS Improvements, (2008).



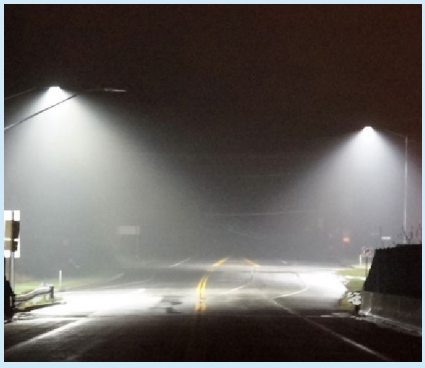
Safety Benefits:

Lighting can reduce crashes up to:

42%
for nighttime injury pedestrian crashes at intersections.[1]

33-38%
for nighttime crashes at rural and urban intersections.[2,1]

28%
for nighttime injury crashes on rural and urban highways.[1]



Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/other/visibility/roadway-lighting-resources.

FHWA-SA-21-050

Lighting

The number of fatal crashes occurring in daylight is about the same as those that occur in darkness. However, the nighttime fatality rate is three times the daytime rate because only 25 percent of vehicle miles traveled (VMT) occur at night. At nighttime, vehicles traveling at higher speeds may not have the ability to stop once a hazard or change in the road ahead becomes visible by the headlights. Therefore, lighting can be applied continuously along segments and at spot locations such as intersections and pedestrian crossings in order to reduce the chances of a crash.

Adequate lighting (i.e., at or above minimum acceptable standards) is based on research recommending horizontal and vertical illuminance levels to provide safety benefits to all users of the roadway environment. Adequate lighting can also provide benefits in terms of personal security for pedestrians, wheelchair and other mobility device users, bicyclists, and transit users as they travel along and across roadways.

Applications

Roadway Segments

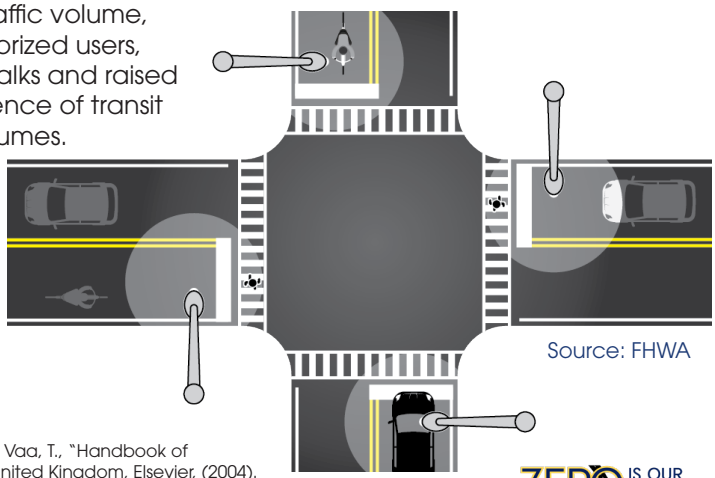
Research indicates that continuous lighting on both rural and urban highways (including freeways) has an established safety benefit for motorized vehicles.[1] Agencies can provide adequate visibility of the roadway and its users through the uniform application of lighting that provides full coverage along the roadway and the strategic placement of lighting where it is needed the most.

Intersections and Pedestrian Crossings

Increased visibility at intersections at nighttime is important since various modes of travel cross paths at these locations. Agencies should consider providing lighting to intersections based on factors such as a history of crashes at nighttime, traffic volume, the volume of non-motorized users, the presence of crosswalks and raised medians, and the presence of transit stops and boarding volumes.

Considerations

Most new lighting installations are made with breakaway features, shielded, or placed far enough from the roadway to reduce the probability and/or severity of fixed-object crashes. Modern lighting technology gives precise control with minimal excessive light affecting the nighttime sky or spilling over to adjacent properties. Agencies can equitably engage with underserved communities to determine where and how new and improved lighting can most benefit the community by considering their priorities, including eliminating crash disparities, connecting to essential neighborhood services, improving active transportation routes, and promoting personal safety.



Source: FHWA

1 (CMF ID: 436,433,192) Elvik, R. and Vaa, T., "Handbook of Road Safety Measures." Oxford, United Kingdom, Elsevier, (2004).
2 (CMF ID: 2376) Ye et al. A Simultaneous Equations Model of Crash Frequency By Collision Type for Rural Intersections, 87th Annual Meeting of the Transportation Research Board, (2008).



Safety Benefits:

Agencies have experienced the following benefits after LRSP implementation:

25%
reduction in county road fatalities in Minnesota.

17%
reduction in fatal and serious injury crashes on county-owned roads in Washington State.

35%
reduction in severe curve crashes in Thurston County, WA.

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/local-rural/local-road-safety-plans.

FHWA-SA-21-033

Local Road Safety Plans

A local road safety plan (LRSP) provides a framework for identifying, analyzing, and prioritizing roadway safety improvements on local roads. The LRSP development process and content are tailored to local issues and needs. The process results in a prioritized list of issues, risks, actions, and improvements that can be used to reduce fatalities and serious injuries on local roads. FHWA has developed several resources including an LRSP Do-It-Yourself website which further explains the process and includes resources local agencies and their partners need to create and implement an LRSP.[1]

Approximately 75 percent of rural roads are owned by local agencies.[2] While local roads are less traveled than State highways, they have a much higher rate of fatal and serious injury crashes.[2] Developing an LRSP is an effective strategy to improve local road safety for all road users and support the goals of a State's overall Strategic Highway Safety Plan (SHSP).

Although the development process and resulting plan can vary depending on the local agency's needs, available resources, and targeted crash types, aspects common to LRSPs include:

- Stakeholder engagement representing the 4E's: engineering, enforcement, education, and emergency medical services.
- Collaboration among municipal, county, Tribal, State, and/or Federal entities to leverage expertise and resources.
- Identification of target crash types and crash risk with corresponding recommended proven safety countermeasures.
- Timeline and goals for implementation and evaluation.

Local road agencies should consider developing an LRSP to be used as a tool for reducing roadway fatalities, injuries, and crashes.[3] LRSPs can help agencies create a prioritized list of improvements. LRSPs are also a proactive risk management technique to demonstrate an agency's responsiveness. The plan should be viewed as a living document that can be updated to reflect changing local needs and priorities.



Infographic showing the LRSP process. Source: FHWA

1 https://highways.dot.gov/safety/local-rural/local-road-safety-plans
2 Anderson et al. Noteworthy Practices: Addressing Safety on Locally-Owned and Maintained Roads A Domestic Scan, FHWA-SA-09-019, (2010).
3 Developing Safety Plans: A Manual for Local Rural Road Owners, FHWA-SA-12-017, provides guidance on developing an LRSP.

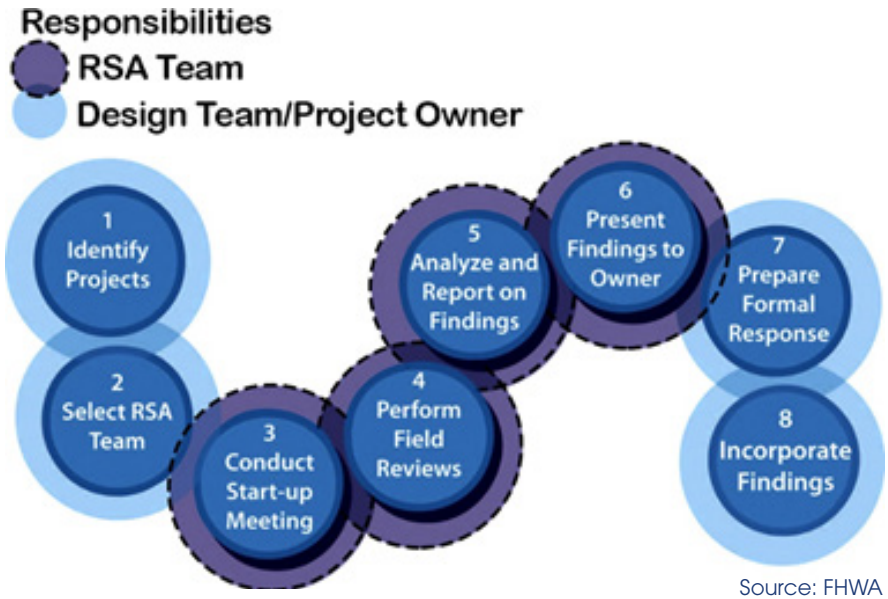


Safety Benefits:

10-60%
reduction in total crashes.[1]

Road Safety Audit

While most transportation agencies have established traditional safety review procedures, a road safety audit (RSA) or assessment is unique. RSAs are performed by a multidisciplinary team independent of the project. RSAs consider all road users, account for human factors and road user capabilities, are documented in a formal report, and require a formal response from the road owner. (See the eight steps for conducting an RSA below.)



Source: FHWA

RSAs provide the following benefits:

- Reduced number and severity of crashes due to safer designs.
- Reduced costs resulting from early identification and mitigation of safety issues before projects are built.
- Increased opportunities to integrate multimodal safety strategies and proven safety countermeasures.
- Expanded ability to consider human factors in all facets of design.
- Increased communication and collaboration among safety stakeholders.
- Objective review by independent multidisciplinary team.

RSAs can be performed in any phase of project development, from planning through construction. Agencies may focus RSAs specifically on motorized vehicles, pedestrians, bicyclists, motorcyclists, or a combination of these roadway users. Agencies are encouraged to conduct an RSA at the earliest stage possible, as all roadway design options and alternatives are being explored.



Multidisciplinary team performs field review during an RSA. Source: FHWA

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://highways.dot.gov/safety/proven-safety-countermeasures and https://highways.dot.gov/safety/data-analysis-tools/systemic/road-safety-audits-rsa.

1 Road Safety Audits: An Evaluation of RSA Programs and Projects, FHWA-SA-12-037; and FHWA Road Safety Audit Guidelines, FHWA-SA-06-06.



https://highways.dot.gov/safety/proven-safety-countermeasures

FHWA-SA-21-071



Minnesota's Best Practices for Pedestrian and Bicycle Safety

DEPARTMENT OF TRANSPORTATION

January 2021

Document Information and Disclaimer



Purpose of this Guide

This guide is intended to assist practitioners in their efforts to improve bicycle and pedestrian safety on their roadway networks. The strategies included in this handbook include a mix of treatments that have been used widely across the state and are considered proven strategies, along with emerging treatments that are considered experimental. This guide is not intended to supersede other existing design guidance or rules, and practitioners should always consult the appropriate design guidance when using these treatments, including, but not limited to:

Minnesota Manual of Uniform Traffic Control Devices (MnMUTCD) - https://www.dot.state.mn.us/trafficeng/publ/mutcd/

- Signs and pavement markings are governed by the MnMUTCD

Federal Highway Administration (FHWA) Interim Approvals - https://mutcd.fhwa.dot.gov/res-interim_approvals.htm

- Some markings and signs included in this Guide are not included in the MnMUTCD, and are allowed instead by an FHWA Interim Approval. When using a device allowed under interim approval, practitioners should follow the requirements of the Interim Approval carefully, and provide the location of any installed elements to the MnDOT Traffic Standards Engineer at 651-234-7388. See MnMUTCD Section 1A.104 for more information on Interim Approvals.

MnDOT Bicycle Facility Design Manual - http://www.dot.state.mn.us/bike/bicycle-facility-design-manual.html

Other MnDOT, State Aid, FHWA, and/or American Associate of Highway Transportation Officials (AASHTO) Manuals/Guidance/Rules. Refer to the Appendix for a list of potential resources.

Each best practice contained within this document includes the following information, to help practitioners answer common questions about these practices and provide tools to help use them.

- What is its purpose?
  - A description of the purpose of the strategy.
- Is it a proven strategy?
  - Refer to the following text on determining the efficacy of a certain treatment.
- Where would we use it?
  - A description of where this strategy is typically used. It's important to note that strategies may still be used in other situations not listed within this guide, however their efficacy may vary from what's noted in the guide. Practitioners should use judgement when applying treatments in other situations.
- What are the maintenance impacts?
  - A summary of the maintenance impacts associated with the strategy.
- What are the advantages?
  - Advantages associated with implementing the strategy.
- What are the challenges?
  - Challenges associated with implementing the strategy.
- Best Practices
  - The best practices for implementing the strategy.
- Design Features
  - Typical design features of the strategy.
- Resources
  - List of resources for more information on the strategy.

Determining the Efficacy of a Certain Treatment

This guide includes information on the crash reduction associated with certain treatments, as well as notes about whether a treatment is proven, tried, or experimental., based on research conducted on previous installations. Note that any information provided on the efficacy of a given treatment is particular to the context noted within the strategy – for example, a treatment that is proven effective on low-speed roadways may not be effective at all on high speed roadways.

Treatments within this document are noted as **PROVEN** when they have been widely deployed and properly designed evaluations have shown them to be effective when used under certain conditions. Any treatment that has been granted FHWA Interim Approval is considered **PROVEN** because FHWA has reviewed the efficacy of those treatments through the experimentation process.

Treatments within this document are noted as **TRIED** when they have been implemented in a number of locations where the results of the evaluations have not been fully evaluated or are inconsistent.

Treatments within this document are noted as **EXPERIMENTAL** when they have been suggested and at least one agency has considered sufficiently promising to try on a small scale in at least one location. Note that some experimental treatments are not included in either the MnMUTCD or an FHWA Interim Approval, and therefore require a Request to Experiment if they are to be used. For more information on Requests to Experiment, refer to MnMUTCD Section 1A.10.2 and contact the MnDOT Traffic Standards Engineer at 651-234-7388.

In an effort to help reduce the potential exposure to claims of negligence associated with motor vehicle crashes on an agency's roadway system, the following two key points should be considered:

1. Minnesota tort law provides for discretionary immunity for decisions made by agency officials when there is documentation of the decision and evidence of consideration of social, economic, and political issues.
2. Minnesota tort law also provides for official immunity for decisions made by agency staff where there is written documentation of the thought process supporting project development and implementation.

Proven/Tried/Experimental

This document refers to treatments as "Proven", "Tried", or "Experimental". Treatments are categorized according to the definition in NCHRP Report 500:

• **Tried** (T)—Those strategies that have been implemented in a number of locations and that may even be accepted as standards or standard approaches, but for which there have not been found valid evaluations. These strategies—while in frequent or even general use—should be applied with caution, carefully considering the attributes cited in the guide and relating them to the specific conditions for which they are being considered. Implementation can proceed with some degree of assurance that there is not likely to be a negative impact on safety and very likely to be a positive one. It is intended that as the experiences of implementation of these strategies continue under the AASHTO Strategic Highway Safety Plan initiative, appropriate evaluations will be conducted so that effectiveness information can be accumulated to provide better estimating power for the user and the strategy can be upgraded to a "proven" (P) one.

• **Experimental** (E)—Those strategies that have been suggested and that at least one agency has considered sufficiently promising to try on a small scale in at least one location. These strategies should only be considered after the others have proven not to be appropriate or feasible. Even where they are considered, their implementation should initially occur using a very controlled and limited pilot study that includes a properly designed evaluation component. Only after careful testing and evaluations show the strategy to be effective should broader implementation be considered. It is intended that as the experiences of such pilot tests are accumulated from various state and local agencies, the aggregate experience can be used to further detail the attributes of this type of strategy so that it can be upgraded to a "proven" (P) one.

• **Proven** (P)—Those strategies that have been used in one or more locations and for which properly designed evaluations have been conducted that show it to be effective. These strategies may be employed with a good degree of confidence, but any application can lead to results that vary significantly from those found in previous evaluations. The attributes of the strategies that are provided will help the user judge which strategy is the most appropriate for the particular situation.

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The contents of this handbook reflect the views of the authors who are responsible for facts and accuracy of the data presented. The contents do not necessarily reflect the views or policies of the Local Road Research Board or the Minnesota Department of Transportation at the time of publication. This handbook does not constitute a standard, specification, or regulation.

	Strategy	Pages	Crash Modification Factor (CMF)	Evidence (Proven/Tried/ Experimental)	Candidate Locations	Construction Estimates
General Intersection Elements	**Marked Crosswalks**	4-7	Varies, Marked Crosswalks alone should not be considered a safety treatment	Tried	Signalized intersections, unsignalized locations with AADT below 15,000, school zone crossings, unsignalized locations with high pedestrian activity, and mid-block crossing locations.	$3,000
	Medians and Crossing Islands	8-10	Medians - 0.54 CMF Crossing Islands - 0.46 CMF Source: https://safety.fhwa.dot.gov/provencountermeasures/ped_medians/	Proven	Mid-block crossing locations, high-priority pedestrian crossing location such as transit stop, school and parks, and on roads with four or more, speeds greater than 35 mph and AADT greater the 9,000.	$25,000-$50,000
	Curb Extensions and Curb Radii	11-14	Curb Extensions - 0.55 CMF Source - http://www.dot.state.mn.us/stateaid/trafficsafety/county/CRSPEnhancedCrosswalks.pdf	Proven	Mid-block curb extensions or pinch points, offset curb extensions or chicanes, and bus stops.	$2,000-$3,500/ corner; $10,000-$20,000/corner with storm sewer impacts
	Crosswalk Lighting	15-17	0.55 CMF Source: http://www.cmfclearinghouse.org/detail.cfm?facid=436	Proven/Tried	Isolated intersections with crosswalks that are not along continuously lit roadways, and mid-block crosswalks.	$10,000 per intersection to over $40,000
	Raised Crosswalks	18-21	0.55 CMF Source: https://safety.fhwa.dot.gov/ped_bike/step/docs/TechSheet_RaisedCW_508compliant.pdf	Proven	Along 2-lane or 3-lane roadways with speeds 30 mph or less and with AADT of 9,000 or less, locations with high pedestrian or bicycle activity, roundabout crossing locations, and locations where shared use paths cross commercial driveways or ramps.	$7,000 to $40,000 each
	Intersection Geometric Design	22-24	Varies	Proven	Where on-street parking or bike lanes are present, where channelized right-turn lanes create more conflicts with pedestrians and bicyclists, where left turns are permitted to occur concurrent with bicycle or pedestrian movements, and at locations where the design must still accommodate turning movements by larger vehicles.	Varies depending on the specific treatment

	Strategy	Pages	Crash Modification Factor (CMF)	Evidence (Proven/Tried/ Experimental)	Candidate Locations	Construction Estimates
Controlled Intersection Elements	**Traffic Signals**	25-27	Countdown timers - 0.22 CMF Source: http://www.cmfclearinghouse.org/detail.cfm?facid=5272	Proven/Tried	Intersection needs additional enhancements to improve motorist yielding rates or address limited gaps in traffic, and where there is a high volume of pedestrian activity, such as transit stops, schools, and parks.	$250,000 to $500,000
	Leading and Separate Exclusive Signals	28-30	Leading Ped Signal - 0.87 CMF Source: https://safety.fhwa.dot.gov/provencountermeasures/lead_ped_int/	Proven/Tried	Intersection with high crossing volumes, intersection with high turning vehicle volumes, and intersection with patterns of pedestrian or bicycle conflict with vehicles.	Varies depending on existing infrastructure
	Bicycle Signals	31-34	Bicycle Signal - 0.55 CMF Source: www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/CRF-Appendix.pdf	Proven (Separate Bicycle Signal) Experimental (Leading Bicycle Interval)	Intersections with high motor vehicle/bicycle conflicts, Intersections with a with two-way or contraflow bicycle movement, where a bicycle facility transition requires the bicyclist to cross through a motor vehicle lane, and locations where bicyclist are required an increase level of control to facilitate unusual or unexpected movements.	Varies depending on existing infrastructure
	Right Turn on Red Prohibition	35-36	Varies	Tried	Locations that have limited sight distance and/or unusual geometry, at locations with high pedestrian activity such as schools, libraries, senior center and trasit stations, and at any crosswalk where the MnMUTCD pedestrian volume and/or school warrant is met.	$200/standard sign; $3,000/LED blank-out sign
	Roundabouts	37-39	0.40 CMF for pedestrian crashes	Tried	Intersections with a pattern of fatal, angle, turning,and head-on crashes and intersections that would benefit from platoon and gap acceptance management.	$1 million
	Bicycle Boxes	40-42	0.65 CMF Source: www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/CRF-Appendix.pdf	Proven	Signalized intersections, roadways with bike lanes that experience a substantial volume of bicycle traffic, and at intersections with a high number of motor vehicle conflicts.	$1,000 per bicycle box
	Protected Intersections	43-45	Varies	Proven	Locations with high numbers of conflicts between bicyclists and turning vehicles	$100,000 to upgrade a signalized intersection

	Strategy	Pages	Crash Modification Factor (CMF)	Evidence (Proven/Tried/ Experimental)	Candidate Locations	Construction Estimates
Uncontrolled Intersection Elements	**Pedestrian Hybrid Beacon (PHB)**	46-48	Pedestrian Crashes - 0.45 CMF Source: https://safety.fhwa.dot.gov/provencountermeasures/ped_hybrid_beacon/	Proven	Locations with marked crosswalks, and high traffic volumes and speeds combined with high volumes of pedestrians crossing.	$100,000-$170,000
	Rectangular Rapid Flashing Beacon (RRFB)	49-51	0.53 CMF Source: https://safety.fhwa.dot.gov/ped_bike/step/docs/TechSheet_RRFB_508compliant.pdf	Proven	Locations with traffic volumes less than 12,000 vehicles per day, and speeds less than 40 MPH.	Varies; $15,000-$100,000
	Crossing Guards	52-54	Not Available	Tried	Crossing guards are commonly applied within school zones as part of MnDOT Safe Routes to School program. This program allocates funds to communities and schools to complete safety improvement projects on routes students use to walk and bike to school.	Nominal costs for training student and parent volunteers
	Grade-separated Crossings	55-57	0.13 CMF Source: https://www.dot.state.mn.us/stateaid/trafficsafety/reference/ped-bikehandbook-09.18.2013-v1.pdf	Proven	Locations with heavy volumes of pedestrian and bicycle traffic crossing a roadway with high vehicular traffic volumes, locations where pedestrian and bicyclists will want to cross the road, and locations with difficult terrain or geographic obstacles to cross the roadway	$1,800/lf + $19,000 per end section

	Strategy	Pages	Crash Modification Factor (CMF)	Evidence (Proven/Tried/ Experimental)	Candidate Locations	Construction Estimates
Linear Facilities	**Route Modifications**	59-61	Not Available	Proven	On routes that experience and encourage bicycle activity, such as a bicycle boulevards, locations where vehicle traffic is lo, and in urban settings on low-speed, low-volume local streets.	Varies depending on treatment
	Road Diets	62-64	0.53-0.81 CMF Source: FHWA	Proven	On roadways with volumes up to 20,000 ADT.	$25,000-$40,000 per mile
	Sidewalks	65-66	0.11-0.35 CMF Source: https://safety.fhwa.dot.gov/provencountermeasures/walkways/	Proven	Along all urban streets and suburban arterials and collectors, adjacent to streets that connect pedestrian origins and destinations, along high-speed and high-volume roadways without shoulder width, shoulder space should be considered on any rural or suburban roadway that cannot feasibly implement a sidewalk or walkway.	$8 per square foot of concrete sidewalk, $6,000 per curb ramp
	Shared Space /Complete Streets	67-69	Not Available	Tried	Locations with a high volume of pedestrian activity, little through motor vehicle traffic, and motor vehicle operating speeds between 5 and 15 MPH.	$50,000 per block
	On-Road and Buffered Bicycle Lanes	70-72	0.65 CMF Source: https://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/page2.cfm#linktarget_t3	Proven	On roadways with motor vehicle speeds of 35 MPH or less. Bike lanes are likely to be comfortable for bicyclists of all ages and abilities when traffic volumes are less than 6,000 vehicles per day and speeds are 25 mph or lower.	Varies depending on type of construction project
	Paved Shoulders	73-75	Pedestrian Crashes - 0.29 CMF Source: https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa11018/	Proven	Any road is a suitable candidate for paved shoulders, but rural or suburban locations where motor vehicle speeds are equal to or exceed 50 mph are particularly important to improve bicyclist comfort and safety.	$60,000-$100,000 per mile

	Strategy	Pages	Crash Modification Factor (CMF)	Evidence (Proven/Tried/ Experimental)	Candidate Locations	Construction Estimates
Linear Facilities	**Bicycle Boulevards**	76-78	0.37 CMF Source: http:// www.cmfclearinghouse.org/ detail.cfm?facid=3092	Tried/Proven	On local/residential streets that are parallel to and near an arterial road or community destination, On street segments that are of sufficient length to reasonably serve long-distance bicycle trips or serve as a missing link in the bicycle network, and on local/residential streets that have less than 3,000 ADT, low operating speeds (25 mph or less), and few heavy commercial vehicles	$5,000 to $150,000 per mile, depending on the extent of traffic calming devices used
	Shared Use Paths	79-82	0.63 CMF Source:https://www.fdot.gov/ docs/default-source/ contentdocs/ roadway/qa/tools/CRF.pdf/	Proven	Where there is a greater mix of users, high user volumes, and a wide range of speeds between shared use path users, when space is limited, shared use paths can be placed in lieu of separated bike lanes, and wider paths may be necessary where there are either large numbers of people bicycling or large percentages of other nonmotorized users	$300,000 to $600,000 per mile
	Separated Bicycle Lanes	83-85	0.41 CMF Source: http://www. cmfclearinghouse.org/detail. cfm?facid=4102	Tried	In areas with traffic volumes over 6,000 ADT or high motor vehicle speeds (over 30 mph), in areas with peak hour bicycle traffic over 100 per hour, in areas with a wide range of user types and variety of speeds, in areas that connect existing or planned biking networks, and where roadways experience freight movements, delivery locations, on-street parking, accessible parking, pedestrian curb ramps,bus and transit access, and curb cuts.	$75,000 per mile for tube delineator separated, up to $1,000,000 per mile for urban, two-way, curb separated reconstruction
	Temporary On-Street Shared Use Paths	86-88	Not available	Experimental	Areas where there is limited right-of-way, areas with limited bicycle or pedestrian demand, where missing links exist in the bicycle and/or pedestrian network	vary depending on type, size and materials

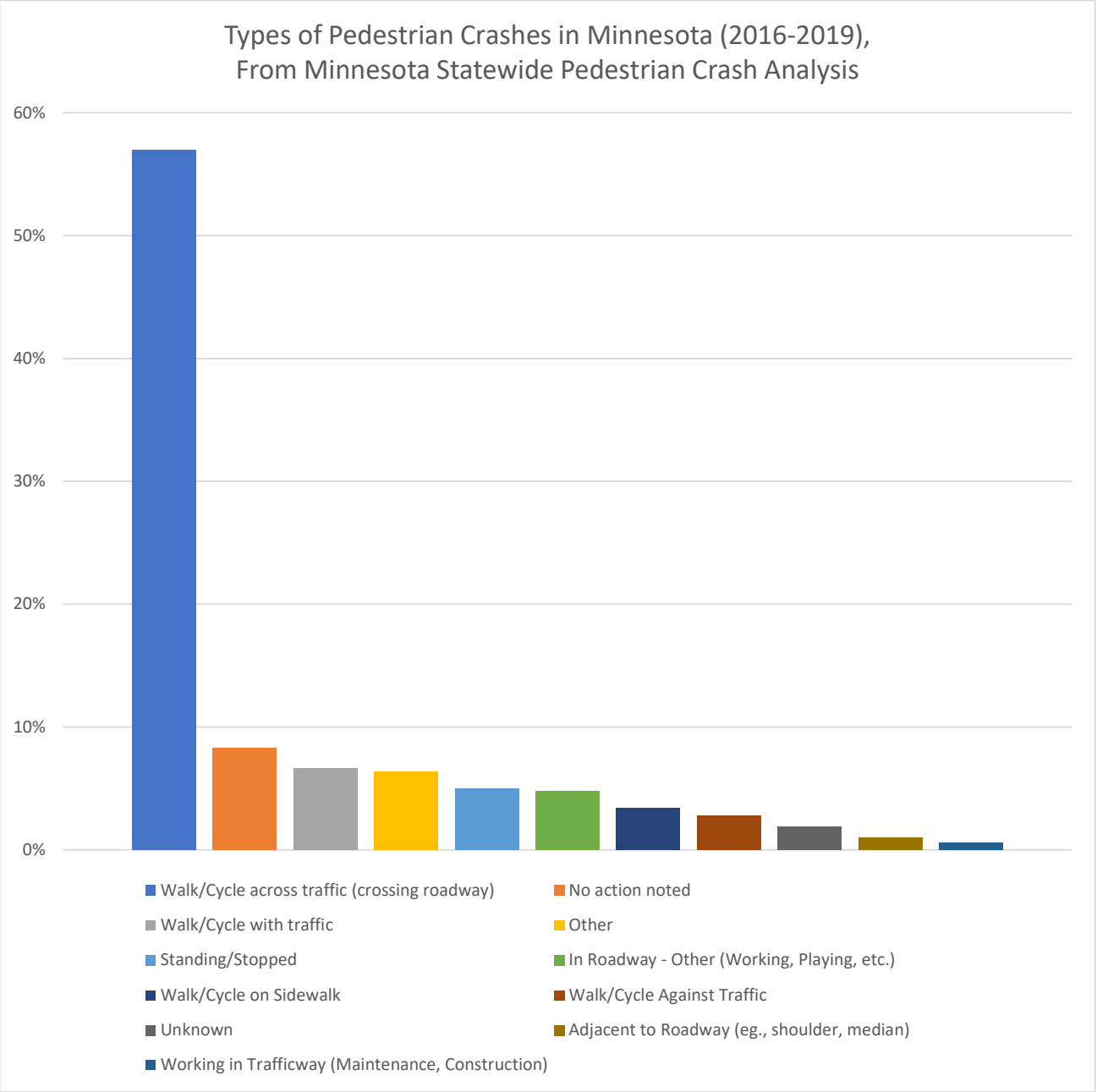
Bicycle and Pedestrian Design and Planning Considerations



Pedestrian and Bicyclist Crashes and Safety Issues in Minnesota

A review of statewide pedestrian crashes in Minnesota found that the majority of crashes - 57% - occurred when the user was crossing the roadway.

More than half of all pedestrian crashes occured on minor arterials, meaning that these roadways are overrepresented as they represent only 7% of the total roadway network in Minnesota. Practitioners should focus improvement efforts on these minor arterial roadways to realize the greatest impact on reducing pedestrian crashes.



Intersection Design Techniques



Marked Crosswalks

What is their purpose?

A marked crosswalk is a type of pavement marking that both indicates to pedestrians the recommended location to cross the roadway and alerts approaching motorists as to where pedestrians may be crossing the street. Section 1A.13 of the MnMUTCD defines a crosswalk as the extension of the sidewalk or the shoulder across an intersection, regardless of whether it is marked or not. A crosswalk also includes the portion of a roadway distinctly indicated for pedestrian activity by lines or other markings on the surface, such as at mid-block crossings (MN Statute 169.011, Subd. 20).



Marked Crosswalk at Golden Valley Road and Winnetka Avenue, Golden Valley, MN

Are they a proven strategy?

Marked crosswalks alone are considered **TRIED**.

When installed with other treatments, such as curb extensions or a Rectangular Rapid Flashing Beacon, marked crosswalks have been **PROVEN** to improve safety (refer to section on Rectangular Rapid Flashing Beacons).

The efficacy of marked crosswalks, whether installed as a stand-alone treatment or in conjunction with other improvements, decreases as traffic volumes, speeds, or number of lanes increases.

An FHWA study concluded that the presence of marked crosswalks alone, without supplemental enhancements, neither improve or decrease safety.

The study also stated that these findings should not be misused as justification to do nothing to help pedestrians cross streets safely. Instead, pedestrian crossing issues and needs should be identified routinely, and appropriate solutions should be selected to improve pedestrian safety and access.

Where would we use them?

Prior to installing a marked crosswalk, an agency should always consider pedestrian volumes, vehicular volumes, stopping sight distance for drivers, the distance to adjacent crosswalks and signalized intersections, the number of driving lanes, and the operating speed of vehicles. MnDOT's Traffic Engineering Manual provides a flowchart and summary table (Table 13-1) to help communities determine appropriate application of crosswalks at a given location. Additionally, the FHWA Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations provides direction on evaluating

Marked Crosswalks

crossing locations and selecting potential crossing treatments.

Marked crosswalks with or without supplemental treatments can be installed at:

- Signalized intersections
- Unsignalized locations with vehicle volumes below 15,000 vehicles per day
- School zone crossings (whether signalized or not)
- Unsignalized locations where it is determined there is sufficient crossing activity for a marked crossing (transit stop, library, recreation center, trail, major commercial destination)
- Mid-block crossing locations

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance. Similar to other roadway markings, crosswalk markings will require routine maintenance to sustain effectiveness and meet reflectivity standards. Ground-in poly preform or thermoplastic crosswalk markings may have higher installation costs, but these options will improve the life of crosswalk markings and reduce maintenance costs.

What are the advantages?

- A low cost way to guide pedestrians to the best location to cross.
- Help designate school zones and other high-pedestrian activity crossing locations.
- Reinforce the presence of a crossing at an intersection.
- Establish a legal mid-block crossing.

Supplemental treatments

Marked crosswalks, especially at uncontrolled intersections, are often combined with additional treatments. Reference the MnDOT Traffic Engineering Manual, Table 13-1 and Section 13-3.02, to help determine additional treatment options. Additional treatment options include:

- High-visibility crosswalk markings
- Parking restrictions on crosswalk approaches
- Improved lighting
- Advance (Stop Here For) pedestrians sign and (stop) line
- Advanced signing
- In-street pedestrian crossing sign
- Curb extensions or median islands
- Raised crosswalks (not allowed on State Aid roadways)
- RRFBs or PHBs

What are the challenges?

- FHWA study shows safety effects of marked crossings are minor; are dependent on number of lanes and vehicular volumes; and are indirectly related to speed.
- In most cases, marked crosswalks are most effective with additional treatments (e.g. roadway lighting, curb extensions, raised islands, advanced warning signs, or flashing beacons), which require a range of investment.
- Require continued maintenance.

Best practices

Marked crosswalks markings should be considered at all signalized intersections where there is pedestrian activity. Marked crosswalks at uncontrolled intersections should include additional features such as improved lighting, advance warning signs, medians, and curb extensions, whenever possible.

How much do they cost?

Depending on the material, type of crosswalk, and supplemental signing, cost per square foot of crosswalk can vary between $100 and $5,000. Supplemental features such as curb extensions, median islands, RRFBs, and lighting bring additional costs.

Marked Crosswalks

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	❶ ❸ 5 7 9	① ❸ 5 ❼ ❾	① 3 4 5	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 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 ❾	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 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	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)**

Application of pedestrian crash countermeasures by roadway feature

**Refer to Chapter 4 from the Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations, 'Using Table 1 and Table 2 to Select Countermeasures,' for more information about using multiple countermeasures.*

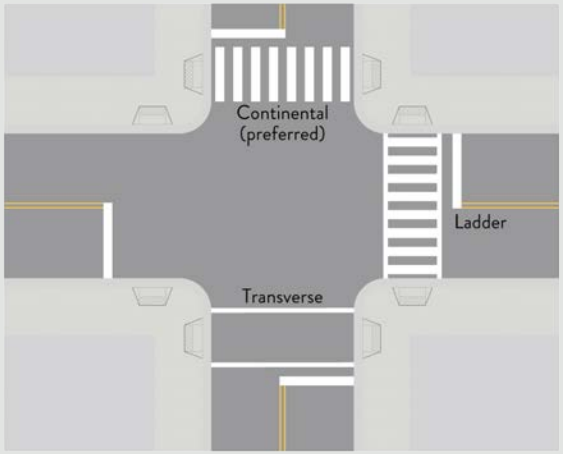
***It should be noted that the PHB and RRFB are not both installed at the same crossing location.*

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; FHWA. Pedestrian Safety Guide and Countermeasure Selection System (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.

Marked Crosswalks

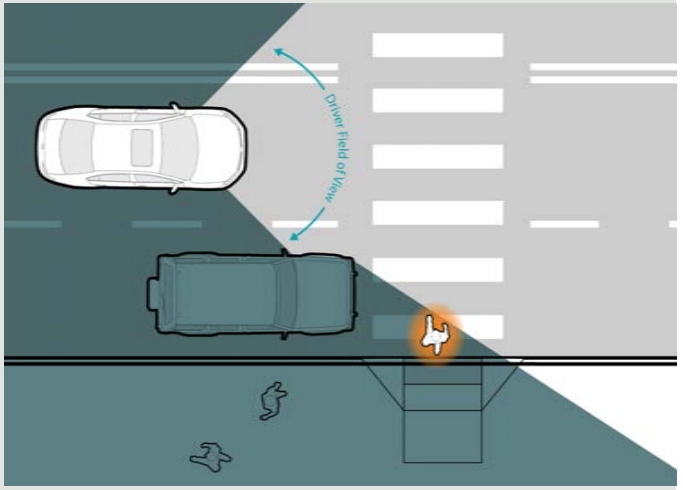
Design Features

There are a variety of marked crosswalks, such as continental, ladder, and transverse, that are more visible to motorists than traditional parallel marked crosswalks. The locations should be convenient, accessible, and aligned with pedestrian routes.



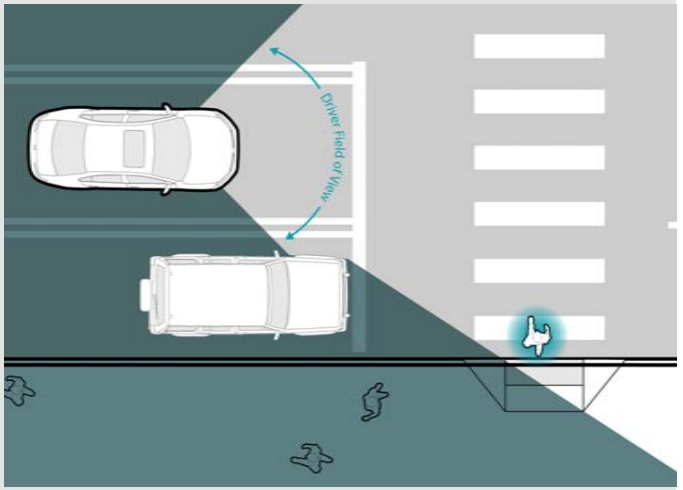
Types of crosswalk markings

Additionally, advance warning signs prior to the crossing are typically installed when signing is needed to better alert drivers of an upcoming crosswalk. Advanced stop bars can improve sight distance and reduce the risk of a "multiple-threat" pedestrian crash on multi-lane roadways, which occurs when one vehicle stops for a pedestrian at the marked crosswalk and blocks the line of sight between the crosswalk user and approaching vehicles in the adjacent lane. The advance yield line allows more time and distance for a collision to be avoided.

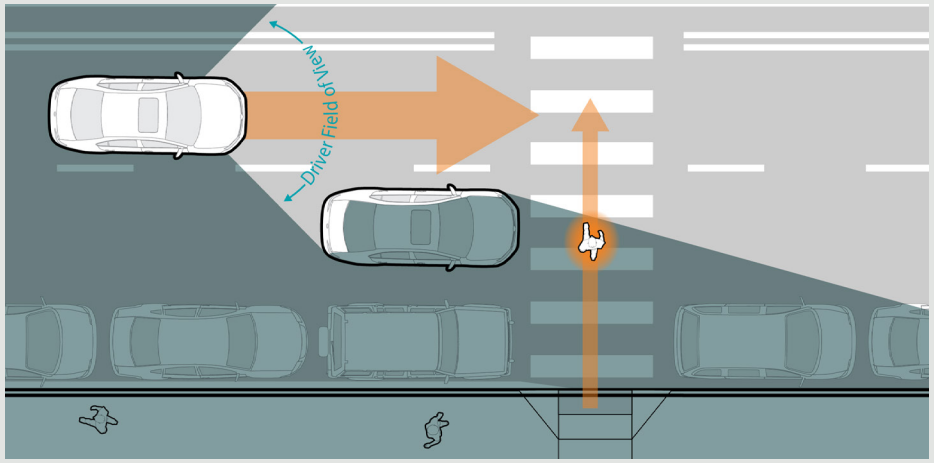


No advanced stop bar

Overhead lighting, curb extensions, and/or median islands can also be considered to improve a crossing's effectiveness. In-pavement lights are another design strategy, however they may have ongoing maintenance issues related to climate and snow plow damage.



Advanced stop bar



An image of a multiple threat situation

Medians and Crossing Islands

What is their purpose?

Medians and crossing islands (also known as refuge islands or center islands) are raised areas that are constructed in the center portion of a roadway, serving as a place of refuge for people who cross the road mid-block or at an intersection. They allow pedestrians and bicyclists to concentrate their attention on one direction of traffic at a time while crossing the roadway. After crossing to the center island, users wait for motorists to stop for an adequate gap in traffic before crossing the second half of the street. Refuge islands can drastically reduce pedestrian delay and vehicle conflicts by increasing the number of safe gaps that are available.



Median at Maryland Avenue and Greenbrier Street, Saint Paul, MN

Are they a proven strategy?

FHWA research shows that median and crossing islands are a **PROVEN** safety countermeasure.

Supporting Document: FHWA Proven Countermeasures – Pedestrian Medians

Where would we use them?

When installing a median or crossing island, an agency should develop a design that allows accessibility for all users and adheres to ADA crossing standards. 6' is the minimum median width where detectable warning surfaces are required. However, to allow storage space for a bicycle and to allow space for a level landing and truncated domes, a best practice is to construct crossing islands or medians of at least 8' in width. 10' or greater width is preferred, especially where bicycle traffic is expected. Crossing islands less than 6' are not considered pedestrian refuges since they cannot include detectable warning surfaces and may not safely serve as a refuge for all users.

Crossing islands are commonly installed at:

- Mid-block crossing locations or candidate locations
- High-priority pedestrian crossing locations such as transit stops, schools, and parks
- On roadways where marked crosswalks alone may not be sufficient, including roadways with speeds greater than 35 mph, and when annual average daily traffic (AADT) is greater than 9000. The raised medians must be accessible by all users, and should adhere to ADA crossing standards.

Medians and Crossing Islands

What are the advantages?

- Separates opposing vehicle travel lanes and allows pedestrians/bicyclists to cross the roadway in two stages rather than all at once.
- Reduces certain types of motor vehicle crashes, such as head-on crashes.
- Can help slow vehicle speeds by providing visual narrowing/traffic calming of the roadway.
- Can be implemented using low-cost, interim materials such as striping, flexible posts, and other bollards until a permanent improvement can be funded through a reconstruction project or other programming.
- Can provide area for landscaping and other visual enhancements as well as stormwater treatment.
- Studies show that a **raised median can reduce up to 46% of pedestrian crashes, and a pedestrian crossing island can reduce up to 56% of pedestrian crashes.**

What are the challenges?

- Permanent medians can be costly and are recommended to be included in larger construction projects.
- May restrict driveway access and on-street parking.
- Can introduce more significant design features and construction costs if stormwater management is impacted and additional inlets are required at locations with curb extensions.
- Require additional winter maintenance considerations.

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months, to keep the crossing island clear of snow and debris, along with the rest of the sidewalk network. Median crossings can pose an obstacle to snow plows, and to reduce plow strikes on median island curbs, designers should follow the pedestrian approach nose details in MnDOT Standard Plan 5-297.250.

Supplemental treatments

Raised medians and crossing islands are often combined with the following treatments:

- High-visibility crosswalk markings
- Advanced warning signs
- Curb extensions
- Street lighting
- Advance stop bars
- RRFBs or PHBs



A median with a refuge island

Best practices

To accommodate all users, medians must be fully accessible by ramp or cut through, and should provide tactile cues for pedestrians with visual impairments to indicate the border between the pedestrian refuge area and the motorized vehicle roadway.

How much do they cost?

The average cost for a raised island or crossing island is approximately $10/sf, and the total cost can vary widely from approximately $2,000 to $45,000. Costs depend on the design, site conditions, and whether the median can be included as part of a larger construction project.

Medians and Crossing Islands

Design Features

Continuously raised medians may not be appropriate or physically possible at all locations. They may need to be weighed against other roadway features such as wider sidewalks, bicycle lanes, landscaping buffers, or on-street parking.

At both intersections and mid-block locations, short sections of median at high-priority crossings such as schools and parks provide benefit to pedestrians. Pedestrian islands may be appropriate at unsignalized and signalized crossing locations.

Raised medians must incorporate the following:

- Fully accessible ramps.
- Tactile cues for pedestrians with visual impairments, that meet ADA standards.
- Adequate visibility between pedestrian and approaching vehicles.
- The median crossing can be angled (rather than perpendicular) to allow pedestrians easier visibility of on-coming traffic.
- Crossing islands may also be staggered (also known as a Z–crossing), which is a treatment that forces pedestrians to turn in the median and face the direction of traffic. Staggered crossings may be difficult for pedestrians with vision impairments to navigate, so it's important to provide a detectable edge along the crossing.



Pedestrian approach nose shown at a refuge island



Z-crossing treatment

Resources

- Proven countermeasure: https://safety.fhwa.dot.gov/provencountermeasures/ped_medians/
- http://pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=6
- CRFs: https://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/fhwasa08011.pdf
- https://www.dot.state.mn.us/ada/pdf/5-297-250.pdf

Curb Extensions and Curb Radii

What is their purpose?

A curb extension is an extension of the sidewalk into the roadway that reduces the crossing distance of a roadway for pedestrians and pedestrian exposure to vehicular traffic. Curb extensions can provide visual cues to drivers that encourage them to reduce speeds and be aware of pedestrians and bicyclists. Curb extensions also improve intersection sight distance for vehicles and pedestrians since they restrict parking near the intersection. They can also provide additional space to construct ADA-compliant curb ramps, making them an effective strategy on ADA retrofit projects where constructing and ADA-compliant ramp may be otherwise difficult. Curb extensions are used at intersections and at mid-block crosswalks.



A curb extension at an intersection

Are they a proven strategy?

Curb extensions are **PROVEN** safety strategies. Research shows that reducing the crossing distance, restricting the street width, and reducing wide corner radii improve pedestrian safety and enhance the sight distance between motorists and pedestrians.

Supporting Documentation: MnDOT Enhanced Crosswalks

Where would we use them?

Curb extensions are most appropriate in urban settings when there is an on-street parking lane or a shoulder where the extensions will not impede bicycle travel. The curb extension physically precludes vehicles parking near an intersection or pedestrian crossing, improving sight lines and visibility both for and of crossing pedestrians near parked vehicles. Beyond being used at intersections, curb extensions can be applied in a variety of ways depending on the roadway's needs. Examples include the following:

- Mid-block curb extensions or pinch points
- Offset curb extensions or chicanes
- Bus stops

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months. Curb extensions may increase the level of effort required to remove snow from the parking lane. This can be minimized by adding delineators or markers on the curb extension to help guide snow plows, and by flattening the taper rate of the curb extension to 1:5 so plows can maintain a limited forward speed while clearing snow adjacent to the curb extension.

Curb Extensions and Curb Radii

What are the advantages?

- May be temporarily implemented and evaluated using low-cost, interim materials such as gravel, planters, paint and striping, flexible posts, or bollards until a permanent improvement can be funded through a reconstruction project or other programming.
- Increase visibility of pedestrians and bicyclists crossing the street.
- Encourage slower turning speeds.
- Reduce crossing distance at mid-block crosswalks.
- Serve as a gateway or visual cue for drivers entering a slower, more residential area.
- May dedicate width for bus stops (bus bulbs).
- May dedicate width for on-street parking.
- Increase space for street furniture, landscaping, and stormwater treatment.
- Improve intersection sight distance (by prohibiting parking near the intersection)
- Provide additional space to construct ADA-compliant curb ramps.
- Studies show a reduction in crashes up to 45%.

What are the challenges?

- Design can be restricted by the turning radius of the larger design vehicles (trucks and buses).
- Stormwater management needs associated with the new curb alignment (e.g., catch basin locations) can bring additional design and construction costs.
- Require additional winter maintenance considerations.
- Curb extension retrofits may reduce the amount of available on-street parking

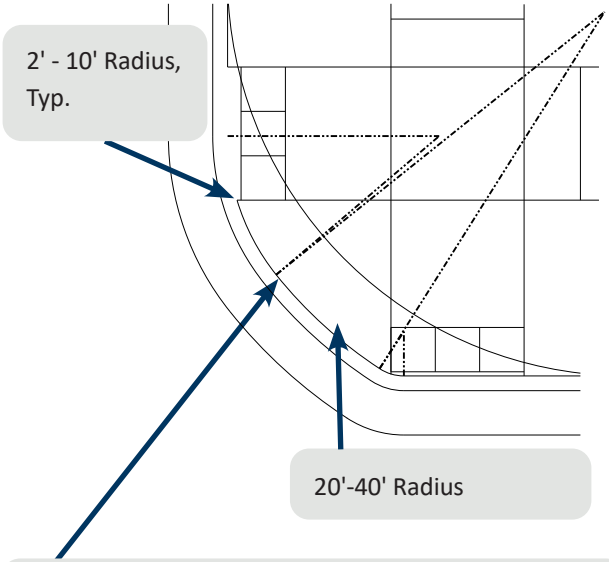
Supplemental treatments

Curb extensions and curb radii can be combined with the following treatments:

- High-visibility crosswalk markings
- Advanced warning signs
- Right turn on red restrictions at signalized intersections
- Landscaping or other aesthetic improvements

Best practices

Curb extensions can often be lengthened to provide additional space for landscaping, stormwater treatment, transit waiting areas, and bus shelters. In addition, curb extensions can create additional space to fit ADA-compliant curb ramps, improving accessibility in constrained locations where it may otherwise be difficult to do so.



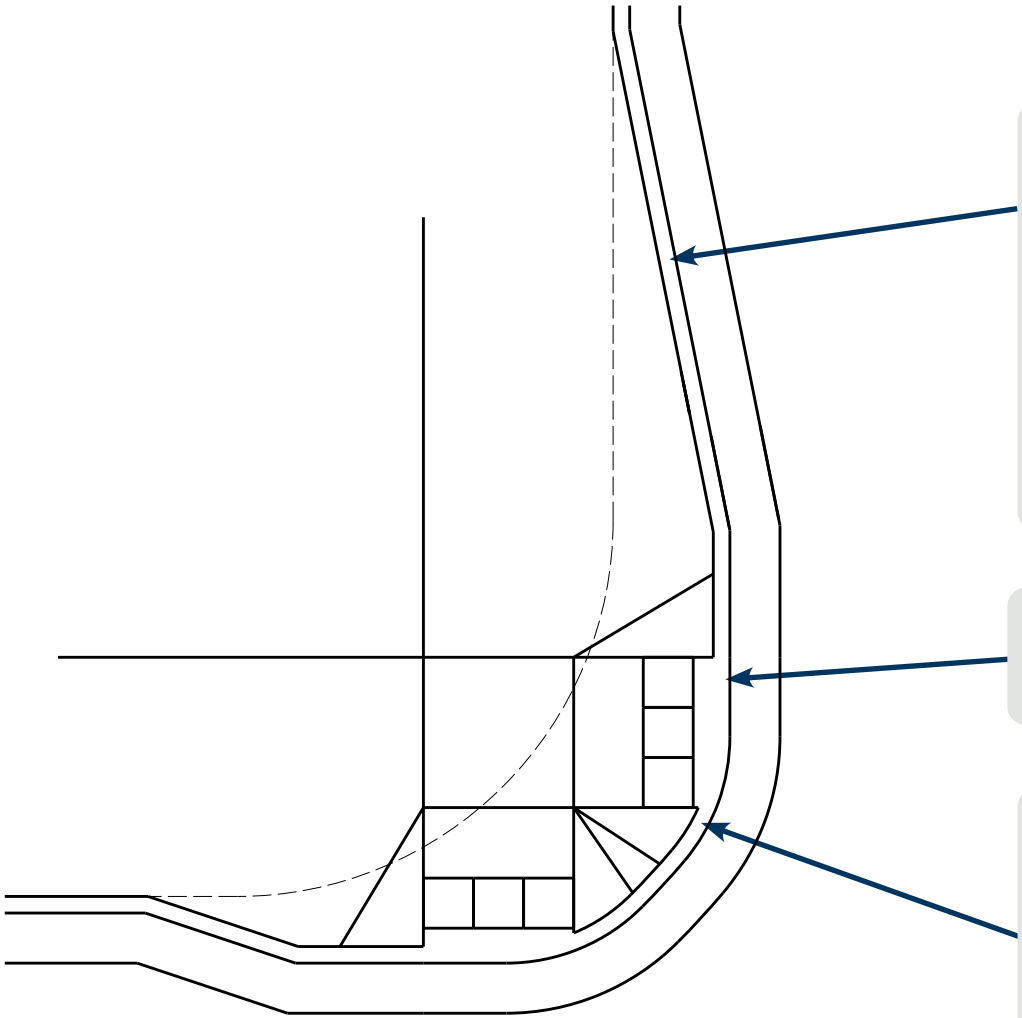
A compound radius can increase available curb extension space while still allowing large vehicles to turn, especially on multi-lane roadways.

Compound radius detail, Source: MnDOT Curb Ramp Standard Plan

How much do they cost?

Costs depend on site conditions, drainage impacts, pavement design, and ADA accommodations. Curb extension installation can range between $2,000-$3,500 per corner if it does not cause storm sewer impacts and between $10,000-$20,000 per corner if it does cause storm sewer impacts.

Curb Extensions and Curb Radii



1:3 minimum taper. Using a 1:5 taper on the upstream (plow-facing) side can improve ease of maintenance, but is so flat that vehicles may still attempt to park along the taper. Even with a 1:3 taper, signage may be needed such as "no parking here to corner".

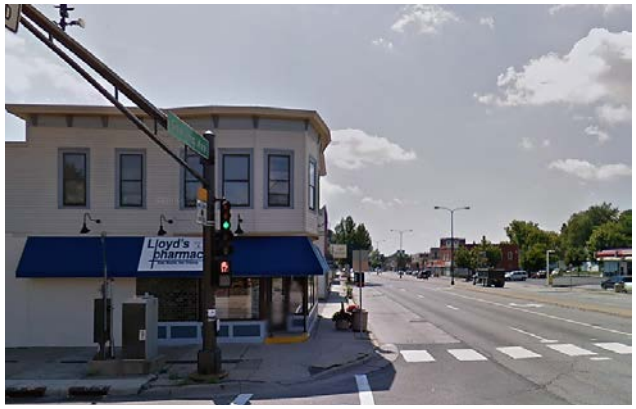
Where prohibiting parking is a primary concern, a steeper taper can be helpful (some agencies have used as steep as 1:2 taper; designers should take care to adequately delineate steep tapers).

Having at least 5' of non-zero height tangent curb helps establish the presence of the curb ramp and

With the previous curbline, it would have been difficult to construct an ADA-compliant curb ramp at this location, especially if trying to match into a doorway at the intersection. This design creates enough space to construct ADA-compliant curb ramps, while still keeping the back of the sidewalk at the existing elevation.

Curb extension detail, Source: MnDOT Curb Ramp Standard Plan

Curb Extensions and Curb Radii





Curb retrofit on Snelling Avenue, Saint Paul, MN; Source: Google

Before/after photo of curb ramp retrofit. The curb extension allowed the construction of ADA-compliant ramps on an otherwise constrained corridor. Note the upstream side of curb extension has a flatter taper than the downstream side.

Design Features

Curb extensions should be tailored to the unique characteristics of the site at which they are installed, though MnDOT's Pedestrian Curb Ramp Standard Plans has details that may be helpful. See Curb Extensions and Curb Radii section of this handbook.

Designers should also consider or incorporate the following:

- Curb extensions should extend the full width of an adjacent parking lane.
- Maintain proper sight distance between pedestrians and motorists, including street furniture and landscaping features.
- Stormwater runoff may be impacted and additional catch basins may be required as part of the design. Avoid designs that cause water to pool on the sidewalk.

Resources

- Proven: http://www.dot.state.mn.us/stateaid/trafficsafety/county/CRSP-EnhancedCrosswalks.pdf
- https://safety.fhwa.dot.gov/intersection/conventional/signalized/fhwasa13027/ch9.cfm#s911
- Minnesota DOT Roadway Design Manual, Chapter 5-1.04
- http://www.pedbikeinfo.org/cms/downloads/Countermeasure%20Costs_Report_Nov2013.pdf
- Bump Outs: http://pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=5
- https://nacto.org/publication/urban-street-design-guide/street-design-elements/curb-extensions/
- Curb Radii: http://pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=28
- https://safety.fhwa.dot.gov/ped_bike/step/docs/STEP_Guide_for_Improving_Ped_Safety_at_Unsig_Loc_3-2018_07_17-508compliant.pdf

Crosswalk Lighting

What is its purpose?

Crosswalk lighting is a strategy that installs street lights at and in advance of intersections and crosswalks to improve visibility, safety, and comfort, especially at night. Crosswalk lighting can contribute significantly to safety by providing an advance warning to drivers that they are approaching a point of potential conflict with pedestrians and bicyclists. Street lights can be located at individual intersections or crosswalks, or be continuous along roadway corridors.



Lighting at a midblock crosswalk

Is it a proven strategy?

Research shows that the installation of street lights at rural intersections is a **PROVEN** strategy to reduce crashes,—especially nighttime crashes, fatal and serious crashes, and vehicle-pedestrian and vehicle-bicycle crashes.

However, there is no research into the effectiveness of street lights relative to reducing pedestrian crashes at urban intersections or along urban roadways; this strategy has been **TRIED**.

Where would we use it?

Crosswalk lighting is commonly installed at:

- Isolated intersections with crosswalks that are not along continuously lit roadways
- Mid-block crosswalks

What are the maintenance impacts?

Crosswalk lighting requires routine maintenance to ensure the lighting is uniform at the intersection and all other material and fixtures are functioning appropriately. Maintenance depends on power source; for example, back-up battery packs require periodic replacement.

Supplemental treatments

Most strategies discussed in this guide would benefit from additional lighting, including mid-block crossings, marked crosswalks, curb extensions, and signalized intersections.

Crosswalk Lighting

Best practices

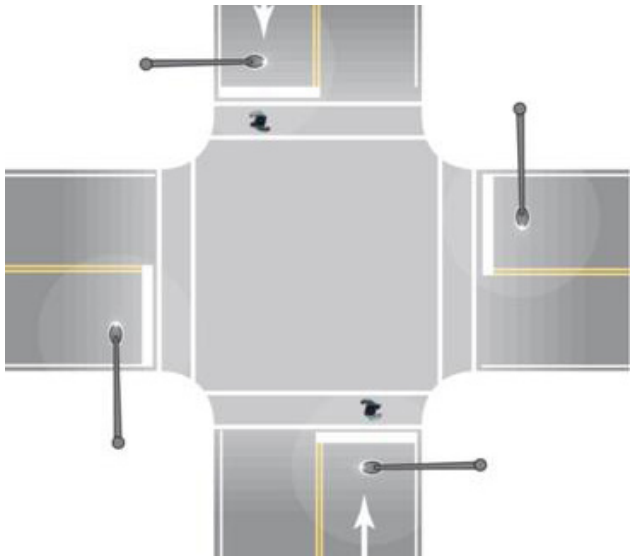
Properly designed street lights improve drivers' ability to see pedestrians during low light conditions. Crosswalk lighting should be provided on urban and suburban corridors that do not have continuous street lighting. Crosswalk lighting provides valuable visual cues for drivers, including a visual cue to pay attention for the possibility of a pedestrian in the roadway.

What are the advantages?

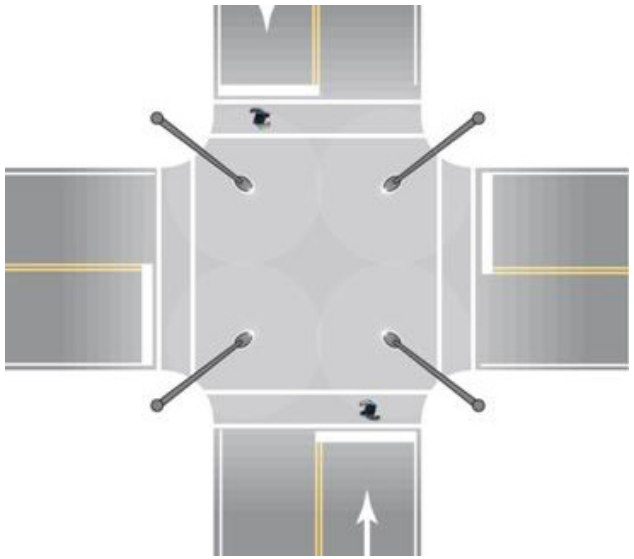
- Some construction costs may be eligible to be covered by federal and state funds.
- Solar-powered lighting can be used as an alternative to traditionally powered fixtures.
- Intersection illumination can reduce nighttime vehicle/pedestrian crashes by up to 42%.

What are the challenges?

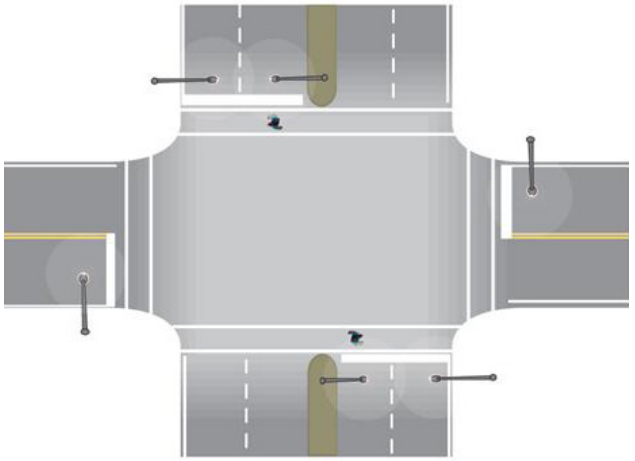
- Increased maintenance and power cost or battery costs (solar fixtures).
- Requires power source.
- Some communities are concerned about light pollution (consider full cutoff fixtures).



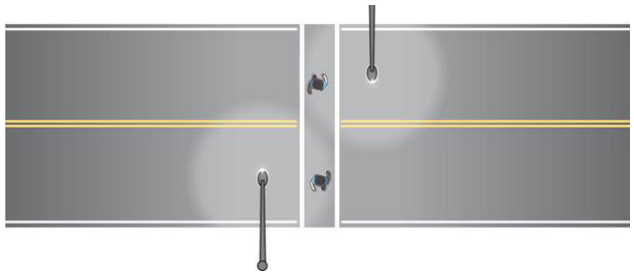
Intersection lighting over the stop bars



Intersection lighting over the center of the intersection



Intersection lighting with a four-lane divided roadway



Midblock crossing with two lights



Midblock crossing with a single light

How much does it cost?

Costs for implementation vary widely, depending on available utilities, power source, and fixture type. Typically, street light installation can range from around $10,000 per intersection to over $40,000.

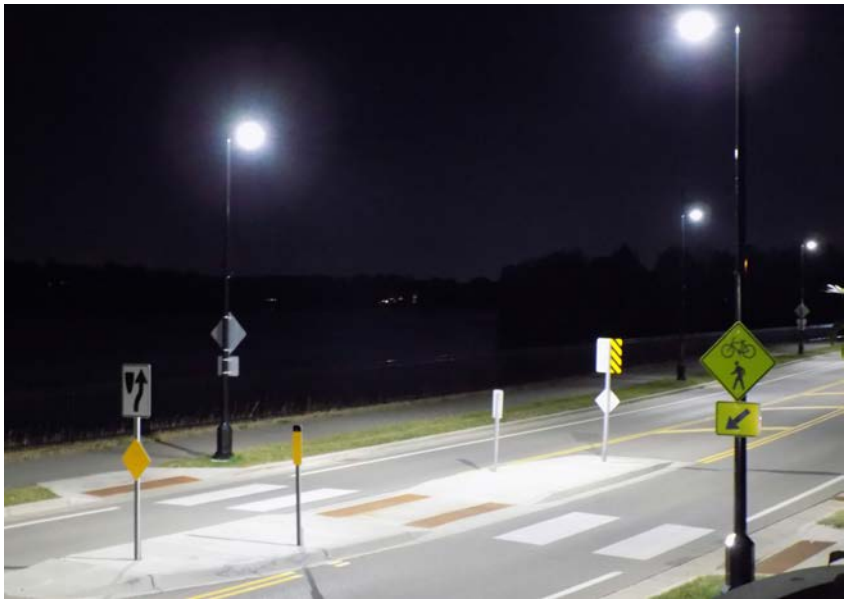
Crosswalk Lighting

Design Features

Agencies should reference MnDOT's Roadway Lighting Design Manual, AASHTO's Roadway Lighting Design Guide, and FHWA's Informational Report on Lighting Design for Midblock Crossings for information on state and federal lighting design practices.

Typical street light designs at crosswalks include the following:

- LED luminaires, davit arms that extend the luminaire out towards the roadway, and 30'-40' poles. There is a variety of options for pole material, such as aluminum, stainless steel, and fiberglass. More expensive options can include decorative luminaries and poles.
- Use breakaway poles and bases to reduce the severity of vehicle crashes involving the street lights. This is a common practice along high-speed and high-volume arterials where poles are placed in close proximity to the driving lanes.
- Ensure uniform lighting levels.
- Lights should be located in advance of crosswalks to illuminate the front of the pedestrian.
- A variety of lighting arrangements are possible at intersections or other crossing locations depending on the size and configuration of the site. For example, on wider or commercial streets, lighting should be installed on both sides.
- Consider the use of full cutoff lighting fixtures where light pollution is a concern. Full cutoff fixtures eliminate stray up-lighting.



Crosswalk lighting on Wayzata Boulevard, Long Lake, MN

Resources

- http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=8
- http://www.cmfclearinghouse.org/detail.cfm?facid=436
- https://www.dot.state.mn.us/trafficeng/lighting/2010_Roadway%20Lighting_Design_Manual2.pdf

Raised Crosswalks

What is their purpose?

Raised crosswalks combine a marked crosswalk with a speed table that extends the full width of the crossing. A speed table is a mid-block traffic calming device that raises the entire wheelbase of a motor vehicle. This type of vertical deflection can have a positive effect for bicyclists and pedestrians, as it reduces motor vehicle speeds.



Raised crosswalk on Wheelock Parkway, Saint Paul, MN

Are they a proven strategy?

Based on FHWA research, raised crosswalks are a **PROVEN** strategy to reduce pedestrian crashes, and are a good candidate treatment for unsignalized intersections on roads with posted speeds 30 mph or less and AADT of 9,000 or less.

Where would we use them?

The same considerations for installing a marked crosswalk should also be made prior to installing a raised crosswalk. Reference MnDOT's Traffic Engineering Manual, Chapter 13 for more information on where a marked crosswalk is appropriate.

Typically, raised crosswalks are placed at mid-block locations where a marked crossing exists. Locations with the following characteristics are also good candidates, with examples including:

- At locations with high pedestrian or bicycle activity, such as at school crossings, park entrances, and commercial shopping districts
- At roundabout crossing locations
- At locations where shared use paths cross commercial driveways or ramps

In Minnesota, raised crosswalks have been implemented sparsely, and they may not be appropriate on major streets, truck, or transit routes. A majority of installations to date have been on minor streets, often on the stop-controlled leg of an intersection.

Raised Crosswalks

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months, to keep the raised crosswalk and its approaches clear of debris and snow. The design should ensure that the maintenance vehicles can clear the vertical deflection safely and without damaging the raised walk. One maintenance benefit of a raised crosswalk is that it can be simpler to remove snow from the pedestrian facility.

In addition, signing and markings require routine maintenance to sustain effectiveness and meet reflectivity standards.

Supplemental treatments

Similar to traditional marked crosswalks, raised crosswalks are often combined with the following treatments:

- High-visibility crosswalk markings
- Parking restriction on crosswalk approach
- Improved lighting
- Advanced stop lines and Stop Here for Pedestrians (R1-5b or R1-5c) signs
- Advanced or in-street signing
- In-street pedestrian crossing sign
- Curb extensions or median islands
- RRFBs or PHBs

What are the advantages?

- Reduced vehicle speeds at intersections can reduce bicycle and pedestrian crash severity.
- Improve driver ability to perceive and react to bicycles and pedestrians in the intersection by slowing vehicle speeds.
- May eliminate the need for separate ADA curb ramp construction, although tactile detectable warnings such as truncated domes are still necessary.
- Provide a strong gateway treatment at the entrance to a bicycle boulevard or a downtown area.
- Raised crosswalks can reduce pedestrian crashes by 45%.

Best practices

Raised crosswalks can be placed mid-block or at an intersection, and they are commonly constructed to be flush with the roadside curb. Raised crosswalks can also be constructed separate from the curb, but this requires ADA-compliant curb ramps on both sides of the crosswalk.

When considering raised crosswalks, evaluate local bus, truck, and emergency vehicle needs, and tailor the vertical design of the raised crosswalk to accommodate the appropriate design vehicles.

What are the challenges?

- Not appropriate on high-speed roadways.
- If not designed properly, may pose an obstacle to some low-clearance commercial vehicles and emergency vehicles. Coordination with fire departments, Emergency Management Services (EMS), and the trucking industry may be required.
- Modifications to existing drainage infrastructure may be required.
- Require additional winter maintenance considerations, especially related to snow removal.

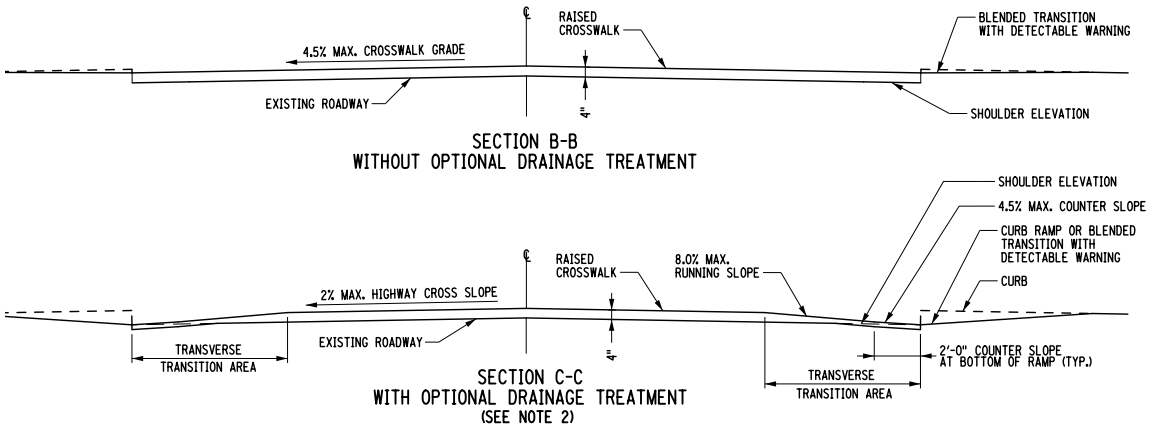
How much do they cost?

Depending on the material, stormwater impacts, and roadway type, costs for a raised crosswalk range from approximately $7,000 to $40,000 each.

Design Features

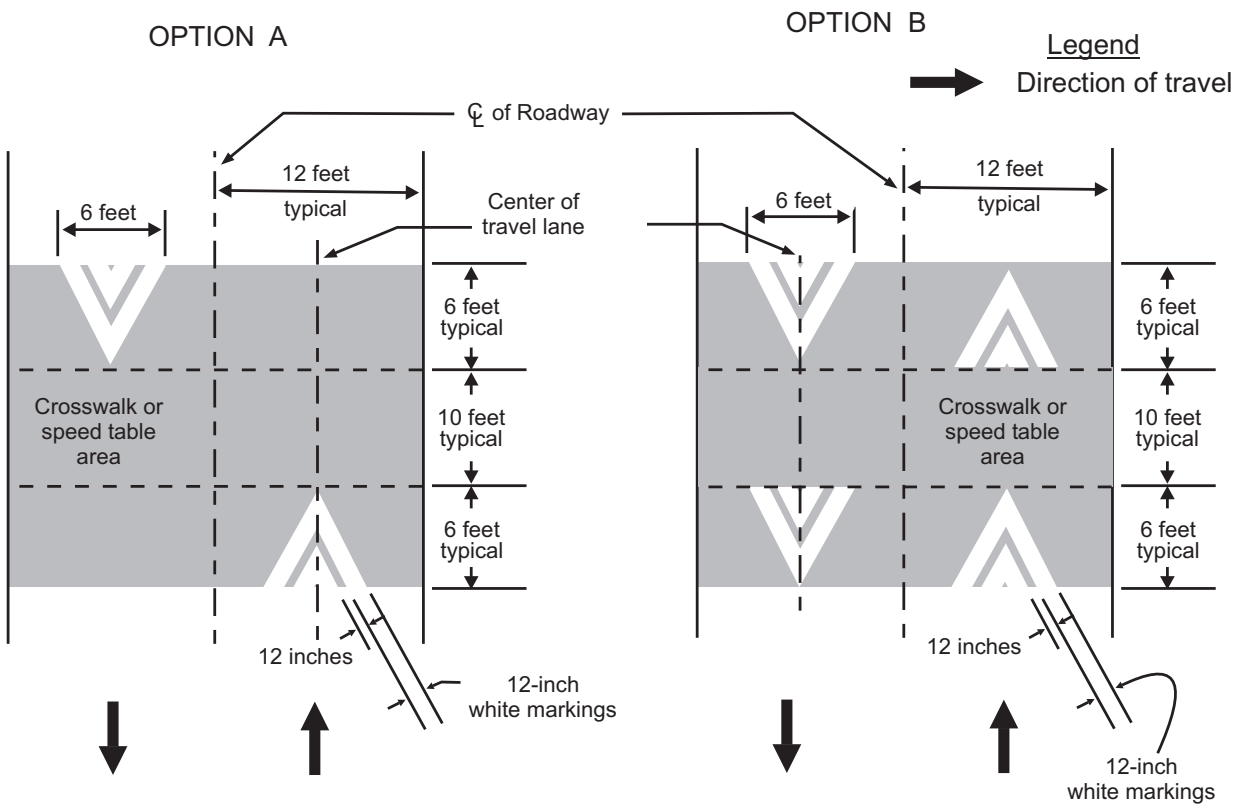
Design features can vary depending on the context of the installation. One example cited below is New York State DOT Standard Sheet 608-07 for raised crosswalk details. Several features of these details include:

- 3" -6" vertical deflection
  - New York State recommends a 4" height, so that a low-boy trailer (with a 5" clearance) can traverse the crosswalk.
  - 6" is a common height for installations that don't need to accommodate low-clearance vehicles. The width of the raised crossing is usually at least 10'.
- Typically, crosswalks are flush with the height of the sidewalk.
- ADA standards should be incorporated, including detectable warning fields and transverse transition areas.
- Approaches should have approach grades between 4% and 7%.
  - New York State recommends a 4% approach, with the rationale that a 4% grade break is no different than crossing a crowned roadway at an intersection.
  - Steeper (up to 7%) approaches are more typical at stop-controlled locations or areas unlikely to see low-clearance vehicles or higher speeds.
- The length of the approach grade varies as needed to achieve the desired approach grade break (7'-10' is common).
- A drainage channel may be provided through the raised crosswalk.
- Use pavement material that is different than the approach roadway to help draw attention to the presence of the raised crossing.
- Raised crossing pavement markings (refer to MnMUTCD Chapter 3).



Section view of raised crosswalk drainage treatment, Source: New York Department of Transportation

Raised Crosswalks



Note: optional crosswalk lines are not shown in this figure

Figure 3B-30 Pavement Markings for Speed Tables or Speed Humps with Crosswalks

Pavement markings for speed tables with crosswalks, Source: Minnesota MUTCD

Resources

- https://www.dot.ny.gov/programs/completestreets/repository/ei_13-018_raised%20crosswalks.pdf
- https://safety.fhwa.dot.gov/ped_bike/step/docs/TechSheet_RaisedCW_508compliant.pdf
- http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=7

Intersection Design Standards

What is its purpose?

Intersection design should reduce conflicts between turning motor vehicles and crossing bicyclists or pedestrians. Design strategies to eliminate conflicts can include stop bar positions, channelized right-turns, and mountable truck aprons. When conflicts cannot be eliminated, intersection design should control the speed of turning vehicles to improve the visibility of bicycles and pedestrians, which force motorists to yield and ensure that if crashes do occur, they are less likely to result in injury. Intersection design elements must accommodate the design vehicle of the intersection.

Is it a proven strategy?

Individual intersection design strategies have been **PROVEN** to improve yielding and slow turning vehicles. For example, a study in New York City showed both pedestrian crashes and vehicles speeds reducing by 20% when hardened centerlines were implemented.

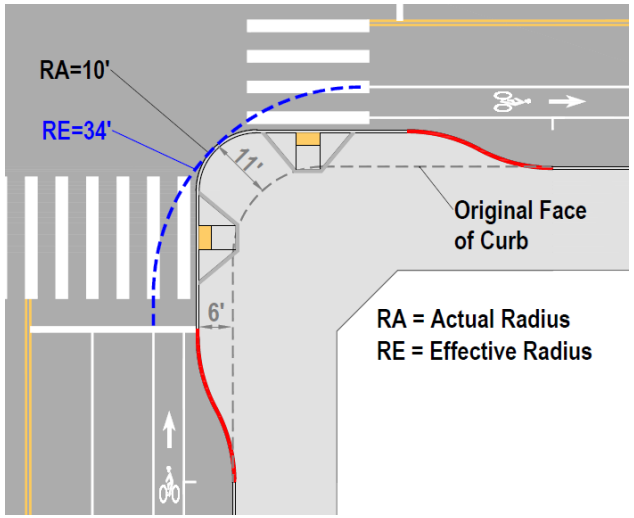


Hardened centerline

Where would we use it?

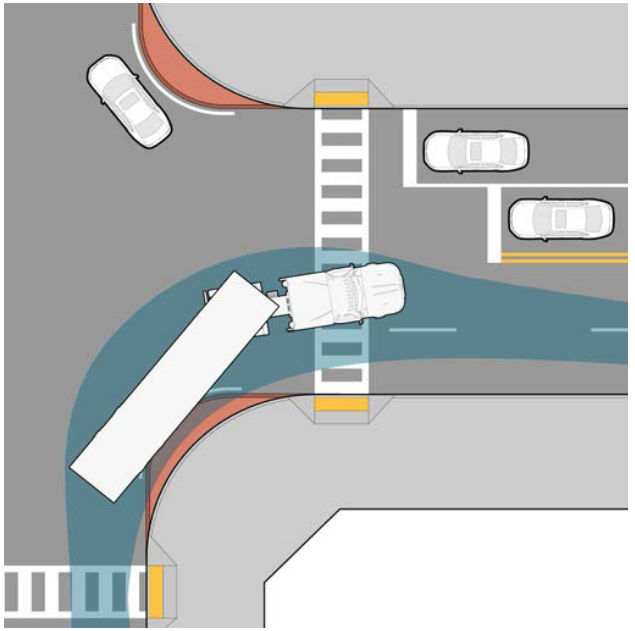
Changes to intersection design to achieve improved safety for pedestrians and bicyclists should be considered at the following locations:

- Where on-street parking or bike lanes are present, designers should examine "effective" turning radius rather than the actual curb radius. See the graphic below to compare effective turning radius with actual turning radius. Where the effective turning radius is greater than 25', consider curb extensions, mountable truck aprons, and/or hardened edge lines to create a more compact intersection that encourages slower speeds.



Effective vs. actual turning radius, Source: Los Angeles Supplemental Street Design Guide

- Where channelized right-turn lanes create higher speed conflicts with pedestrians and bicyclists at urban intersections due to the high turning speeds and large turning radii.
- Where left turns are permitted to occur concurrent with bicycle or pedestrian movements, hardened centerlines are a left-turn traffic-calming measure that may slow left-turning motorists.
- At locations where the design must still accommodate turning movements by larger vehicles, stop bars can be shifted back on the cross streets and mountable truck aprons can be implemented to reduce lane encroachments. Truck aprons are commonly used on the center island of roundabouts, but they may also be applied to intersection corners as well.



Truck turning right over a mountable curb, Source: FHWA Achieving Multimodal Networks

Intersection Design Standards

What are the advantages?

- Can reduce vehicle speeds at intersections, reducing bicycle and pedestrian crash severity.
- Can increase motorist yielding rates by improving drivers' ability to perceive and react to bicycles and pedestrians in an intersection.
- Can reduce intersection width by providing smaller curb radii and shorter crossing distance, minimizing pedestrian and bicycle exposure in the intersection.

What are the challenges?

- Reducing curb radii or removing channelized right turns can make it difficult for larger vehicles to navigate an intersection without encroachment into opposing lanes of travel.
- Adjustments to curb radii and channelized right turns may require modifications to existing drainage infrastructure.
- Removal of channelized right turns may increase motor vehicle delay at intersections.

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months. Intersections should be designed to allow proper street sweeping, snow plowing, and other routine maintenance along curb edges with curb extensions or smaller corner radii. In addition, hardened centerlines with bollards can require increased maintenance, as bollards may need to be repaired or replaced if they are struck by motor vehicles.

Supplemental treatments

- Refer to the Curb Extensions and Curb Radii section
- Refer to the Right Turn on Red Prohibition section

Resources

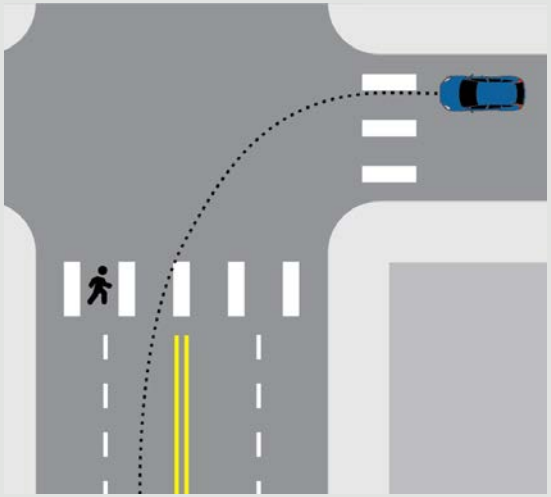
- NYC DOT study on Left Turn Traffic Calming: https://www1.nyc.gov/html/dot/html/pedestrians/left-turn-traffic-calming.shtml
- FHWA Achieving Multimodal Networks: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_networks/fhwahep16055.pdf
- MnDOT Performance-Based Practical Design Process and Design Guidance: https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=2156389
- https://www.iihs.org/news/detail/simple-infrastructure-changes-make-left-turns-safer-for-pedestrians

How much does it cost?

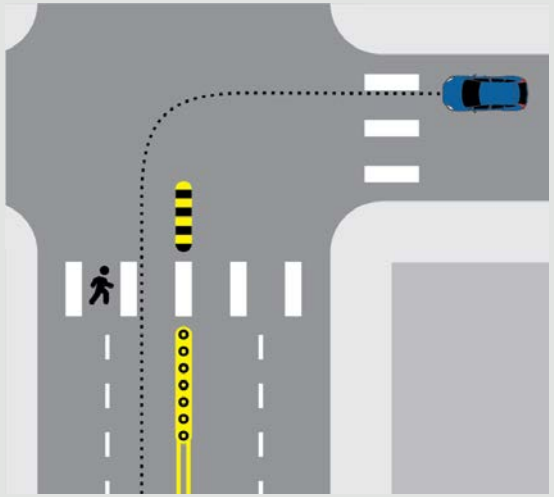
Typical costs for improvements to intersections vary depending on the specific treatment. For example, mountable truck aprons are similar in cost to standard mountable S-type curb and gutter. Hardened centerlines are approximately $5,000 per approach.

Design Features

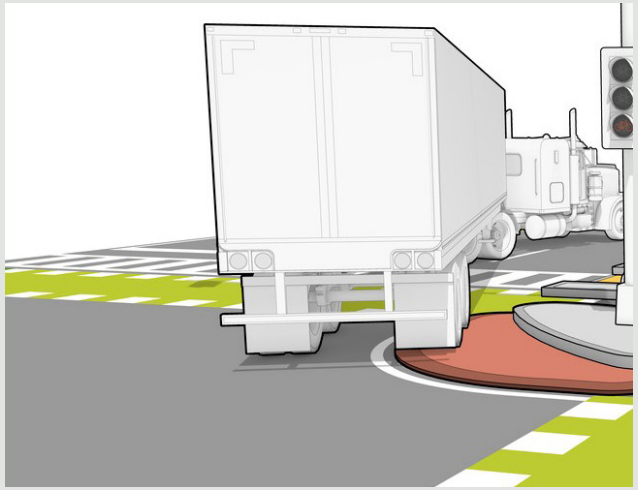
- Design vehicles - Selection of design vehicle(s) and assumptions made about their operating behavior are a major determining factor in intersection design. To achieve optimal intersection performance, the accommodation of oversized vehicles must be balanced with providing a safe, usable, and functional environment for passenger vehicles and pedestrians. Whereas "design vehicle" is defined as a frequent user of a facility, a "control vehicle" is an infrequent large user or fire apparatus which is permitted to use the entirety of the pavement area to navigate an intersection. Passenger cars and school buses are typical design vehicles on most urban streets and rural roads.
- Curb radii – Curb radii should be designed for the vehicle that turns at the intersection most frequently, typically a passenger car and a school bus. Smaller curb radii and curb extensions position vulnerable users in a more visible location, reduce crossing distances, reduce motor vehicle speeds, and provide additional space for curb ramps. Generally, for local urban streets, curb radii should be between 10' and 15' unless special circumstances require a larger radius. Curb extensions can be used to create smaller curb radii.
- Mountable truck aprons – Mountable truck aprons encourage passenger vehicles to make tighter turns while allowing oversized vehicles, such as trucks, to track over an apron. Mountable truck aprons deter passenger vehicles from making higher speed turns, but accommodate the control vehicle without encroachment or off-tracking into pedestrian waiting areas. Mountable truck aprons should be visually distinct from the adjacent travel lane and sidewalk to reduce use by most vehicles and communicate to pedestrians that it is not a safe place to stand or walk. For more details on mountable truck aprons, see the MnDOT Bicycle Facility Manual.
- Hardened Centerlines – Centerline hardening may be accomplished with rubber curbs or bollards installed on the yellow center line near an intersection and continued past the crosswalk, similar to an extended median nose, to slow turning drivers.



Before centerline hardening, Source: IIHS



After centerline hardening, Source: IIHS



Mountable outside truck apron, Source MassDOT Separated Bike Lane Planning and Design Guide

Traffic Signals

What is their purpose?

Traffic signals assign right-of-way to various traffic movements at intersections and help reduce conflict between different roadway users. Signal design typically focuses on the operating characteristics of motorized vehicles, but can also benefit pedestrians and bicyclists by creating gaps in traffic to cross. For example, in areas with pedestrian activity, traffic signals can include features such as countdown timers, leading pedestrian intervals, and exclusive pedestrian signal timings.

MnMUTCD Chapter 4C includes a list of nine warrants, which are threshold conditions that should be analyzed to help determine if signalization is appropriate for an intersection. These warrants are based on the volume of pedestrians and vehicles crossing the intersection, the presence of a school crossing, coordinated signal system, a grade crossing, and the crash experience at the intersection location. Engineering judgment should always be used when assessing traffic control change and signal warrant analysis.



Bicyclists at a traffic signal

Are they a proven strategy?

A traffic signal alone is not a proven safety countermeasure for pedestrians and bicyclists. There are a number of reasons for this, including lack of attention and failure of motorists to yield to pedestrians, lack of signal compliance by drivers and pedestrians, and speeding.

Supplemental strategies should be considered to improve pedestrian accommodations at signalized intersections. Strategies include countdown timers, which are **PROVEN** countermeasures to reduce crashes; and leading pedestrian intervals, which are **PROVEN** countermeasures. No Turn on Red restrictions, which are a **TRIED** countermeasure; and exclusive pedestrian signal timings, which are **TRIED** countermeasures.

Where would we use them?

Traffic signals serve many purposes. Before they are used, an engineering study of traffic conditions, pedestrian activity, and location characteristics should be performed. Additionally, the MnMUTCD signal warrants must be analyzed as part of the study. It should be noted that a location meeting one or more traffic signal warrant criteria does not in itself mandate the installation of a traffic signal.

Traffic signals are most effective for pedestrian and bicycle safety when:

- The intersection needs additional enhancements to improve motorist yielding rates or address limited gaps in traffic.
- There is a high volume of pedestrian activity, near transit stops, schools, and parks.

Traffic Signals

What are the advantages?

- Stop vehicles on red, allowing pedestrians and bicyclists to cross and create gaps in traffic flow to allow pedestrians and bicyclists to cross.
- Can be enhanced with many supplemental design features to further improve pedestrian safety.
- Widely used strategy to manage traffic
- Can reduce the severity of motor vehicle crashes.
- With countdown timers, pedestrian-vehicle crashes can be reduced up to 70% relative to signals without countdown timers.

What are the maintenance impacts?

Traffic signals require routine maintenance by properly trained technicians and ongoing funding to repair, replace, or upgrade signal controllers, detectors, and other signal hardware. It is also important to regularly assess the condition of traffic signal control equipment, including verifying that detectors are working properly, traffic signal controller timings are entered correctly, and signal displays are operational. Additionally, all traffic signal and pedestrian displays should be routinely checked to ensure they are visible to motorists and pedestrians. A maintenance management system database is typically employed to track these items.

What are the challenges?

- Installation of a traffic signal will increase delay and travel time for some motorists .
- Rely on driver attention and behavior to obey signals, to stop behind the stop bar, and to yield to crosswalks when turning.
- Some crash types could increase, including rear-end collisions.

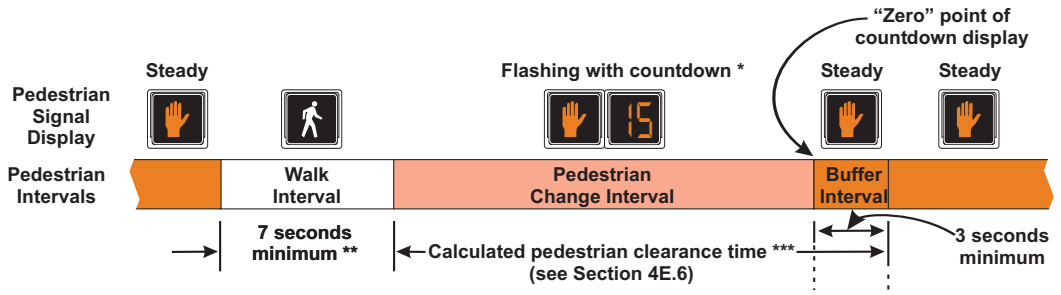
For pedestrians and bicyclists, it is especially important that all indications, push buttons, detectors, and other components are positioned and working properly.

Supplemental treatments

Traffic signals are often combined with one or more of the following treatments:

PROVEN treatments:

- Countdown pedestrian timers reduce pedestrian-vehicle crashes up to 70% after installation.
- Leading pedestrian intervals (LPI) reduce up to 60% of pedestrian-vehicle crashes at intersections.
- Backplates with retroreflective borders improve the visibility of the signal face during daytime and nighttime conditions. Research shows that the installation of retroreflective backplates can reduce total crashes by up to 15% at intersections.
- Yellow change intervals should be well-timed to reduce the number of red-light running vehicles. Red-light running vehicles cause a majority of the severe crashes at signalized intersections, and improvements to yellow change intervals can improve overall intersection safety. Research shows that optimized yellow change intervals can reduce red light running by up to 50%, reduce total crashes up to 14%, and reduce injury crashes up to 12%. Requirements and guidance about optimal yellow change interval timing can be found in the FHWA Traffic Signal Timing Manual.



Pedestrian signal display, Source: Minnesota MUTCD

Traffic Signals

Other Common Treatments:

- Fixed pedestrian phases are common at intersections with steady pedestrian activity throughout the day.
- Pedestrian push buttons are common in areas with intermittent pedestrian activity. When push buttons are installed, the design should consider implementing an Accessible Pedestrian Signal (APS). An APS is a device that communicates information about WALK and DON'T WALK intervals at signalized intersections through audible tones, speech messages, and vibrating surfaces to assist pedestrians with visual impairments.
- Implementing shorter cycle lengths (approximately 90 seconds).
- Implementing turn restrictions or left-turn phasing for vehicles.
- Ensuring that the signal has proper crossing times for pedestrians per MnMUTCD guidance.
- Exclusive pedestrian signal timings are most common in urban areas. These stop vehicles from all directions to allow pedestrians the right-of-way to cross the street in any direction (including diagonally).

Best practices

Traffic signals are used to assign right-of-way to conflicting traffic modes at intersections. There are several proven safety countermeasures that can be paired with traditional signalized intersections to enhance safety. Examples include countdown pedestrian timers, leading pedestrian intervals, backplates with retroreflective borders, and yellow change intervals.

Resources

- Crash Modification Factors
- Cost
- http://www.dot.state.mn.us/trafficeng/publ/mutcd/mnmutcd2018/mnmutcd-4.pdf
- http://guide.saferoutesinfo.org/engineering/traffic_signals.cfm
- https://www.dot.state.mn.us/trafficeng/publ/fundamentals/2015-mndot-safety-handbook-

How much do they cost?

Installing a new traffic signal can vary from approximately $250,000 to $500,000, depending on the site conditions, existing utilities, and additional enhancements. Annual maintenance costs are approximately $2,000 to $4,000 per intersection.

Design Features

Reference the MnDOT Traffic Control Signal Design Manual for a detailed review of traffic signal design elements, including signal phasing and operations, detection design, and signing and pavement markings. The goals of the design should include providing a safe and efficient operation for the intersection's unique conditions.

Key strategies for improving pedestrian accommodation at signalized intersections include the following:

- Adding accessible pedestrian push buttons where signals are pedestrian actuated.
- Implementing short cycle lengths (90 seconds maximum)
- Adding countdown timers, which are usually installed with pedestrian indication lights. These provide the number of seconds remaining during the pedestrian phase. MnMUTCD Chapter 4D.7 now requires countdown timers to be installed at signals with pedestrian signal heads at crosswalks with pedestrian change intervals greater than 7 seconds.
- Leading pedestrian intervals, which can be installed to improve the safety of the crossings by providing pedestrians 3-7 seconds to enter an intersection prior to giving the green indication to vehicles. More information can be found in the section on Leading and Separate Exclusive Signals.
- Using a fixed pedestrian phase - if pedestrian traffic is frequent, this timing strategy does not require pushing the pedestrian button to activate the WALK phase.
- Maintaining optimal sight distance and visibility of signals to pedestrians.
- Implementing MnMUTCD guidelines for creating optimal WALK and DON'T WALK times for pedestrians.

Leading and Separate Exclusive Signal Phases

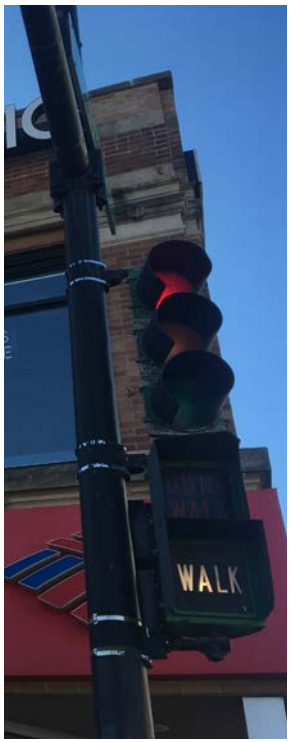
What is their purpose?

A leading pedestrian interval (LPI) activates the WALK interval at least 3 to 7 seconds before drivers are given a green signal. This gives pedestrians additional time to establish their presence in the crosswalk, making them more visible to drivers, especially right- and left- turning vehicles. The effectiveness of LPIs can be seen the most at intersections with patterns of pedestrian or bicycle conflict with vehicles.

An exclusive pedestrian phase is a signal phase dedicating the right-of-way to pedestrian traffic with the WALK indication by stopping vehicular movements in all directions simultaneously. The pedestrian phase is sometimes referred to as a "pedestrian scramble" and allows pedestrians to cross streets in all directions, sometimes including diagonally. This strategy is most effective in high-density urban areas with high volumes of pedestrian and low-to-moderate volumes of vehicles since the phase can cause undesirable vehicle and pedestrian delay.



Protected walk phase with a right turn restriction



Leading pedestrian signal

Are they a proven strategy?

As a result of the FHWA Proven Safety Countermeasures initiative, leading pedestrian intervals are officially a **PROVEN** safety countermeasure. Exclusive pedestrian signal phasing is not yet a proven safety countermeasure and is considered a **TRIED** countermeasure.

Supporting Documentation: FHWA Safety Countermeasures - LPI

Where would we use them?

Leading pedestrian intervals are most effective when:

- Intersections have relatively high crossing volumes.
- Intersections have relatively high turning vehicle volumes.
- Intersections have patterns of pedestrian or bicycle conflict with vehicles.

Exclusive pedestrian phases are most effective when:

- Intersections with large concentrations of pedestrians often need to cross a busy street at the same time. This is typically in urban areas, tourist-heavy areas, college campuses, places with major shift changes.
- Intersections that experience high vehicular delay due to heavy pedestrian traffic.
- Intersections that experience patterns of vehicle-pedestrian conflicts for all movements.

Leading and Separate Exclusive Signal Phases

What are the advantages?

- Can be programmed into an existing traffic signal for a relatively low cost ($0 to $3,500) .
- Increase visibility of crossing pedestrians, especially for pedestrians who may be slower to enter the intersection.
- Improve comfort for pedestrians crossing busy intersections.
- Increase likelihood of motorists yielding to pedestrians.
- LPIs reduce pedestrian-vehicle crashes by 60% at intersections.

What are the challenges?

Leading Pedestrian Intervals

- Can increase delay for drivers.
- Older traffic signals may not support the infrastructure needed to easily and cost effectively implement this phasing. In these cases, there would be an increased cost to support the technology due to new controller and other traffic signal infrastructure.

Exclusive Pedestrian Phases

- May increase pedestrian delays by reducing amount of pedestrian crossing time during a signal cycle.
- Operations do not meet most pedestrian or driver expectations, and therefore additional educational efforts may be necessary.



Pedestrian scramble crossing at New Brighton Boulevard & Stinson Boulevard NE, Minneapolis, MN, Source: Google Earth

How much do they cost?

Depending on the existing infrastructure at the signalized intersection, timing adjustment costs can range from almost nothing to approximately $3,500. If pedestrian signals are required, the infrastructure costs can range approximately $8,000 to $75,000 per intersection. Additional costs for pedestrian countdown timers, push buttons, and other signal infrastructure components can add up to a total of approximately $150,000 per intersection.

Leading and Separate Exclusive Signal Phases

Design Features

LPIs and exclusive pedestrian phase designs can typically be programmed into an existing traffic signal. The phase can be activated by the pedestrian or with pedestrian phases that are on automatic recall.

The MnMUTCD provides guidance for LPIs. It states that if they are used, designs should include the following:

- Accessible pedestrian signals
- A minimum 3-second interval, depending on the crossing width, site location, and other factors
- Consider prohibition of turns across the crosswalk during the LPI

Supplemental treatments

LPIs and exclusive pedestrian phase designs can be enhanced with the following treatments:

- Curb extensions at the intersection to further improve pedestrian visibility.
- Marked crosswalks in all directions (including diagonally if desired for exclusive pedestrian phase).

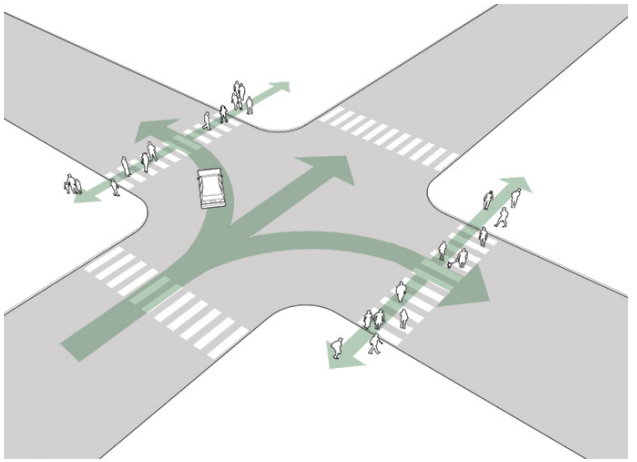
Resources

Leading Pedestrian Interval

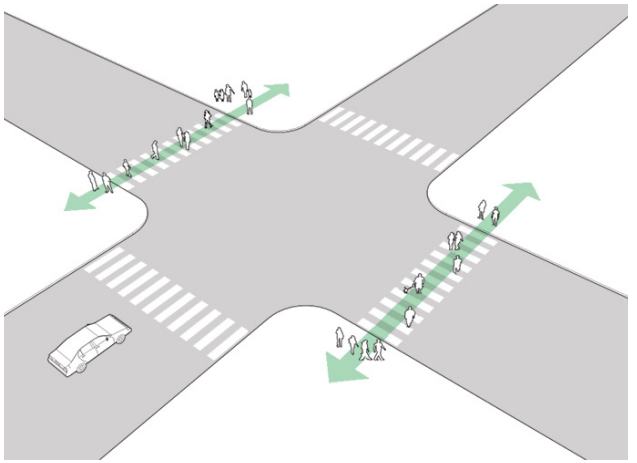
- https://safety.fhwa.dot.gov/provencountermeasures/lead_ped_int/
- http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=12
- https://nacto.org/publication/urban-street-design-guide/intersection-design-elements/traffic-signals/leading-pedestrian-interval/

Exclusive Pedestrian Signal

- https://safety.fhwa.dot.gov/ped_bike/legis_guide/rpts_cngs/pedrpt_0808/chap_3.cfm
- http://www.pedbikesafe.org/pedsafe/countermeasures_detail.cfm?CM_NUM=47



Potential conflict with pedestrians without a leading pedestrian interval, Source: NACTO Urban Street Design Guide



Potential conflict with pedestrians avoided with the use of a leading pedstrian interval, Source: NACTO Urban Street Design Guide

Bicycle Signals

What is their purpose?

A separate bicycle signal can improve operations involving bicycle facilities and designate right-of-way for bicyclists at locations where their needs may differ from other roadway users and a separate bicycle facility exists. For example, bicyclists may be allowed to enter an approach leg that vehicles are restricted to turn onto. With the inclusion of bicycle signals in the MnDOT Bicycle Facility Design Manual and the Interim Approval of Bicycle Signal Faces (IA 16), there is an opportunity to use similar strategies to minimize or eliminate bicycle-motor vehicle conflicts at signalized intersections.

Similar to a leading pedestrian interval (LPI), the purpose of a leading bicycle interval (LBI) is to allocate dedicated time for bicyclists to enter the intersection prior to vehicles being given the green indication. This time reduces the risk of conflicts between bicyclists and turning vehicles. It also gives bicyclists additional time to safely make necessary turning or lane change maneuvers. An LBI is a supplemental strategy that requires bicycle signal infrastructure.



Bicycle signal lens with supplemental plaque. Note the right turn signal with a blank out sign to restrict turns across the bikeway during the bicycle signal phase. Jackson Street, Saint Paul, MN

Are they a proven strategy?

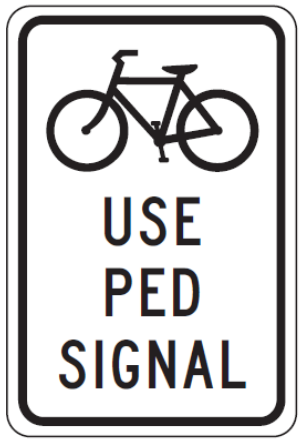
Separate Bicycle Signal

As part of the Interim Approval process, the FHWA reviewed research of bicycle lenses where bicyclists have separate signal phases. The use of a bicycle signal, in accordance with FHWA Interim Approval 16, is considered **PROVEN**.

Leading Bicycle Interval

The FHWA Interim Approval does not allow for the use of bicycle signal lenses where permissive motor vehicle movements conflict with bikeway traffic (such as a leading bicycle interval). Therefore, LBIs are considered **EXPERIMENTAL**, and a Request to Experiment to the FHWA is required when using a signal with a bicycle signal face lens.

An alternative approach for a leading bicycle interval that does not require a request to experiment is to implement a leading pedestrian interval in conjunction with a "Bikes use ped signal" sign (R9-5). R9-5 signs and leading pedestrian intervals are both included in the MnMUTCD, and there is nothing that precludes their use together. This approach has been **TRIED**, but there is no research documenting its efficacy.



R9-5

Bicycle Signals

What are the advantages?

Separate Bicycle Signal

- Separating bicycle and motor vehicle movements can reduce conflicts, and thus reduce the risk of a crash.
- Bicycle signals facilitate unusual or unexpected arrangements of the bicycle movement.

Leading Bicycle Interval

- Once bike signal infrastructure is in place, the LBI can be programmed into an existing traffic signal for a relatively low cost.
- Increase visibility of crossing bicyclists.
- Improve comfort for bicyclists crossing busy intersections.
- Increase the likelihood of motorists yielding to bicyclists.

Where would we use them?

Separate bicycle signals are most appropriate when you have two or more of the following conditions:

- Intersections with relatively high motor vehicle/ bicycle conflicts for certain signal phases
- Intersections with a with two-way or contraflow bicycle movement that may not be expected by motor vehicles
- Bicycle facility transitions that require bicyclists to cross through a motor vehicle lane
- Intersections that permit a relatively short cycle length, and have either bicycle detection or a bicycle phase on recall, such that it comes up with each cycle
- Locations where bicyclists may require an increased level of control to facilitate unusual or unexpected arrangements of the bicycle movement through complex intersections and conflict areas. Locations where bicyclists are physically separated from motorists and pedestrians.

Separate bicycle signals are less appropriate where these conditions don't exist. Bicyclists are less likely to obey separate bicycle signals if there are few bicycle-motor vehicle conflicts and if the bicycle signal phase isn't reliably called in a timely manner.

Leading bicycle intervals should be considered at the following locations:

- Complex intersections with high bicycle demand.
- Locations where a protected phase is not operationally feasible.
- Locations where there is history of bicycle-vehicle conflict or visibility concerns.
- Reference the Interim Approval 13 for more details regarding the federal guidance.

What are the challenges?

Separate Bicycle Signal

- Older traffic signals may not support the infrastructure needed to easily and cost effectively implement this phasing. In these cases, there would be an increased cost to support the technology due to new controller and other traffic signal infrastructure.
- Can help simplify bicycle movements at complex intersections.
- Bicycle signals require bicycle detection unless located at a pre-timed signal. Options include passive detection (inductive loop detectors, video, infrared, microwave/radar) and active detection (push buttons). In Minnesota, the most common type of detection are inductive loop detectors, and video detection is sometimes used. Detection costs have a wide range, and bicycle detection equipment should be tested and calibrated under a variety of bicycle sizes, material types, and lighting and weather scenarios to confirm effectiveness.
- Bicyclists may disregard a bicycle signal if it is unnecessary or if detection is ineffective.

Leading Bicycle Interval

- Can increase delay for drivers, especially turning vehicles.
- May require additional education for drivers and bicyclists.

How much do they cost?

Depending on the existing infrastructure at the signalized intersection, timing adjustment costs can range from almost nothing to approximately $3,500. If new signal equipment such as controllers, wiring, loop detectors, and bicycle signal heads is required, the cost can be up to approximately $150,000. Installing video detection would bring additional costs.

Bicycle Signals

Design Features

Prior to implementing a bicycle phase or bicycle signals, the agency should review the existing traffic volumes, existing bicycle amenities, traffic signal equipment, and signal phasing. NACTO provides design guidance for bicycle signal heads, including clearance interval calculations, signal head locations, and additional infrastructure recommendations.

In locations where leading bicycle intervals are recommended, bike signals must be provided at the intersection to designate the interval.

Bike signal designs should include:

- Signal heads placed in a location visible to approaching bicycles.
- A bicycle recall phase for each cycle, or installed detection and actuation. There is currently no standard for detection in Minnesota; inductive loop detectors and video detection have been used.
- Proper clearance interval of at least 3 seconds, based on bicycle travel speeds and crossing distance.
- Prohibited right-turn on red movements if the bicycle movements would conflict with right-turning vehicles.
- Consideration for adjacent signalized intersections to ensure the bicycle signal does not cause undesirable delay.
- The MnDOT Bicycle Facility Design Manual states that the primary bicycle signal head should be 8" or 12" in diameter; this is based on the MnMUTCD, which allows 8" diameter signals for the purpose “of controlling a bikeway or a bicycle movement.”
- Supplemental, near-side bicycle signal faces may be 4" per the Interim Approval 16.

The Interim Approval only allows the use of a bicycle signal lens where there are no conflicting motor vehicle movements. If practitioners wish to use a bicycle signal in a condition where permissive motor vehicle movements conflict with the bikeway, they need to do one of the following:

- Use a traditional signal lens with a “bicycle signal” plaque in accordance with the Interim Approval;
- Instruct bicyclists to follow the pedestrian signal and program a leading pedestrian interval; or
- Obtain a “Request to Experiment” from the FHWA for the use of a bicycle signal lens in conjunction with a conflicting permissive motor vehicle movement.

What are the maintenance impacts?

Bike signal heads and leading interval timings will require similar routine maintenance as standard traffic signals.

Inductive loop detectors are used at many locations throughout the state due to their low maintenance and relatively low cost. However, these detectors do not always work for bicycles that are made of non-metal material. Video detection captures all bicycle types, but requires additional maintenance to ensure the lens is cleaned and positioned correctly.

Supplemental treatments

LBIs and separate bicycle signal designs can be enhanced with the following treatments:

- Restriction of all turn movements that would conflict with the bicycle movements
- Bicycle detection by means of inductive loop detectors or bicycle push buttons
- Bicycle boxes
- Intersections with LBIs commonly implement parallel leading pedestrian intervals

Best practices

Bicycle signals should only be used in combination with existing traffic signals or a pedestrian hybrid beacon to improve safety or operational problems that involve bicycle activities. Bicycle signals typically use standard three-lens signal heads in green, yellow, and red lenses. Design should comply with Interim Approval 16.

Bicycle Signals

Resources

- MnDOT Bicycle Facility Design Manual
- http://www.dot.state.mn.us/bike/bicycle-facility-design-manual.html
- MassDOT Separated Bike Lane Planning and Design: https://www.mass.gov/files/documents/2017/10/26/SeparatedBikeLaneChapter6_Signals_1.pdf
- https://nacto.org/publication/urban-bikeway-design-guide/bicycle-signals/bicycle-signal-heads/
- http://www.minneapolismn.gov/www/groups/public/@publicworks/documents/images/wcmsp-195582.pdf
- Cost: http://pedbikesafe.org/bikesafe/countermeasures_detail.cfm?CM_NUM=55
- https://mutcd.fhwa.dot.gov/resources/interim_approval/ia16/



A bicycle signal on Jackson Street in Saint Paul, MN

Right Turn on Red Prohibition

What is its purpose?

Prohibiting right turning movements on red at signalized intersections is an option to enhance the safety for pedestrians at the intersection. Static or dynamic signage is installed prohibiting the turning movement during the red signal, either at all times or certain times of day. This practice helps to mitigate conflicts stemming from motorists basing turning decisions on gaps in conflicting traffic rather than looking for crossing pedestrians.

Allowing right turns on red except where signs prohibited them was a policy adopted nationwide in the 1970s (with the exception of New York City) as an effort to save energy. While the law requires motorists to come to a full stop and yield to cross street traffic and pedestrians prior to turning right on red, many motorists do not fully comply with the regulations. As mentioned above, some motorists focus mainly on traffic approaching from the left and do not look for pedestrians on their right. Additionally, many motorists encroach into the crosswalk to wait for a gap in traffic, blocking pedestrian crossing movements. In some instances, motorists simply do not come to a full stop.



No turn on red blank-out sign



No turn on red static sign

Is it a proven strategy?

Prohibiting right turns on red (RTOR) can help reduce crashes that involve right-turning vehicles, drivers with limited sight distance, and pedestrians. Because of the lack of specific data for this treatment, this is a **TRIED** measure.

Where would we use it?

The RTOR restriction should be considered for improving pedestrian and bicycle safety at:

- Locations that have limited sight distance and/or unusual geometry.
- Locations within school zones (especially at school crosswalks) and near libraries, senior centers, transit stations, or other pedestrian traffic generators.
- Locations that intersect exclusive bicycle facilities (especially two-way bicycle facilities with contraflow bicycle traffic) and trail crossings.
- At any crosswalk where the MnMUTCD pedestrian volume and/or school crossing warrant is met (MnMUTCD, Section 4C, Warrants 4 and 5).

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, such as checks to ensure the signs meet retroreflectivity standards and that electronic signs, if used, are functioning properly.

Supplemental treatments

- Leading pedestrian interval (LPI)

Right Turn on Red Prohibition

What are the advantages?

- Protects bicyclists and pedestrians crossing with a signal from crashes with right-turning vehicles.
- Provides a way to mitigate risks of crashes when limited sight distance or contraflow bicycle movements exists at an intersection

Best practices

Restricting RTOR movements is a low-cost strategy to improve safety at intersections for crossing pedestrians. This should be implemented at intersections with consistent pedestrian activity and at intersections with limited sight distance.

Resources

- https://safety.fhwa.dot.gov/saferjourney1/library/countermeasures/44.htm
- https://nacto.org/wp-content/uploads/2016/04/1-11_nchrp500_antonucci-on-NACTO-website.pdf
- https://nacto.org/publication/transit-street-design-guide/intersections/signals-operations/turn-restrictions/
- http://pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=49
- Page 114: https://www.chicago.gov/content/dam/city/depts/cdot/Complete%20Streets/CompleteStreetsGuidelines.pdf

What are the challenges?

- Drivers may fail to comply with the RTOR prohibition.
- Additional enforcement may be necessary to improve compliance, and enforcement may be more difficult with a blank out sign relative to a static sign.
- Implementation may lead to an increase in right turn on green conflicts with pedestrians. Using an LPI to establish pedestrians in the crosswalk before drivers have the green indication to turn right may be the best way to address this issue.
- Could cause intersections to experience an increase in motor vehicle delay, making it more challenging to implement where vehicle volumes are higher.
- Require additional maintenance considerations

What are the maintenance impacts?

RTOR signals require routine maintenance by properly trained technicians and ongoing funding to repair, replace, or upgrade signal controllers, detectors, and other signal hardware. Additionally, all No Turn on Red signs should be routinely checked to ensure they are visible to motorists. It is also important to regularly assess the condition of RTOR signal control equipment, including verifying that detectors are working properly, and signal displays are operational.

Design Features

Restricting right turn on red movements at a signalized intersection generally does not require physical design changes. When right-turn restrictions are implemented, the following is recommended:

- Install No Turn on Red sign – this sign can be traditional static sign posting or an electronic sign.
- Signs should be placed within proper sight lines of potentially turning drivers, ideally installed adjacent to a signal face viewed by drivers in the right lane.
- RTOR prohibitions may be signed to occur only during the peak travel times during the day.
- No Right Turn LED Blank-out signs can also be installed, and can be programmed to be activated by the pedestrian.

How much do they cost?

The cost for a static sign is approximately $200. An LED blank-out sign costs approximately $3,000.

Roundabouts

What is their purpose?

The modern roundabout is a circular intersection that helps traffic move safely and efficiently. Roundabouts include channelized approaches and a center island, and entering traffic yields to vehicles already circulating. They have lower speeds and fewer conflict points than a typical signalized intersection, which leads to improved operational performance.

Generally, there are two types of roundabouts: single-lane and multi-lane. Single-lane roundabouts are typically simpler and safer for pedestrians and bicyclists to cross. Neighborhood traffic circles and mini-roundabouts are similar strategies for streets with lower traffic volumes and speeds.



Roundabout at CSAH 15 and 7th Street, New Prague, MN

Are they a proven strategy?

Roundabouts provide substantial safety and operational benefits for motorists compared to other intersection types, most notably a reduction in severe crashes. Roundabouts are an effective strategy for reducing severe crashes involving vehicles. Comprehensive studies of both pedestrian and bicycle safety at roundabouts are limited, so they are considered **TRIED**.

Roundabouts have demonstrated improved safety performance compared to traffic signal control, especially for the most severe types of crashes. In Minnesota, the most common type of severe intersection-related crash is an angle crash. In roundabouts, angle crashes still may occur, but at lower speeds and at shallower angles.

A 2017-2018 MnDOT study of Minnesota roundabout traffic safety found that single-lane roundabouts had an 89% reduction in fatal crashes. The study also found that while some other roundabouts had an increase in total crash rates, the severity of the crashes was reduced. The study found that roundabouts do not increase the risk to pedestrians and bicyclists from collisions with motor vehicles. Further research in Minnesota found that roundabouts provide an approximate 60% Crash Reduction Factor (CRF) for pedestrian crashes after conversion from a four-legged intersection.

Supporting Documentation: FHWA Proven Safety Countermeasures, MnDOT Roundabout Study, MnDOT Roundabout Study Addendum

Roundabouts

What are the advantages?

- Crash Reduction Factor (CRF) for all crash types vary widely according to FHWA. When converting a two-way stop-controlled intersection, there is an 82% reduction in severe crashes for all crash types. When converting a signalized intersection, there is a 60% reduction in severe crashes for all crash types.
- Can reduce vehicle speeds, which benefits bicyclists and pedestrians crossing the roundabout.
- Can increase the capacity of an intersection compared to traditional stop sign or signal-controlled intersections.
- Observational studies have found that vehicles in single-lane roundabouts have higher rates of yielding to pedestrians than vehicles in multi-lane roundabouts.

What are the challenges?

- Multi-lane roundabout crosswalks can present the same multiple-threat sight line challenges as other uncontrolled crossings.
- Available right-of-way can restrict or limit the construction of a roundabout.
- Additional enhancements may be necessary for pedestrians with visual impairments or at intersections with significant pedestrian, bicycle, and vehicle traffic, particularly at multi-lane roundabouts. Supplemental treatments include raised crosswalks and RRFBs or PHBs at the splitter islands.

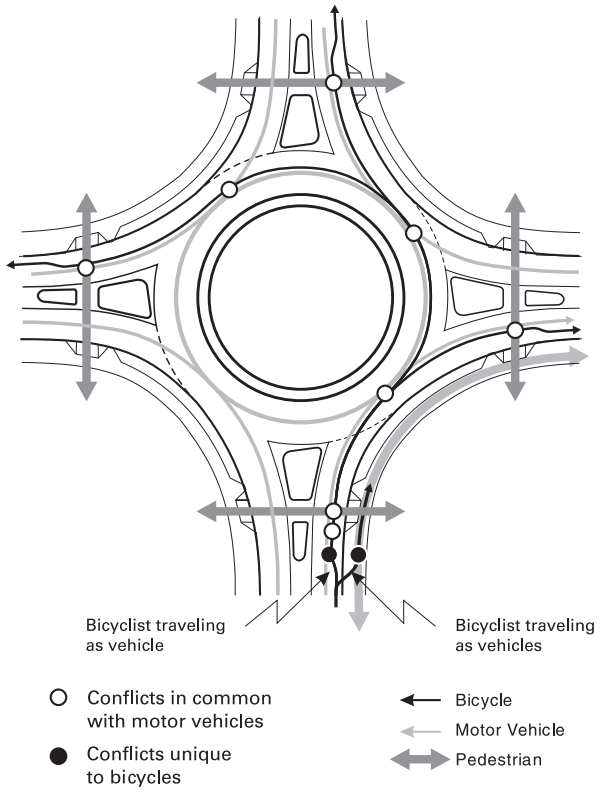
Where would we use them?

Roundabouts can be considered at the following locations:

- At intersections with a pattern of fatal, angle, turning, and head-on crashes.
- Roundabouts can be implemented in both urban and rural areas under a wide range of traffic conditions, but are commonly installed when intersections experience undesirable delay at stop-controlled or signalized intersections.
- Roundabouts are commonly installed as an alternative to all-way stop controlled or signalized intersections

What are the maintenance impacts?

Due to the lack of hardware, electric needs, and timing equipment, the costs to maintain and operate a roundabout are typically less than the maintenance costs for signal-controlled intersections.



An illustration of bicycle conflict points at a roundabout, Source: FHWA Roundabouts: An Informational Guide

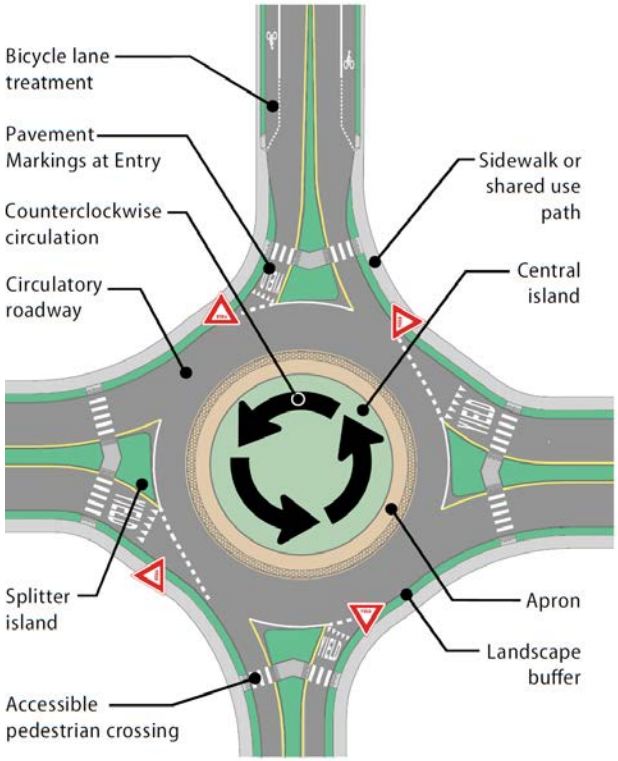
How much do they cost?

The typical cost of a basic roundabout is approximately $1 million, not including right-of-way acquisition. Costs will vary depending on location and size of the roundabout.

Design Features

MnDOT specific roundabout design details can be found in Chapter 7 of MnDOT's Bicycle Facility Manual, Chapter 12 of MnDOT's Road Design Manual, and NCHRP Report 672 - Roundabouts: An Informational Guide. General roundabout design considerations to maintain or improve pedestrian/bicycle safety include the following:

- If long-term traffic projections suggest the need for a multi-lane roundabout, but the need isn't likely for several years, the roundabout can be constructed as a single-lane roundabout and designed for additional lanes to be constructed if warranted in the future.
- Designers should be cognizant of bicycle traffic when designing roundabouts, constraining design speeds to those compatible with typical bicycle speeds to promote bicyclist safety and comfort, refer to MnDOT's Bicycle Facility Manual for more information.
- Separated bike lanes can be continued through roundabouts, with crossings that are similar to, and typically adjacent to, pedestrian crosswalks. Drivers approach the bicycle crossings at a perpendicular angle, maximizing visibility of approaching bicyclists.
- Roundabouts can include truck aprons along the approaches or exits to keep entering and exiting vehicle speeds low at conflict points with pedestrians and bicyclists while still accommodating larger design vehicles.
- Proper roadway deflection angles at all entries and exits and are critical to reducing motor vehicle speeds through the intersection.
- Bicycle slip lanes or exit ramps to shared use paths are another design element that should receive detailed consideration.



An illustration of a roundabout, Source: FHWA



A pedestrian crossing at a roundabout

Resources

- https://safety.fhwa.dot.gov/provencountermeasures/roundabouts/
- http://www.dot.state.mn.us/bike/design-engineering.html
- https://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/fhwasa08011.pdf
- http://www.dot.state.mn.us/trafficeng/safety/docs/roundaboutstudy.pdf
- http://www.dot.state.mn.us/trafficeng/safety/docs/roundaboutsafetyaddendum.pdf

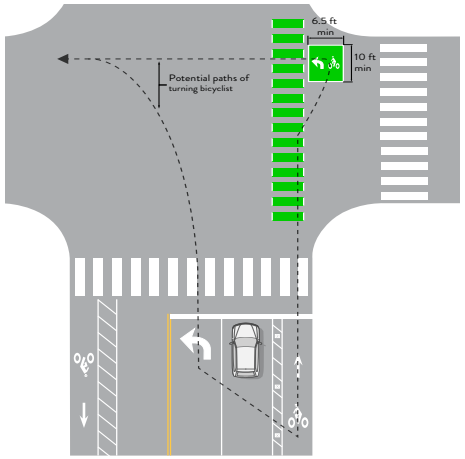
Bicycle Boxes

What is their purpose?

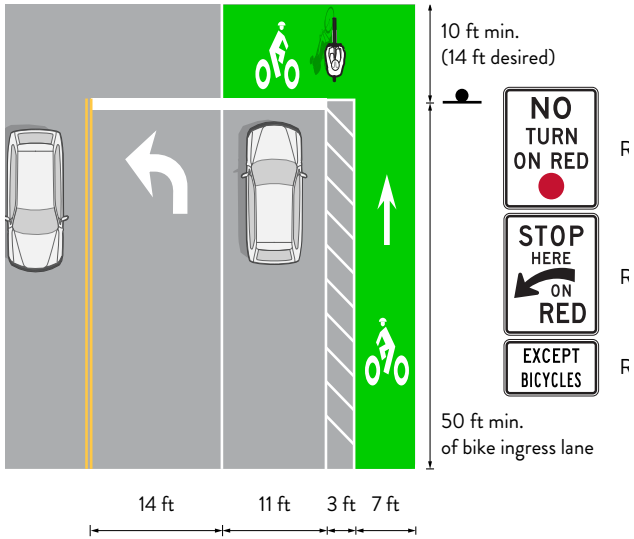
A bicycle box is a set of pavement marking elements installed at signalized intersections that allows bicyclists to pull in front of waiting traffic at a red light. This makes bicyclists more visible to motorists and gives bicyclists a head start when the light turns green, thus providing the opportunity to avoid conflicts with turning motor vehicles.

There are two types of bicycle boxes: two-stage turn boxes and intersection boxes (also referred to as simply "bicycle boxes"). Two-stage turn bicycle boxes are located adjacent to the bicyclist's direct path of travel and downstream of a crosswalk and stop line, and are typically used for facilitating bicycle left turns. Intersection bicycle boxes are located in front of the vehicle stop bar but behind the pedestrian crosswalk and are used for all bicycle turning movements.

MnDOT received statewide Interim Approval from FHWA for the use of green-colored pavement for bike lanes (IA 14), the use of bicycle boxes (IA 18), and for two-stage turn boxes (IA 20). Statewide Interim Approval allows any jurisdiction within Minnesota to use the devices, as long as the jurisdiction agrees to notify the MnDOT Traffic Standards Engineer of the location for each installation and agrees to the specific conditions outlined for Statewide Interim Approvals.



Two-stage bicycle turn box, using optional green colored pavement. This drawing also illustrates dotted bicycle lane extensions with green colored pavement.



Intersection bicycle box, using optional green colored pavement.

Are they a proven strategy?

Bicycle boxes and two-stage turn boxes have been tested through the FHWA experimentation process and are considered **PROVEN**. FHWA has concluded that bicycle intersection boxes reduce conflicts between motor vehicles and bicyclists and that motorists and bicyclists understand the purpose and proper usage of the box. FHWA has also found positive operational effects after the installation of two-stage turn boxes, including bicyclists using a two-stage turning maneuver with greater consistency.

Where would we use them?

Bicycle boxes are often installed at the following locations:

- At signalized intersections (if one is installed, it must be at a signalized intersection).
- On roadways that already have bike lanes and a substantial volume of bicycle traffic, especially bicycle traffic that primarily continues through the intersection.
- At intersections where a left turn is necessary to continue on a dedicated bicycle route or other shared use path.
- In locations where there are bicycle-motor vehicle turning conflicts.
- In locations where right turn on red prohibitions for motor vehicles can be added.
- Two-stage turn bicycle boxes can be used on roadways of any speed, but they provide a greater benefit on roadways with speeds of 35 MPH or higher.

Bicycle Boxes

What are the advantages?

- Reduce the number of conflicts between bicyclists and turning drivers, especially those turning right.
- Reduce the number of avoidance maneuvers by both bicyclists and motorists.
- Reduce the number of bicycles and motor vehicles encroaching into pedestrian crosswalks when stopped at an intersection.
- Help prioritize bicyclists at intersections with major streets.
- Reduce bicyclist delay at signalized intersections.
- Motorists and bicyclists both understand the purpose and proper usage of the bicycle box.
- 35% reduction in bicycle crashes.



Bicyclist waiting at a signal in a bicycle box with optional green colored pavement

What are the challenges?

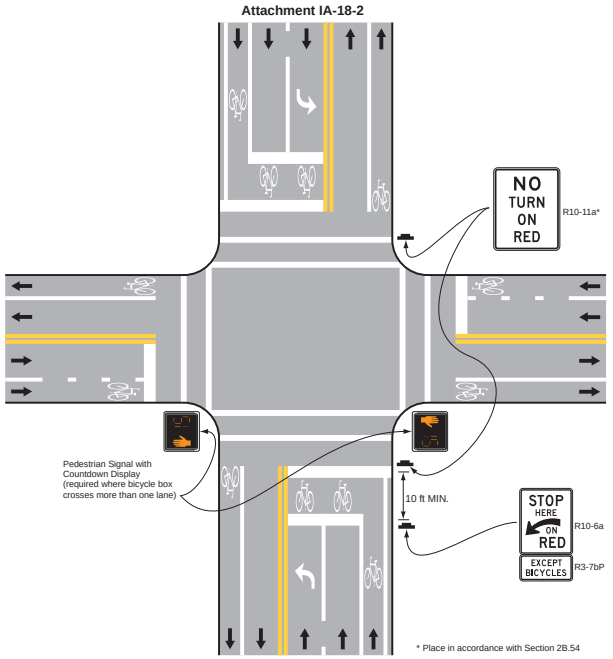
- Cars may encroach into the bicycle boxes, reducing the available space for bicycles to queue safely.
- Right turn on red movements must be prohibited to avoid conflicts between right-turning motor vehicles and waiting bicyclists.
- In cases where there are multiple travel lanes and where the bicycle box does not extend to all travel lanes, bicyclists may still have difficulty turning left.

What are the maintenance impacts?

The use of durable pavement markings will help minimize ongoing maintenance, especially when using green-colored pavement, which may be difficult for some agencies to refresh. Ground-in thermoplastic pavement markings are commonly used in Minnesota and typically have a service life of several years.

Best practices

- Place an advance stop line at least 10' from the intersection stop line.
- Prohibit right turn on red movements to avoid conflicts between right-turning motor vehicles and waiting bicyclists.
- Provide at least 50' of a bicycle lane prior to the bicycle box.



Bicycle box at an intersection, Source: FHWA Interim Approval 18

How much do they cost?

The cost for a bicycle box can vary depending on whether a bike lane already exists or needs to be added. Costs are typically about $1,000 per bicycle box.

Bicycle Boxes

Design Features

Reference FHWA Interim Approval 18 for detailed design provisions for intersection bicycle boxes. NACTO can also be referenced for additional recommended and optional design features for bicycle boxes. A summary of key design features is below:

- Place an advance stop line at least 10' from the intersection stop line.
- Countdown pedestrian signals shall be provided at adjacent crosswalks to inform bicyclists of the remaining time to cross; this is especially important at locations with multiple lanes to cross.
- A bicycle box should be paired with an approach lane as well as a lane that extends through the intersection.
- Provide at least 50' of a bicycle lane prior to the bicycle box.
- Prohibit right turn on red movements to avoid conflicts between right-turning motor vehicles and waiting bicyclists.
- Install a sign assembly of STOP HERE ON RED (R10-6 or R10-6a) and EXCEPT Bicycles (R3-7bP) in advance of the stop line for motor vehicles.
- For intersection bicycle boxes: 10'-wide bicycle boxes are the minimum, 14'-wide bicycle boxes are recommended.
- For two-stage turn bicycle boxes: 6.5'-wide bicycle boxes are the minimum, 10'-wide bicycle boxes are recommended.
- Use a high-friction pavement marking material, such as MnDOT's Enhanced Skid Resistance Thermoplastic to avoid slipping on wet markings.



Bicycle box with optional green colored pavement

Resources

- https://mutcd.fhwa.dot.gov/res-interim_approvals.htm
- https://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/fhwasa08011.pdf
- http://www.dot.state.mn.us/bike/design-engineering.html
- https://nacto.org/publication/urban-bikeway-design-guide/intersection-treatments/bike-boxes/

Protected Intersections

What is their purpose?

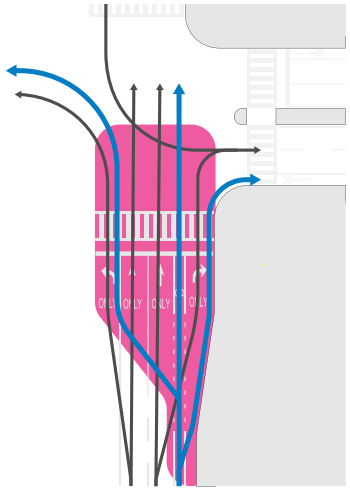
Protected intersections separate pedestrians and bicyclists from motor vehicles using physical barriers that eliminate merging and weaving movements. Well-designed protected intersections are intuitive and comfortable, provide clear right-of-way assignment, promote predictability of movement, and allow eye contact between motorists, bicyclists, and pedestrians. A comparison of conflict points at conventional (on-road) bike lanes and at protected intersections is shown in pink on the figures to the right. The single conflict point at a protected intersection can be eliminated by providing a separated signal phase for turning traffic, when used in conjunction with dedicated turn lanes..

Protected intersections can also incorporate intersection design elements that reduce speeds (see Intersection Design section).

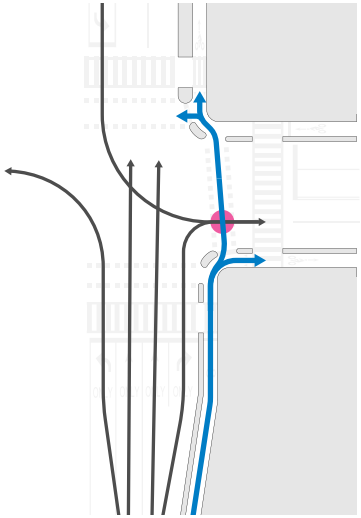
By moving the bicycle through movement further from the vehicle lane, it becomes easier for a cyclist to spot a right-turning vehicle in time to avoid a collision, and improves motorist sight lines as well.



A protected intersection



Conflict area between bicycles and motor vehicles (in pink) at a conventional intersection, Source: MassDOT Separated Bike Lane Planning and Design Guide



Conflict points with a protected intersection, Source: MassDOT Separated Bike Lane Planning and Design Guide

Protected Intersections

What are the advantages?

- Reduce motor vehicle speeds at intersections, which reduces bicycle and pedestrian crash severity.
- When combined with intersection design practices such as smaller curb radii, can reduce crossing distance, minimizing pedestrian and bicycle exposure at the intersection.
- Reduce the interaction between bicyclists and motor vehicles through an intersection, which minimizes bicycle exposure at the intersection.
- Improve the ability of drivers to perceive and react to bicyclist in the intersection, and improve ability of cyclists to recognize when a vehicle is turning right.
- Forward queuing area for bicyclists and pedestrian refuge median reduces crossing distances for both users and improves their visibility to motorists.
- Can reduce bicyclist speeds by adding deflection to the bike lane or sidepath.

What are the challenges?

- Design may require additional right-of-way depending on the existing roadway's cross-section. Existing roadway amenities, such as on-street parking lanes, may need to be removed to fit the design.
- Reducing curb radii and removing channelized right turns can make it difficult for larger vehicles to navigate an intersection without encroaching into opposing lanes of travel.
- Adjustments to curb radii and channelized right turns may require modifications to existing drainage infrastructure.
- Channelized right-turn lanes may need to be removed from an intersection in order to make the design fit, which may increase motor vehicle delay.
- If motorists and bike/pedestrian movements are concurrent or uncontrolled, sight lines on the approach must be kept clear to maintain visibility between street users.
- Significant impacts on maintenance efforts.

Are they a proven strategy?

Individual strategies to slow vehicles at intersections have been **PROVEN**. Protected intersections have **PROVEN** safety benefits at signalized and unsignalized intersections where bicycle crossings are offset from the motorist travel way by a preferable distance of between 6' and 16.5'.

Where would we use them?

Protected intersections can be considered at the following locations:

- At signalized or stop-controlled intersections to create safe, comfortable conditions for people bicycling and walking, where there are high volumes of turning motor vehicle traffic.
- They are most commonly used with separated bike lanes and sidepaths, but can be used with conventional (on-road) bike lanes, paved shoulders, or shared lanes.

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months, to keep the bike lane and small concrete islands free of snow and debris. The design should ensure that maintenance vehicles can clear snow and debris from the narrow bikeways.

How much do they cost?

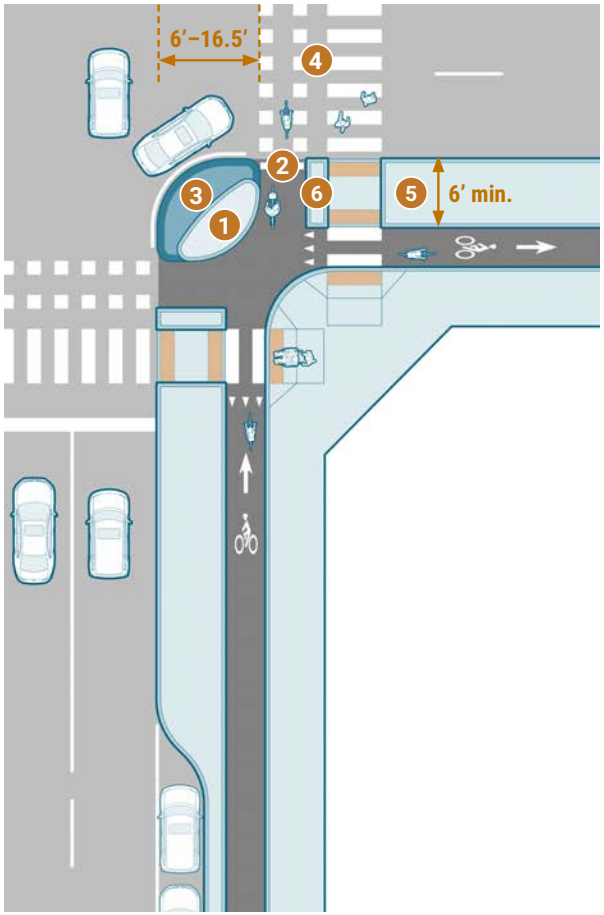
The cost for a protected intersection varies widely depending on the site conditions, drainage impacts, and existing intersection features. On average, it costs approximately $100,000 to upgrade a signalized intersection to a protected intersection with permanent features, without a separate bicycle phase. A seasonal or other short-term design (only intended for a few years) can be achieved at a much lower cost by using flexible posts.

Protected Intersections

Design Features

FHWA Achieving Multimodal Networks report and Chapter 4 of the MassDOT Separated Bicycle Lane Planning and Design Guide both provide additional detailed guidance for protected intersections. Noteworthy design features include the following (specific points in some notes are illustrated in the graphic on the right):

- Key features include a corner island, forward bicycle queuing area, driver yield zone, and pedestrian refuge median.
- Corner island – A corner island allows the bike lane to be physically separated from motor vehicle traffic up to the edge of the intersection and reduces motor vehicle turning speeds (1). Mountable truck aprons can accommodate large vehicles (3).
- Forward bicycle queuing area – Forward bicycle queuing area provides a waiting area for bicyclists that is fully within view of drivers waiting behind the pedestrian crosswalk (2).
- Driver yield zone – A driver yield zone creates a space for turning drivers to yield to bicyclists and pedestrians by setting the bicycle and pedestrian crossings back from the intersection, similar to the offset geometry recommended for sidepath crossings (4). If pedestrian and/or bicyclist movements are to be protected by signal phasing, a driver yield zone is not as critical.
- Pedestrian refuge median – A pedestrian refuge median enables pedestrians to cross bicycle and motor vehicle traffic separately and reduces the pedestrian crossing distance ((5) and (6)). Medians less than 6'-wide should not be considered refuges, and cannot include detectable warning surfaces.
- Can be constructed of curbs and more permanent features, or using flexible delineators and other rapid implementation materials.



A protected intersection. Source: FHWA Achieving Multimodal Networks

Supplemental treatments

Protected intersections include several other treatments discussed in more detail in the following sections of this handbook:

- Intersection Design
- Bicycle Boxes
- Medians and Crossing Islands
- Curb Extensions and Curb Radii
- Bicycle Signal Indications
- LPI and/or LBI

Resources

- FHWA Achieving Multimodal Networks: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_networks/fhwahep16055.pdf
- MnDOT's Bicycle Facility Manual: http://www.dot.state.mn.us/bike/design-engineering.html
- MassDOT Separated Bicycle Lane Planning and Design Guide: https://www.mass.gov/lists/separated-bike-lane-planning-design-guide

Pedestrian Hybrid Beacon Systems

What is their purpose?

A pedestrian hybrid beacon (PHB) system, formerly known as a High-Intensity Activated crossWalK (HAWK), is a beacon installed at unsignalized locations to assist pedestrians in crossing a street at a marked crosswalk. The beacon warns and controls traffic with the use of two side-by-side red lenses and a single yellow below the red.

Per the Manual on Uniform Traffic Control Devices (MnMUTCD), a PHB may be considered for installation at marked crossing locations that do not meet traffic signal warrants or at locations that meet traffic signal warrants but the agency has not yet decided to install a traffic signal. The MnMUTCD, Chapter 4F, provides additional guidelines and appropriate volumes that should be reached prior to installation. The guidelines include separate criteria for low speeds (35 mph or less) and high speeds (greater than 35 mph). Consideration should also include major street volumes, pedestrian volumes, operating speeds, widths, gaps in traffic, walking speeds, and pedestrian delay.



Pedestrian Hybrid Beacon

Are they a proven strategy?

As a result of the FHWA Proven Safety Countermeasures initiative which began in 2008, PHB systems are a **PROVEN** safety countermeasure.

Supporting Document: FHWA Proven Countermeasures - PHB

Where would we use them?

Per the MnMUTCD, a PHB shall:

- Only be installed with a marked crosswalk and warning signs
- Only be installed to assist pedestrians to cross a street or highway

Additional guidance suggests that PHBs are most effective when:

- Locations need additional enhancements to improve motorist yielding rates or address limited gaps in traffic at marked crosswalks.
- There is a high volume of pedestrian traffic, such as near transit stops, schools, and multi-use trail crossings. The MnMUTCD states that the lowest pedestrian volume threshold for a PHB is 20 pedestrians/hour to cross the major street.
- Traffic signals are not yet warranted and/or are too costly to install.
- Installed at mid-block crossings. Consideration can be given to their use at minor, uncontrolled intersections, but this is not typically encouraged as it may create ambiguity for the assignment of right of way for vehicles on the minor road.

Pedestrian Hybrid Beacon Systems

What are the advantages?

- Proven countermeasure per FHWA.
- Improve visibility of pedestrians.
- Assign right-of-way for vehicles and pedestrians.
- Advantageous at mid-block crossings and uncontrolled intersections
- Effective option for crossing locations with higher speeds and vehicle volumes but not the pedestrian or vehicle volumes required to warrant a traffic signal.
- Studies have shown a 55% reduction in pedestrian crashes, 29% reduction in total crashes, 15% reduction in serious injury and fatal crashes, and over 90% compliance rate.

- Prior to installing a PHB system, an engineering study should consider the major-street volumes, speeds, sight distance, widths of the crossing, gaps in traffic, pedestrian volumes, walking speeds, and delay. The MnMUTCD provides additional guidance for the installation of PHB systems on Low-Speed Roadways and High-Speed Roadways.

What are the maintenance impacts?

PHBs typically involve similar maintenance and requirements as traditional traffic signals. Associated signing and striping also requires routine maintenance.

What are the challenges?

- Technology is not widely implemented, but agencies are becoming increasingly interested in this strategy to improve pedestrian safety.
- Educating drivers and pedestrians on PHB function and purpose is a key component to its effectiveness.
- Appropriate only for locations with moderate to high pedestrian demands.
- Challenging to install on roadways with high driveway density.
- If installing on a roadway with adjacent signals, the PHB will likely need to be programmed to work in coordination with the existing signal timing plan.
- Can increase delays.
- Require routine maintenance, similar to that of a traffic signal.
- If installed at an intersection, appropriate side street traffic control should be considered

Supplemental treatments

PHBs are often combined with the following treatments:

- Marked crosswalk and warning signs (required)
- Marked stop line on the major street approaches
- Countdown pedestrian signal heads and pedestrian pushbuttons
- Parking restrictions
- Curb extensions and ADA curb ramps
- Pedestrian refuge islands



Pedestrian Hybrid Beacon

How much do they cost?

For a two-lane roadway, the cost for a PHB system can range from approximately $100,000 to $120,000. For a four-lane roadway, the cost can range higher from approximately $100,000 to $170,000. The increase in cost accounts for a longer mast arm, a median mounted push button, and a newly constructed pedestrian refuge island.

Significant cost items include the mast arm and pole with an extension, the controller and cabinet, conduit, and signing. Total construction costs will depend on site conditions, available power sources, and curb ramp improvements.

Pedestrian Hybrid Beacon Systems

Design Features

The PHB consists of two side-by-side red lenses and a single yellow lens below the red. The assembly includes both vehicular beacons and pedestrian signals (WALK and DON'T WALK). A stop line should also be installed for each approach to the crosswalk.

The beacon rests in dark until activated manually by a pedestrian using the pushbutton or by a pedestrian detection system. Once activated, the beacon flashes a sequence consisting of six intervals: dark, flashing yellow, steady yellow, steady red, alternating flashing red, and dark. The steady red interval mandates drivers to stop for pedestrians at the crosswalk.

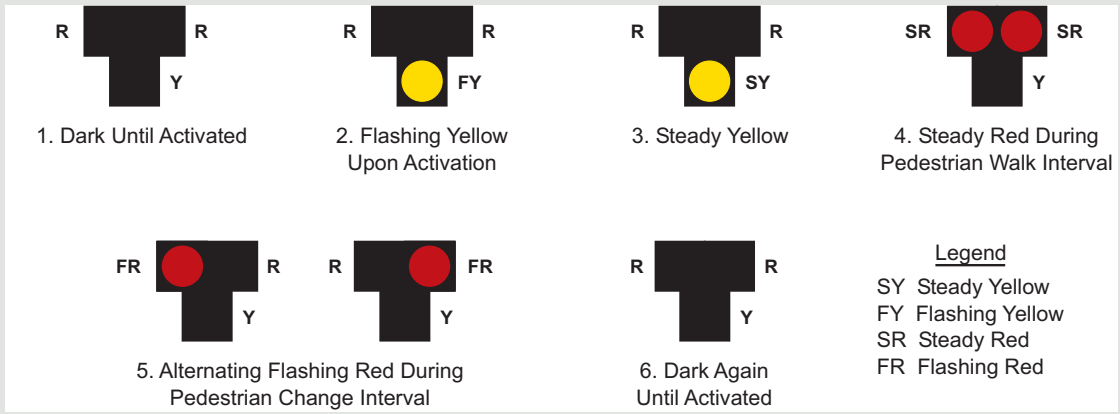
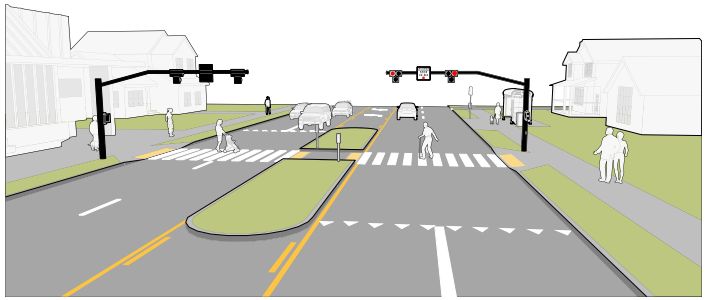


Figure 4F-3. Sequence for a Pedestrian Hybrid Beacon

Best practices

PHBs can be an effective pedestrian safety strategy when used at locations with high rates of pedestrian activity and high volumes of crossing traffic that do not allow adequate gaps for pedestrians to safely cross. They are best suited for mid-block locations.



An illustration of a pedestrian hybrid beacon



An image of a pedestrian hybrid beacon, Source: FHWA STEP

Resources

- FHWA's source for these: 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.
- MUTCD: https://mutcd.fhwa.dot.gov
- https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/STEP-tech-sheets.pdf
- Pros/Cons: https://www.westernite.org/Sections/washington/events/2011/Quad/A-2/A-2%20Pedestrian%20Crossing%20Toolbox%20for%20High%20Speed%20Urban%20Arterials.pdf
- https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa14014/

Rectangular Rapid Flashing Beacons

What is their purpose?

A Rectangular Rapid Flashing Beacon (RRFB) is a crossing enhancement at uncontrolled intersections that can be activated manually by a pedestrian using a pushbutton or by a pedestrian detection system. The RRFB assembly typically includes one RRFB device on each end of a crosswalk. Each device includes two rapidly and alternatively flashing rectangular yellow indications attached to a pole supplementing the pedestrian warning sign (W11-2) or school crossing sign (S1-1) at a crosswalk. The irregular "wig-wag" flashing sequence is similar to emergency flashers on police vehicles (left light on, then right light on, etc.) with a pulsing light source.

MnDOT has received statewide Interim Approval from FHWA for the use of a pedestrian actuated RRFB (IA-21). Statewide Interim Approval allows any jurisdiction within Minnesota to use the device as long as the jurisdiction agrees to notify the MnDOT Traffic Standards Engineer of the location for each installation and agrees to the specific conditions outlined for Statewide Interim Approvals.



RRFB at Johnson Street NE & 22nd Avenue NE, Minneapolis, MN

Are they a proven strategy?

FHWA has reviewed studies related to the effectiveness of the RRFB device and have confirmed its success at uncontrolled marked crosswalks. Therefore, based on the number of successful experiments, the RRFB is a **PROVEN** safety countermeasure strategy for marked crosswalks.

Supporting Research: Evaluation of Pedestrian Hybrid Beacons and Rapid Flashing Beacons

Where would we use them?

The purpose of the RRFB is to increase driver awareness of the presence of pedestrians at crosswalks that are not across approaches controlled by YIELD signs, STOP signs, or traffic control signals. RRFBs can be used on crosswalks across the approach to and/or egress from a roundabout. Research shows that an RRFB is most effective on roadways with volumes less than 12,000 vehicles per day and with speeds less than 40 mph.

Per the IA-21 the use of an RRFB shall:

- Only be installed to function as a pedestrian-actuated enhancement
- Only be used to supplement a post-mounted or overhead-mounted W11-2 (Pedestrian), S1-1 (School), or W11-15 (Trail) crossing warning sign. A diagonal downward arrow (W16-7P) plaque shall supplement the post-mounted signs.

The IA-21 also provides information regarding sign/beacon assembly locations, beacon dimensions and placement, beacon flashing requirements, beacon operations, and accessible pedestrian features. Reference the Interim Approval-21 for more details regarding the federal guidance.

Rectangular Rapid Flashing Beacons

What are the advantages?

- RRFBs can utilize power from the existing grid network or by solar panels furnished on the devices.
- Increases driver awareness of the crosswalks and driver yielding compliance, especially at night. Compliance rates vary per site, and are generally highest on low-speed, single-lane facilities. Studies have found compliance rates from 17% to as high as 98%, which are comparable to a traffic signal or pedestrian hybrid beacon system.
- Can reduce the number of multiple-threat crashes, especially when used in combination with other strategies noted below.
- 47% reduction in vehicle-pedestrian crashes.

What are the maintenance impacts?

Maintenance for the RRFB is dependent on the power supply type. If solar power is used, the primary concern is removing nearby foliage and the amount of sun exposure throughout the day. Solar powered RRFBs typically function for several years without maintenance issues.

Solar powered RRFB systems do not require underground conduit, and would only require a push button to activate the system. The largest solar panel (55 watt) can accommodate around 1,000 activations per day. These solar panels typically can last up to 10 years or longer depending on usage. The batteries require replacement approximately every 5 years.

What are the challenges?

- RRFB effectiveness varies depending on the type of roadway, traffic volumes, and speeds. On higher-speed (40 mph or higher), multilane, or high-volume (over 12,000 vehicles per day), RRFB's are less effective, and other strategies (or a combination of strategies) should be considered.
- Additional maintenance and operating costs, depending on power source

RRFB systems that are hardwired are powered from a nearby electrical source by running wire underground. Hard wired systems are typically recommended at crossing locations that experience very high pedestrian activity. A hardwired system can ensure consistent operation, especially during the fall and winter months when the sun is low in the sky and reducing the ability to charge the batteries as frequently.

Supplemental treatments

Rectangular Rapid Flashing Beacons are often combined with the following treatments:

- Marked crosswalk (required) and Advance STOP markings and signs (recommended if multi-lane)
- Warning signs (required)
- Parking restrictions (required)
- Curb extensions and ADA curb ramps
- Pedestrian refuge island
- Speed bumps

Best practices

The RRFB offers significant safety benefits, achieving high rates of compliance for a relatively low cost. The RRFB increases yield rates at uncontrolled crosswalks, and studies show they are most effective on roadways with volumes less than 12,000 vehicles per day and with speeds less than 40 mph. Reference the Interim Approval-21 for more details regarding the federal guidance.

How much do they cost?

Costs can vary widely for the installation of two RRFB units (one on either side of the street). For an RRFB system using a solar-powered system, the cost is approximately $15,000 for materials and installation. For an RRFB system that is hardwired, the costs range between $30,000 and $50,000 depending on the proximity of a power source. RRFB systems that include overhead flashers cost between $80,000 to $100,000, which includes a mast arm and pole for each direction of traffic and hardwired power.

Rectangular Rapid Flashing Beacons

Design Features

The installation of an RRFB must include two units: one on the right-hand side and one on the left-hand side of the roadway. It is also recommended to consider placing an additional unit within a median if available. The two yellow indications shall flash in a rapidly flashing pattern ("wig-wag"), at a rate not less than 50 or more than 60 times per minute (IA 21). The lights should rest in dark until activated, and should start and stop simultaneously. Additionally, the RRFB indication should be approximately 5" wide by 2" high and aligned horizontally between the bottom of the crossing warning sign and the top of the supplemental downward diagonal arrow plaque. Pedestrian push buttons should be properly installed, in accordance with ADA design standards, and in a position where the activated lights are visible to the pedestrian.

RRFBs typically receive power from solar panel units attached to each device, but can also be hard wired to a traditional power source.



RRFB at CSAH 16, Shakopee, MN

Resources

- https://safety.fhwa.dot.gov/ped_bike/step/docs/TechSheet_RRFB_508compliant.pdf
- https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/STEP-field-guide.pdf
- http://www.dot.state.mn.us/stateaid/trafficsafety/county/CRSP-EnhancedCrosswalks.pdf
- Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments: https://www.nap.edu/download/24627

School Crossing Guards

What is their purpose?

Trained school crossing guards can help stop the flow of traffic and guide students safely across the street in specific times and locations. According to the Minnesota Safe Routes to School Crossing Guard Guide, a school crossing guard can encourage safe crossing behaviors, provide education and reinforcement of safe pedestrian behavior, ensure adequate gaps in traffic, alert motorists of students in the area, and observe incidents and behaviors that create safety hazards.



Crossing guard at E 25th Street and 29th Avenue S, Minneapolis, MN

Are they a proven strategy?

Crossing guards are considered a **TRIED** safety strategy due to the lack of specific research into their effectiveness. Nationwide observations made after implementing crossing guards have shown consistent success in helping students cross roads more safely and improving vehicle compliance with school zone speed limits.

It should be noted that the FHWA Pedestrian Safety Guide and Countermeasure Selection System states that the implementation of trained adult crossing guards is one of the most effective measures for guiding children safely across streets.

2019 Minnesota State Statute, 169.21:

(c) It is unlawful for any person to drive a motor vehicle through a column of school children crossing a street or highway or past a member of a school safety patrol or adult crossing guard, while the member of the school safety patrol or adult crossing guard is directing the movement of children across a street or highway and while the school safety patrol member or adult crossing guard is holding an official signal in the stop position. A peace officer may arrest the driver of a motor vehicle if the peace officer has probable cause to believe that the driver has operated the vehicle in violation of this paragraph within the past four hours.

School Crossing Guards

What are the advantages?

- Serve as an inexpensive countermeasure. Costs vary depending on depending on the type of crossing guard (student, trained adult, or safety official) and whether the crossing guard is paid or a volunteer.
- Alert drivers to students crossing.
- Improve motorist yielding rates.
- Can monitor crossing locations, track and report unsafe incidents or events that occur in the area.
- Encourage physical activities among students by making walking more accessible.

What are the challenges?

- Those serving as guards can feel their safety is at risk depending on the environment.
- Only adult crossing guards should serve at higher speed and higher volume roadways.
- If student crossing guards are to be used, it is recommended that they work with an adult supervisor and at crossings of lower speeds and lower volume roadways.
- Difficulty recruiting paid workers for part time crossing guard work



A crossing guard at a crosswalk

Where would we use them?

Crossing guards are typically provided at crossings near schools, where the traffic flow does not provide adequate gaps for school-aged children to safely cross.

- Crossing guards are commonly applied within school zones as part of MnDOT Safe Routes to School program. This program allocates funds to communities and schools to complete safety improvement projects on routes students use to walk and bike to school.

Communities and school groups should reference the MnDOT Safe Routes to School Crossing Guard Guide and MnMUTCD Section 7D.1 prior to implementing crossing guards.

Supplemental treatments

- Marked crosswalks
- Advanced school zone/crossing signs

Best practices

The use of adult crossing guards is a common practice to improve crossing safety in school zones. At crossings of lower speed and lower volume collectors, the use of student crossing guards with adult supervision is appropriate, but adults should be employed for higher speed and higher volume arterials or at locations with unique features such as poor sight distance.

How much do they cost?

The costs of training and implementing student and parent-volunteer crossing guards at school crossings is relatively nominal. Additional costs may be required for non-volunteer adult crossing guard salaries and uniforms.

School Crossing Guards

Design Features

Crossing guards should be well trained and equipped with reflective safety vests and stop paddles. It is best practice to use student crossing guards, with adult supervision, at crossings of lower speed and lower volume collectives. Adults should be employed for higher speed and higher volume arterials. Even at signalized intersections, studies have documented that the presence of a crossing guard is still beneficial in many elementary school sites too. A successful implementation of crossing guards should also include public information and education campaigns for school-age children and their caregivers so all users are aware of pedestrian rights and safe routes to school.

Resources

- http://www.pedbikesafe.org/pedsafe/countermeasures_detail.cfm?CM_NUM=57
- https://www.dot.state.mn.us/mnsaferoutes/assets/downloads/MN_SRTS_CROSSING%20GUARD%20GUIDE.pdf
- http://guide.saferoutesinfo.org/crossing_guard/the_role_of_the_adult_school_crossing_guard.cfm
- MnMUTCD – 7D: https://www.dot.state.mn.us/trafficeng/publ/mutcd/mnmutcd2015/mnmutcd-7.pdf
- AAA School Safety Patrol Operations Manual: https://www.aaa.com/aaa/049/PublicAffairs/SSPManual.pdf
- https://www.salary.com/research/salary/benchmark/crossing-guard-salary/mn
- https://www.revisor.mn.gov/statutes/cite/169.21

Grade-Separated Crossings

What is their purpose?

A grade-separated crossing provides a vertical separation (overpass or underpass) between pedestrian/bicyclists and motor vehicles. Grade-separated crossings are effective strategies for locations with heavy pedestrian and bicycle volumes crossing a roadway with heavy or high speed traffic, such as interstates, railroad tracks, and other busy roadways. Pedestrians can rarely be convinced to use a poorly located crossing, so grade-separated crossings should be provided within the normal path of pedestrians wherever possible.

Are they a proven strategy?

A grade-separated crossing is a **PROVEN** strategy to eliminate conflicts between pedestrian/bicyclists and motor vehicles.

Where would we use them?

Prior to constructing a grade-separated crossing, agencies should research and consider the following:

- Existing or projected crossing volumes
- Roadway features, including daily volumes, speed, and geometry
- The location of adjacent crossing facilities
- The location of existing pedestrian/bicycle facilities and generators, such as regional trail networks
- Predominant type and age of persons who will use the facility
- Terrain, soil composition, and presence of conflicting utilities

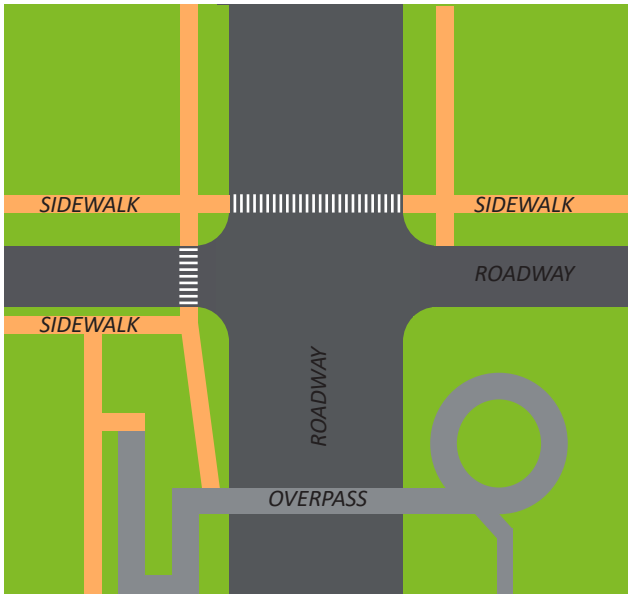
Grade-separated crossings are commonly constructed at:

- Locations with heavy volumes of pedestrian and bicycle traffic crossing a roadway with high vehicular traffic volumes
- Locations where pedestrian and bicyclists will want to cross the road
- Locations with difficult terrain or geographic obstacles to cross the roadway

Grade-separated crossings are most effective where they offer a direct route for nonmotorized users. Many pedestrians and bicyclists will not use an indirect grade-separated crossing if a more direct at-grade route is available.

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months, to keep all accesses, tunnel entries, and paths free clear of snow and debris. All structures should get routine inspection.



This grade-separated crossing may be less effective because it requires more travel distance and physical effort than crossing at-grade. Nonmotorized users are highly likely to cross at-grade instead.



This grade-separated crossing is more effective because it offers a direct route for pedestrians on the trail.

Grade-Separated Crossings

What are the advantages?

- Can help encourage walking or biking.
- Can help connect regions and trail networks separated by busy highways.
- Allow for uninterrupted flow of pedestrian and bicycle movement.
- Can be associated with 86% reduction in pedestrian crashes and 90% reduction in fatal and injury pedestrian crashes.
- Grade-separated crossings are more usable by children or others that may not be comfortable using an at-grade crossing.



Gateway Trail Bridge, Washington County, MN; Source: MnDOT

What are the challenges?

- Grade-separated crossings do not completely prohibit pedestrian or bicyclists from crossing the road at-grade. There is risk for underutilization and decreased value if not properly implemented.
- Require diligent planning and agency/public involvement to determine a location that will have the most benefit.
- Underpasses and overpasses for pedestrians and bicyclists can require right-of-way acquisition and are expensive to construct.
- Underpass design requires careful drainage design and management of underground utilities.
- Design must incorporate ADA-compliant design standards, including maintaining a maximum 5% grade, providing a 5' landing surface for every 30" of elevation change, and handrail requirements.
- Maintenance and security concerns should be considered and managed, especially with underpasses.
- Lighting design is important to mitigate personal safety concerns.



Lakewalk Trail tunnel under TH 61, Duluth, MN

How much do they cost?

Overpasses and underpasses are major construction projects, and costs depend significantly on site characteristics. For example, a recent project in the state for a 16' x 10' underpass cost approximately $1,800 per linear foot, with additional end section costs of $19,000 each. Pre-fabricated truss structures for an overpass can cost approximately $3,500 per linear foot; however, these projects require additional structural material and total project costs can reach up to $3 million.

Best practices

Grade-separated crossings are a proven safety strategy, especially when an underpass or overpass is conveniently located to achieve the most benefit. Due to the high cost of construction, grade-separated crossings should be considered where high volumes of pedestrian/bicycle traffic must cross major high-speed roadways with high volumes of traffic. Grade-separated crossings are typically seen along regional trail networks. They can be a great choice to integrate where roads cross waterways, especially if a trail follows the waterway.

Grade-Separated Crossings

Design Features

Grade-separation should only be constructed when the safe movement of pedestrians and bicyclists cannot be ensured in a simpler, more cost-efficient manner.

Designers should reference state and federal design references, including the MnDOT Bicycle Facility Design Manual, the AASHTO Guide Specifications for Design of Pedestrian Bridges, and the AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities.

Grade-separated crossing facilities should incorporate the following design features:

- Be positioned to be conveniently accessible by pedestrians and bicyclists in order to avoid under use.
- Good sight distance in underpasses, preferably with the open ends of the tunnel in view at all times, to improve security.
- Adequate lighting and ventilation in tunnels.
- ADA design features, especially for approach ramp design. Stairs cannot be the only access to the grade separation; an elevator or ramp that meets the ADA regulations must be provided.
- Be wide enough to allow two-way pedestrian/bicycle traffic; per the MnDOT Bikeway Facility Design Manual, the minimum recommended width is 8' for a shared pedestrian/bicyclist lane and 14' for separate pedestrian and bicyclist lanes.
- Barriers or landscaping to encourage use.
- Provide handrails on overpasses.
- Minimized grades, cross slopes, and unnecessary travel distances.

Resources

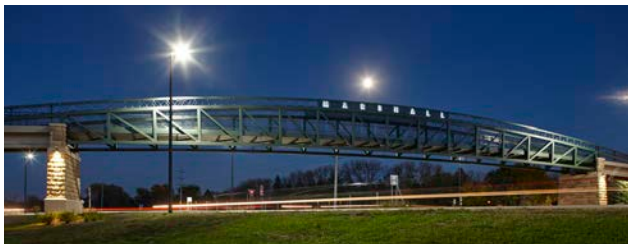
- Minnesota DOT Road Design Manual (11-3)
- MnDOT Bikeway Facility Design Manual (Updated February 2020): http://www.dot.state.mn.us/bike/bicycle-facility-design-manual.html
- http://www.mnltap.umn.edu/publications/handbooks/pedcrossingguide/documents/ped_guidebook.pdf
- http://www.minneapolismn.gov/www/groups/public/@publicworks/documents/webcontent/convert_280659.pdf
- https://safety.fhwa.dot.gov/saferjourney1/library/countermeasures/07.htm



Bridge overpass at TH 23 & Saratoga Street, Marshall, MN



Lakewalk Trail tunnel under TH 61, Duluth, MN



Bridge overpass at TH 23 & Saratoga Street, Marshall, MN



Linear Facilities

Route Modifications

What is their purpose?

Route modifications remove through access for motor vehicles with the goal of diverting traffic from and reducing volumes on key bicycling and pedestrian routes. Modifications that allow pedestrians and bicyclists to maintain access can be made through a variety of tools, including regulatory signs, major street refuge medians, diagonal diverters, forced turns, turn prohibitions, street closures, and partial closures. Such traffic management techniques and plans are most frequently implemented on low-speed streets near residential areas to manage traffic; they have been implemented in Minnesota communities such as Rochester, Moorhead, Orono, Eagan, Roseville, Minneapolis, and Blaine.



Traffic diverter at 11th Avenue S., Minneapolis, MN

Are they a proven strategy?

Route modifications have been **PROVEN** to reduce motorist volumes without affecting emergency services access when well thought out from a network approach. Thoughtful corridor access management is a **PROVEN** safety countermeasure, and route modifications are one factor in corridor access management. Similarly, median refuge islands are a proven safety strategy for crossing bicyclists and pedestrians at street crossings.

Where would we use them?

Given the variety of elements that make up route modifications, a Neighborhood Traffic Management Program is often used to determine which measures should be implemented. An area-wide approach is best, and should receive neighborhood support.

Route modifications can be considered at the following locations:

- On routes that experience and encourage bicycle activity, such as a bicycle boulevards (see Bicycle Boulevards section)
- In locations where vehicle traffic is low and re-routed vehicles can make desired maneuvers at a nearby intersection
- Often in urban settings on low-speed, low-volume local streets

What are the maintenance impacts?

Higher maintenance impacts are expected if elements such as raised medians or traffic diverters are part of implementation. For example, raised medians will impact drainage and need to be cleared of snow and other debris.

Route Modifications

What are the advantages?

- Reducing motor vehicle traffic reduces the likelihood of a crash with a bicycle or pedestrian.
- Reducing motor vehicle traffic can make a street more comfortable for bicycle or pedestrian use.
- Reduce intersection width by providing refuge medians, reducing crossing distance, and minimizing pedestrian and bicycle exposure at the intersection.

What are the challenges?

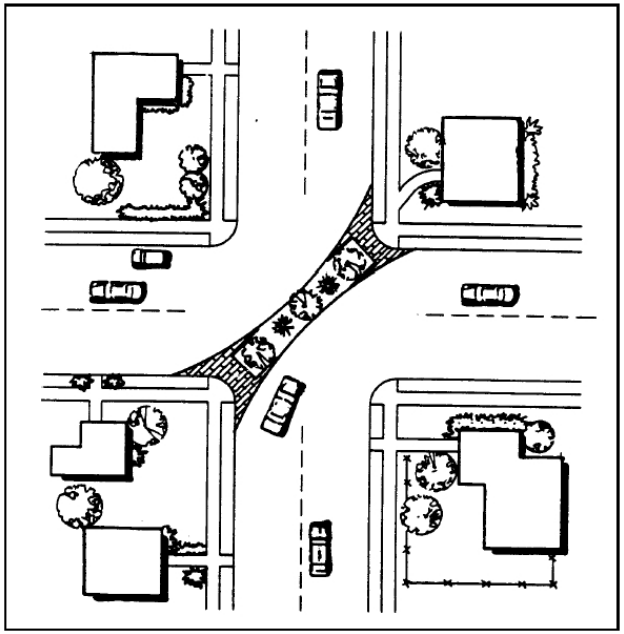
- Design should ensure that diverted motor vehicle traffic will use routes that can accommodate an increase in volume.
- Diverting motorists to other routes will increase interactions with bicyclists and pedestrians on those facilities.
- Travel time and distance can increase for local street users.
- Visitors and tourists using paper maps and wayfinding kiosk maps may be confused if maps are not up to date.
- Community engagement and buy-in on this and perhaps other treatments as well.



Traffic diverter with an opening for bicycles

Supplemental treatments

- Route modifications are often used to create bicycle boulevards. More details are included in the Bicycle Boulevards section of this handbook.



Sketch of a traffic diverter

How much do they cost?

Costs vary widely depending on the type and number of route modification elements that are installed. Regulatory signs are cheaper than diagonal diverters or refuge medians. Diverters can cost between $15,000 and $45,000 depending on the design and site conditions.

Route Modifications

Design Features

- Route modification elements combined with bicycle boulevards can improve bicyclist access to destinations. Bicycle boulevards may incorporate route modification elements such as traffic diverters, median refuges, curb extensions, or yield signs. Traffic diverters at key intersections reduce motor vehicle through traffic but permit bicycle passage and maintain local access.
- Regulatory signs such as “DO NOT ENTER” (R5-1) and mandatory turn signs should be used to restrict motor vehicle traffic. Use “EXCEPT BICYCLES” (W16-xxP) plaques to supplement signs restricting motor vehicle traffic.
- Access for emergency services can be maintained using flexible delineators, mountable curbs, signing, or other similar treatments.



A traffic circle on a bicycle boulevard.

Resources

- FHWA Achieving Multimodal Networks: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_networks/fhwahep16055.pdf
- https://safety.fhwa.dot.gov/saferjourney1/Library/countermeasures/36.htm



A traffic diverter with openings for a bicycle

Road Diets

What is their purpose?

A road diet is a reconfiguration of a roadway's available width to integrate additional modes, such as bike lanes, transit lanes, pedestrian crossing islands, parking, or a combination thereof. A common form of road diet involves converting an undivided four-lane (two-way) roadway into a three-lane roadway made up of two through lanes, a center two-way left turn lane, and a shoulder or bike lane. Road diets can improve safety, mobility, and access management along a roadway.

The FHWA Road Diet FAQ provides additional information on road diets.



Road diet with RRFB on CR-101 S, Minnetonka, MN

Are they a proven strategy?

Road Diets are considered a **PROVEN** effective strategy for reducing crashes when converting from four lanes to three. In these situations, research has found a 19-47% reduction in total crashes.

Supporting Documentation: FHWA Proven Safety Countermeasures – Road Diets

Where would we use them?

Prior to implementing a road diet, the average daily traffic (ADT) volumes must be considered. Several roads in the Minneapolis/St. Paul metropolitan area with volumes as high as 20,000 vehicles per day have had successful road diet implementations.

The FHWA provides a summary of the ADT volume guidelines for four-lane to three-lane conversions:

- **Less than 10,000 ADT**: A great candidate for road diets in most instances. Capacity will most likely not be affected.
- **10,000 - 15,000 ADT**: A good candidate for a road diet in many instances. Agencies should conduct intersection analyses and consider signal re-timing in conjunction with implementation.
- **15,000 - 20,000 ADT**: A good candidate for a road diets in some instances; however, capacity may be affected depending on conditions. Agencies should conduct a corridor analysis.
- **Greater than 20,000 ADT**: Agencies should complete a feasibility study to determine whether the location is a good candidate. There are several examples across the country where road diets have been successful with ADTs as high as 26,000.

Road Diets

What are the advantages?

- Crash Reduction Factor for all crashes range from 19% to 47%.
- Reduce rear-end and left-turn crashes due to the dedicated left-turn lane.
- Reduce side swipe crashes and the likelihood of multiple-threat crashes.
- Improve left-turning vehicle visibility. Also enables dedicated left turn control at signalized intersections.
- Reduce right-angle crashes, as side street motorists cross three versus four travel lanes.
- Create fewer lanes for pedestrians to cross.
- Dedicate space for left-turns for motorists and bicyclists.
- Create opportunity to install pedestrian refuge islands, bicycle lanes, on-street parking, and/or transit stops. Also potential ability to install landscape medians for traffic calming.
- Provide traffic calming and more consistent speeds, which may reduce potential crash severities for all users.

While daily traffic volume can provide a screening measure, knowledge of the turning traffic volumes in conjunction with the potential for safety improvements along a roadway should inform the decision on whether or not to implement a road diet. Road diets, specifically four to three-lane conversions, can be implemented on many roadways where safety improvements are needed, including the following:

What are the challenges?

- Before implementing a road diet, a traffic study should be conducted to evaluate potential reductions in crash frequency and severity, to evaluate roadway capacity /level of service, and to evaluate bicycle level of service.
- Road diets may have negative impacts to roadway capacity and motor vehicle delay, including on routes with transit service where there may not be opportunities to pass buses..
- Reconfiguration of the roadway will likely require modifications to signal head placement/phasing and restriping of pavement markings at intersections.

- Roadways with high numbers of left turn crashes
- Roadways with safety concerns related to the number of lanes for pedestrians to cross
- Roadways where traffic calming is an objective
- Roadways with history of head-on crashes and rear-end crashes
- Roadways where multimodal improvements such as transit and bicycle facilities are desired

What are the maintenance impacts?

Higher maintenance impacts are expected if elements such as curb extensions or raised medians are part of the road diet implementation. Depending on the reconfiguration, there will likely be additional pavement markings to maintain.



Road diet retrofit on Larpenteur Ave, Maplewood, MN

How much do they cost?

The cost for a four-lane to three-lane road diet improvement is about $25,000 to $40,000 per mile. If done during planned resurfacing, costs are typically limited to signalization changes. Cost also depends partly on the number of lane lines that need to be re-painted. The estimated cost of curb extensions or constructing a raised median can amount to $100,000 per mile or more.

Installing bicycle facilities during roadway resurfacing projects is an efficient and cost-effective way for communities to create connected networks of bicycle facilities. See FHWA's Incorporating Bicycle Networks in Resurfacing Projects for more information, cost considerations, and case studies.

Road Diets

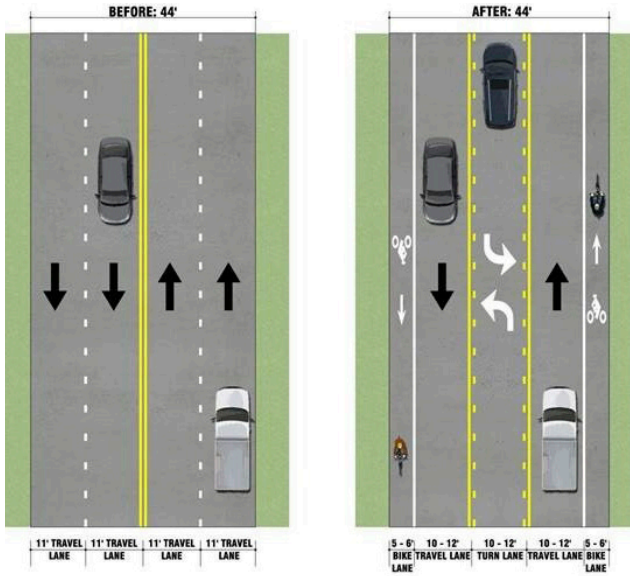
Design Features

Considerations before implementing a road diet should include driveway density, transit routes, and the number and design of intersections along the corridor, as well as operational characteristics. Changes to intersection turn lanes, signing, pavement markings, traffic control devices, signal timing and phasing, transit stops, and pedestrian and bicyclist facilities may be needed to support this concept.

See the FHWA Road Diet: Informational Guide and the NACTO Urban Street Design Guide for design details.

- Narrowing lane widths, often called a "Lane Diet," can also lead to greater safety. Narrower lanes on urban and suburban streets were generally associated with lower crash frequencies compared to wider lanes. Narrower cross-sections reduce crossing distances and have been associated with reduced travel speeds, both direct factors in the safety of pedestrians. For these reasons, lane widths on urban and suburban streets should be designed no wider than necessary to adequately accommodate the vehicular traffic volume and composition.

See Chapter 7 of MnDOT's Bicycle Facility Manual for discussion about narrow lane widths and relocation of car parking.



Before and after image of a road diet, Source: MassDOT Road Diet Guide

Resources

- https://safety.fhwa.dot.gov/provencountermeasures/road_diets/
- http://www.dot.state.mn.us/bike/design-engineering.html
- https://safety.fhwa.dot.gov/road_diets/resources/pdf/roadDiet_MythBuster.pdf
- https://safety.fhwa.dot.gov/road_diets/guidance/info_guide/



Road diet at Portland Avenue and Bischof Lane, Bloomington, MN

Sidewalks

What is their purpose?

A sidewalk is a type of walkway that defines a path for pedestrian travel placed along the side of a roadway. They are usually separated from roadway traffic lanes by curb and gutter and sometimes by a planting strip or buffer zone. Other types of walkways include shared use paths and roadway shoulders.

Are they a proven strategy?

Sidewalks are a **PROVEN** safety strategy. Sidewalks on both sides of a street have been found to significantly reduce occurrences of walking along the roadway (which is a pedestrian crash risk) compared to locations where no sidewalks or walkways exist. Sidewalks provide a 65-89% reduction in crashes involving pedestrians walking along roadways.

Supporting Documentation: FHWA Countermeasure – Walkways





Before and after images of sidewalk construction on 54th Street in Edina, MN

Where would we use them?

Planning for a network of sidewalks should include an audit of the current sidewalk system. The audit should document pedestrian access to transit stops/service, schools, public buildings, parks, etc. The audit should also include consideration of sidewalk design issues, including obstructions (e.g., fire hydrants, signposts, etc.) and compliance with Americans with Disabilities Act (ADA) Standards for Accessible Design (see PROWAG guidelines). Sidewalks can be considered at the following locations, on both sides of the roadway:

- Along all urban streets and suburban arterials and collectors
- Adjacent to streets that connect pedestrian origins and destinations. For example, segments connecting neighborhoods with schools, parks, transit locations, or retail areas
- Along high-speed and high-volume roadways without shoulder width
- Shoulder space should be considered on any rural or suburban roadway that cannot feasibly implement a sidewalk or walkway. See the section on Paved Shoulders

What are the maintenance impacts?

- Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months. Snow clearance from sidewalks may be improved by a buffer zone in between the sidewalk and roadway. This buffer zone can be landscaped and allows for snow storage during winter.
- In addition, sidewalks can become damaged over time from tree roots or other reasons. Vertical lips at these locations must be ground down to avoid tripping hazards and maintain ADA compliance.

Sidewalks

Design Features

- Curb ramps – To meet ADA requirements, crosswalks along a sidewalk must include curb ramps with tactile warnings during reconstruction or resurfacing of a roadway. Curb ramps on each side of a crosswalk not only provide better orientation for pedestrians with vision disabilities, but also assist pedestrians who use wheelchairs by providing a direct connection to the roadway crossing instead of directing them toward the center of the intersection.
- Cross slope – To properly accommodate pedestrians in wheelchairs, the cross slope of sidewalks should be less than 2% percent.
- Sidewalk widths – The minimum recommended sidewalk width is 6', which allows two people to walk comfortably side-by-side or pass each other while traveling in opposite directions. Wider sidewalks are needed in urban areas and commercial districts.
- 4' wide sidewalks may be considered in constrained areas, but require 5'-wide passing areas at regular intervals.
- Continuity – Sidewalks should be continuous, installed on both sides of the roadway, and relatively free of obstacles that could cause a tripping hazard or impede travel by children, senior citizens, and people with visual or mobility impairments.
- See MnDOT's Accessibility Design Guidance for additional ADA design guidance, technical memo, and curb ramp guidelines.

What are the advantages?

- Well-designed sidewalks improve the safety and mobility of pedestrians.
- Wider sidewalk widths accommodate a larger variety and volume of users and allow for people to walk side-by-side while accommodating people going in opposite directions.
- Can encourage multimodal activity and healthier lifestyles among the community.
- Can improve transportation equity.

What are the challenges?

- Sidewalks in constrained conditions may require additional right-of-way to construct and may require costly utility relocations.
- Features like utilities, signs, and vegetation are often in similar locations as sidewalks, requiring careful design and placement.
- Additional maintenance is required.
- Property owners may oppose construction of sidewalks, especially if they will be responsible for clearing snow.

How much do they cost?

Typical costs for implementation of sidewalks vary depending on the location, amount of available right-of-way, and materials used, but are generally in the range of $4 to $5 per square foot for a concrete sidewalk, excluding costs for purchasing additional right-of-way.

The cost for adding standard curbs and gutters is approximately $20 to $35 per linear foot, although the costs will vary depending on the length of sidewalk, the type of base material, and whether curb ramps are needed. Asphalt curbs and walkways are less costly, but require more maintenance than concrete sidewalks.

Resources

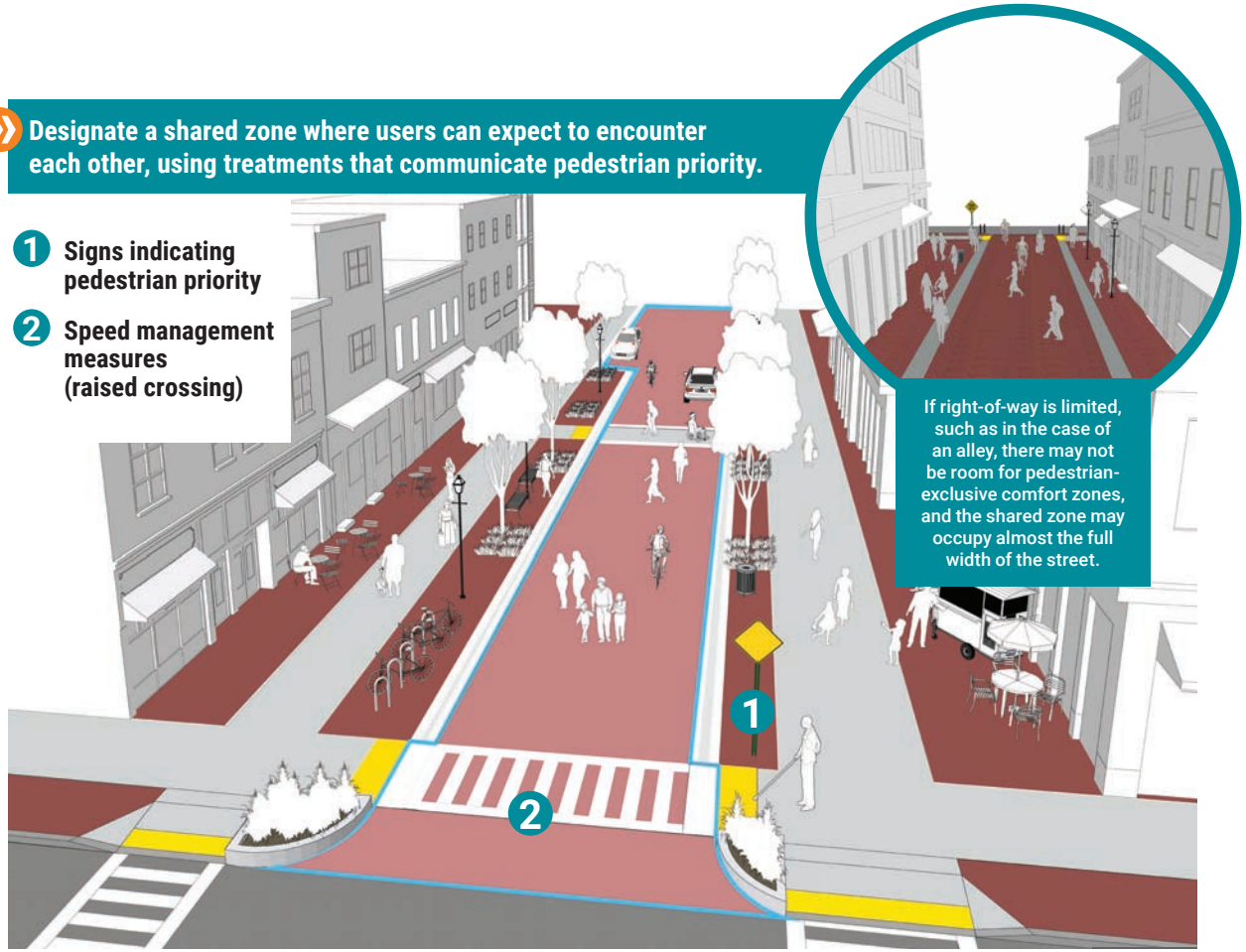
- https://safety.fhwa.dot.gov/provencountermeasures/walkways/
- https://www.dot.state.mn.us/ada/design.html

Shared Streets

What is their purpose?

A shared street, also known as a commercial shared street, is a street that includes a shared zone where pedestrians, bicyclists, and motor vehicles mix in the same space. Shared streets maintain access for vehicles operating at very low speeds. A shared street can include various elements, such as curb cuts and ramps, bicycle parking, benches, lighting, signs, and special plantings.

Shared streets differ from pedestrian malls and curbless streets. Unlike pedestrian malls, shared streets maintain access for vehicles operating at very low speeds. Also, while curbless streets are designed to provide flexible and accessible space for festivals and farmers markets when the street is closed to motor vehicles, they are not intended to encourage the mixing of street users.



Shared Street Zones, Source: FHWA Accessible Shared Streets

Are they a proven strategy?

Shared streets are designed to reduce motor vehicle speeds, but due to the lack of specific data for these treatments, they are considered **TRIED**. However, a number of communities in the United States have built or converted existing conventional streets and alleys to shared streets with success.

Where would we use them?

Shared streets can be considered at the following locations:

- Locations that would benefit from an accessible walking area but where there is insufficient room for accessible sidewalks due to limited right-of-way
- Locations that would benefit from flexible space throughout the day; this might include space for motor vehicle and bicycle delivery activity during the day and more pedestrian activity in the evening, for example
- In areas with high pedestrian activity and low vehicle speeds, such as residential streets or areas targeted for retail development
- Local examples of shared streets include:
  - 29th Street in Minneapolis
  - 8th Avenue Artery in Hopkins

Shared Streets

What are the advantages?

- Reducing vehicle speeds and volumes increases pedestrian comfort and reduces bicycle and pedestrian crash severity. Shared streets are generally designed for vehicle speeds between 5 and 15 mph.
- Slower speeds and reduced vehicle volumes lend themselves to quieter, more inviting streets where sidewalk cafes and outdoor commerce is more enjoyable for customers.
- Can support flexible spaces for routine activities as well as parades, concerts, festivals, and other special events.

What are the challenges?

- Can be challenging for pedestrians with vision impairments because they often lack navigational cues such as curbs and defined crossings, which pedestrians with vision disabilities typically use when navigating the street.
- Candidate locations should be carefully reviewed and selected to avoid user confusion and conflicts.
- Due to the lower vehicle speeds, drivers may avoid the shared street and take alternative routes unless their destination is located on the shared street. Alternative routes should be reviewed before implementing a shared street.



Shared street, 29th Street, Minneapolis, MN

Design Features

Designers should consider the following:

- It is critical to ensure that tactile surfaces provide navigational information to pedestrians with vision impairments. Tactile surfaces need to be detectable, consistent, and predictable.
- Detectable warning surfaces should not be used as a guidance surface or directional indicator.
- Signage and other detectable navigation cues should be provided at the transition to the shared street to indicate the change to all users.
- Because ADA guidance does not address directional indicators to provide linear navigational guidance for pedestrians, directional indicators should conform with International Standard Organization (ISO) 23599.

How much do they cost?

Based on the 29th Street project in Minneapolis, typical costs for implementation of a shared street are approximately $50,000 per block. That project included a comfort zone on the south side, with a narrow furniture zone. There is no curb between the furniture zone and the shared zone where vehicles drive. However, there is a contrasting tactile surface that serves as the detectable edge.

Shared Streets

What are the maintenance impacts?

Proper maintenance of shared streets is critical to ensure usability and safety. Shared streets often feature non-standard paving materials and treatments, which may require more care in installation and long-term maintenance. Partner with maintenance team members to discuss strategies related to routine maintenance, especially during winter months.

Resources

- FHWA Accessible Shared Streets – Notable Practices and Considerations for Accommodating Pedestrians with Vision Disabilities: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/accessible_shared_streets/index.cfm
- US Access Board Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG): https://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way/proposed-rights-of-way-guidelines
- International Standard Organization (ISO) 23599: https://www.iso.org/obp/ui/#iso:std:iso:23599:ed-2:v1:en

Streetscape elements within a shared street should be organized in a way that facilitates navigation by pedestrians with vision disabilities. The defining feature of a shared street is a shared zone where pedestrians, bicyclists, and motor vehicles can safely interact in the same space. If there is sufficient right-of-way, shared streets may also have a pedestrian-only comfort zone.



Figure 24

Frontage Zone varies	Comfort Zone 6' min, more preferred	Furniture Zone	Shared Zone
Landscaping, front stoops, door swings, awnings, café seating, retail signage and displays	Pedestrian access route (NOTE: If there is insufficient right-of-way for a comfort zone of at least 6'-wide, consider the shared alley design shown in Figure 25.)	Lights, signs, utility poles and boxes, trees, bicycle racks, parking meters, transit stops, benches, stormwater facilities and snow storage	Shared circulation for pedestrians, bicycles, vehicles

Shared Street Elements, Source: FHWA Accessible Shared Streets

On-Road and Buffered Bicycle Lanes

What is their purpose?

On-road bike lanes use pavement markings and signs to designate exclusive space for bicyclists. They are normally provided in both directions on two-way streets or on one side of a one-way street.

Buffered bike lanes are a type of on-road bike lane that provide increased horizontal separation between bicyclist, travel lanes, and/or parking lanes. The image shown below, from the MnDOT Bicycle Facility Design Manual, incorporates a double solid white line, some agencies also use a solid line along with a broken line.



Buffered bicycle lane

Are they a proven strategy?

Bicycle lanes are a **PROVEN** safety strategy. The Crash Reduction Factor (CRF) for bicycle crashes where bicycle lanes are provided is 36. Additionally, studies have shown that the provision of a bike lane, even if located along on-street parking in the "door zone," is still safer for bicyclists than the provision of a wide shared lane. However, further research is needed to distinguish between different types of bike lane configurations and street characteristics.

Where would we use them?

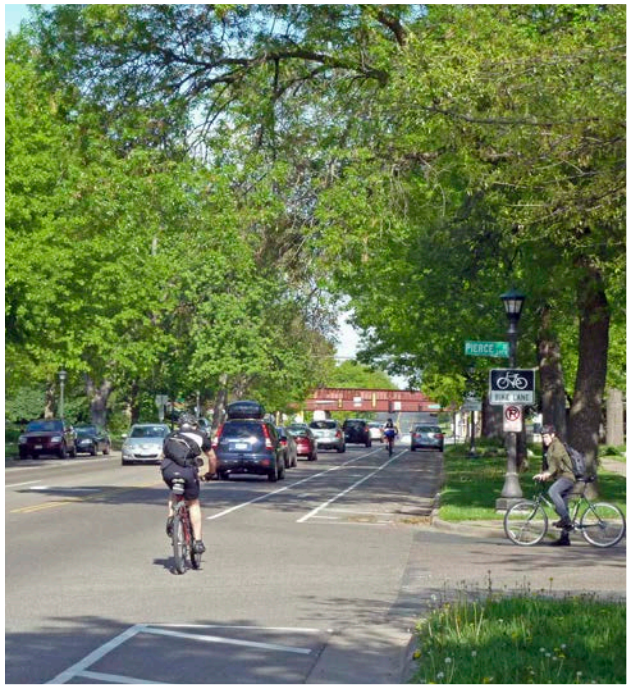
Bicycle lanes can be considered at the following locations:

- On roadways with motor vehicle speeds of 35 mph or less
- Bike lanes are likely to be comfortable for bicyclists of all ages and abilities when traffic volumes are less than 6,000 vehicles per day and speeds are 25 mph or lower.
- Greater separation, such as additional buffer width or a separated bike lane, may be considered when a roadway has any of the following critical factors:
  - Unusually high peak hour traffic volumes (greater than 10%-12% ADT)
  - Considerable volume of large trucks (5%-7% or more of daily volume)
  - On-street parking (which increases the risk of dooring collisions)
  - Concentrations of children or older adults (schools or senior centers)
  - Vehicle turn-lanes and/or high volumes of turning vehicles

On-Road and Buffered Bicycle Lanes

What are the advantages?

- Bike lanes, even those without buffers, help to separate modes of travel by their speed.
- Can improve comfort for both bicyclists and drivers.
- Can improve uniformity of speeds for drivers.
- Buffered bike lanes, with their increased horizontal separation from motor vehicles, further increase comfort for both bicyclists and drivers.



Bicycle lane on Marshall Avenue, Saint Paul, MN

What are the challenges?

- Drivers may confuse overly wide bike lanes (wider than 7') with a parking or travel lane. When space permits, consider a buffered bike lane.
- Bicycle lanes need careful design at intersections and driveways to consider interactions with bicycles and turning vehicles. Turning drivers may have difficulty seeing a cyclist approaching from behind them.
- Bike lanes may need to transition to separated bike lanes or shared use paths when vehicle speeds are not controlled at conflict points.
- Are not comfortable for all users when traffic volumes or speeds are high.
- May be located within the “door zone” of parked vehicles, which accounts for 2%-10% of bike crashes in urban areas.
- It may be challenging to maintain desirable sight distances to bike lanes.

What are the maintenance impacts?

Typically, bike lanes can be cleared along with the mainline roadway without special equipment. However, it is important to partner with maintenance team members to discuss strategies and issues related to routine maintenance since bike lanes should be maintained free of potholes, broken glass, and other debris. This is especially important for buffered bike lanes. Maintenance should also consider upholding clear and legible lane lines, in particular the buffer striping, which is not always longitudinal. Also, additional de-icing material may be needed to achieve a bare pavement condition due to the lack of vehicle traffic and to maintain smooth roadway surfaces for safe riding.

Best practices

- The portion designated for bicycle travel should not be less than 4' (5' adjacent to curbs). Buffers should be at least 2' wide.
- For buffered bike lanes, the buffer space can be provided between driving lanes and the bike lane, between the bike lane and parked motor vehicles, or both.

How much do they cost?

Typical costs range from $16,000 per mile for restriping to $500,000 per mile for overlay to $5 million per mile for reconstruction.

On-Road and Buffered Bicycle Lanes

Design Features

For state-specific design details, see Chapter 5 of the MnDOT Bicycle Facility Manual. Contraflow bike lanes, left-side bike lanes, and combination bus/bike lanes are also covered in Chapter 5. Additional contexts, such as bus stops and/or one-way streets, present other opportunities for bike lanes.

- To ensure appropriate widths of bike lanes and buffers, it is best to narrow motorized lanes as much as practicable while considering the needs of all roadway users.
- The portion designated for bicycle travel should not be less than 4' (5' adjacent to curbs). Buffers should be at least 2'-wide.
- As a bike lane approaches an intersection, solid bike lane markings can be continued, or they are typically replaced with dotted lines. Dotted lines reinforce that motor vehicles will merge into the bike lane prior to turning. Dotted lines are important where there are frequent right-turn movements or a high percentage of trucks. Refer to the MnMUTCD for details.
- For buffered bike lanes, the buffer space can be provided between driving lanes and the bike lane, between the bike lane and parked motor vehicles, or both.
- A buffer between a bike lane and on-street parking is desirable if the parking has high turnover. Dooring can be a risk when a bike lane is next to parallel parking. Dooring is when a vehicle door opening in front of the bicyclist's path of travel causes a collision. This is a serious concern and can lead to bicyclists not using a bike lane, particularly in places where there is high parking turnover. To reduce the risk of dooring, consider adding a buffer next to the parked motor vehicles.

Bike Lane	Preferred Width (ft.)	Minimum Width (ft.)
Adjacent to edge of pavement or gutter pan	5-7*	4
Between travel lanes or buffers	5-7*	4
Adjacent to parking (without buffer)	6-7*	5

Bicycle Lane Dimensions, Source: Adapted from MnDOT Bicycle Facility Design Manual

**If more than 7' are available, consider a buffered bike lane. Drivers may confuse overly wide bike lanes without a buffer or separation as a parking or travel lane.*

Resources

- http://www.dot.state.mn.us/bike/bicycle-facility-design-manual.html
- https://tooledesign.com/wp-content/uploads/2019/12/Winter-Maintenance-Resource-Guide.pdf
- http://www.ocpcrpa.org/docs/projects/bikeped/NACTO_Urban_Bikeway_Design_Guide.pdf



Bicycle lane at Rollins Avenue SE and 15th Avenue SE, Minneapolis, MN

Paved Shoulders

What is their purpose?

A paved shoulder is a multi-purpose area that is separate from but on the same level as the motor vehicle travel lanes, available for bicycle and pedestrian use and separated from vehicles by the roadway's edgeline. Paved shoulders can accommodate people walking or bicycling on or along roads. Paved shoulders can perform various other functions as well, such as reducing pavement edge deterioration, providing motor vehicle parking and space for emergency vehicles, and accommodating stopped vehicles.

Paved shoulders differ from bike lanes because they can be used for motor vehicle parking unless prohibited by local or area restrictions, whereas bike lanes cannot be used by motorists or pedestrians. Paved shoulders can be designated as bike lanes through the installation of bicycle lane symbol markings, but they must meet bike lane criteria.

Are they a proven strategy?

- Paved shoulders are a **PROVEN** safety strategy, providing a 71% reduction in crashes for pedestrians walking along roadways.
- Wider shoulders have been proven to reduce bicycle crashes.

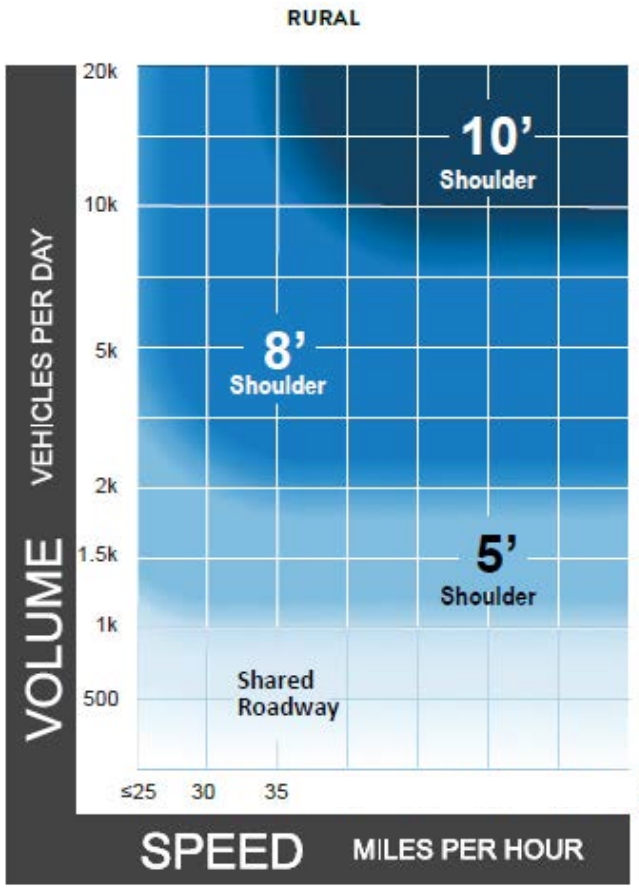
Where would we use them?

Paved shoulders can be considered at the following locations:

- Any road is a suitable candidate for paved shoulders, but rural or suburban locations where motor vehicle speeds are equal to or exceed 50 mph are particularly important to improve bicyclist comfort and safety.
- Paved shoulders are particularly important for bicyclist comfort and safety on any roadway with motorist volumes over 2,000 ADT.
- On roadways where bicycle usage is expected to be limited to higher speed recreational bicyclists.
- On roadways with higher-than-average (greater than 10%) heavy trucks, buses, or recreational vehicles.

What are the maintenance impacts?

Debris from adjacent travel lanes often accumulates in the area where people bicycle. Small rocks, branches, and other debris can deflect the wheel of a bicycle, and broken glass can puncture bicycle tires. These conditions can result in falls and injuries for bicyclists. Because bikeways that are not kept free of debris year-round may discourage bicyclists from using the facility, routine cleaning and clearing as well as more significant repairs and maintenance are necessary to keep bike facilities safe and comfortable in all seasons.



Rural bikeway selection, Source: FHWA Bikeway Selection Guide

Paved Shoulders

What are the advantages?

- Provide separated space for people walking or bicycling on roads where sidewalks, bike lanes, or shared use paths are not provided.
- Paved shoulders have several benefits for motor vehicles as well, such as reducing pavement edge deterioration, reducing run-off-road crashes, providing parking, and providing staging for maintenance activities.
- Improve comfort for both bicyclists and drivers by separating each mode by their speed.

What are the challenges?

- Generally do not accommodate biking by people of all ages and abilities, as they are not often a comfortable place to ride.
- Often collect debris that can make bicycling difficult.
- Rumble strips can create challenges for bicyclists attempting to avoid obstacles or debris in the shoulder.
- Right-of-way and wetland impacts.

Supplemental treatments

Rumble strips are an effective tool to mitigate motorist lane departure crashes, such as run-off-the-road and head-on crashes. However, edgeline or shoulder rumble strips can be difficult for bicyclists to traverse and can impact the use of a paved shoulder as a bicycle facility. See MnDOT Tech Memo 17-08-T-02 for information on the different types of rumble strips and their uses. Rumble strips should be placed in such a way as to provide at least a 4'-wide, smooth, bikeable paved path along the shoulder.



Shoulder widening along an uphill grade

How much do they cost?

On two-lane rural roadways, adding a paved shoulder ranges from $60,000 per mile for 4'-wide shoulders to more than $100,000 per mile or more for 8'-wide shoulders, depending on site conditions. For edgeline rumble strips, the implementation costs approximately $3,000 per mile.

Paved Shoulders



A bicyclist riding on a paved shoulder

Design Features

For state specific design details, including rumble strip design and recommended signage, see Chapter 5 of the MnDOT Bicycle Facility Manual. Key considerations include the following:

- To be considered a bicycle facility, a paved shoulder must be between 4' and 10'-wide, with wider shoulders intended on roadways with higher speeds and volumes.
- Provide paved shoulders on both sides of two-way roads to discourage wrong-way riding; shoulders on one side can be considered on roadways with constrained width and in uphill directions or where sight distances are limited.
- Where rumble strips are provided, they should be placed to maximize the width of the shoulder for bicycle use, should be as narrow as possible, should use a profile that is more bicycle tolerant, and should include regular gaps of sufficient length to allow bicyclist to move between the shoulder and travel lane where necessary.
- While a paved shoulder is not a designated pedestrian facility and therefore is not required to meet ADA requirements, it is a best practice to construct shoulders at a 2% or less cross slope where pedestrian use is expected.
- Paved shoulders are generally only suitable bikeways for highly confident or somewhat confident bicyclists. If connections to schools, parks, residential land uses, or employment centers are present along a roadway, consider providing shared use paths or other suitable bikeways and walkways for less experienced or confident bicyclists.
- Guide signs and wayfinding signs should be placed to inform users how to navigate conflict areas or find popular destinations.

Resources

- FHWA Proven Safety Countermeasures: https://safety.fhwa.dot.gov/provencountermeasures/long_rumble_strip/
- MnDOT Tech Memo on Rumble Strips and Stripes on Rural Trunk Highways: https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=1966746
- FHWA Incorporating On-Road Bicycle Networks into Resurfacing Projects: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/resurfacing/resurfacing_workbook.pdf
- PROWAG (Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way) Guidance: https://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way

Bicycle Boulevards

What is their purpose?

Bicycle boulevards are a type of shared roadway designed to prioritize bicycle traffic on low-volume, low-speed streets such as local and residential streets. They often include treatments such as signs, pavement markings, traffic calming and diversion treatments, and intersection modifications. The image below shows a median island, stop sign, and shared-lane pavement markings as part of a bicycle boulevard.



Bicycle boulevard on E 40th Street and 19th Avenue S, Minneapolis, MN

Are they a proven strategy?

Bicycle boulevards are a **TRIED** treatment since data collection on their effectiveness is difficult due the generally low frequency of conflicts on low-volume and low-speed roadways. However, higher motor vehicle speeds have been proven to lead to a higher likelihood of severe or fatal injury, and the traffic calming treatments associated with bicycle boulevards have been **PROVEN** to reduce speeds, thus reducing the potential for severe or fatal crashes.

Where would we use them?

The FHWA Bikeway Selection Guide can be used as a reference. In general, bicycle boulevards can be considered at the following locations:

- On local/residential streets that are parallel to and near an arterial road or community destination (school, library, commercial district, etc.)
- On street segments that are of sufficient length to reasonably serve long-distance bicycle trips or serve as a missing link in the bicycle network
- On local/residential streets that have less than 3,000 ADT, low operating speeds (25 mph or less), and few heavy commercial vehicles

Supplemental treatments

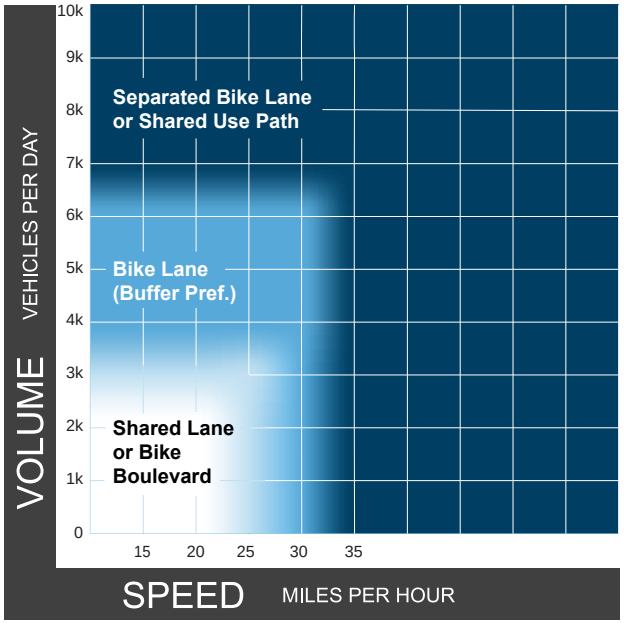
Bicycle boulevards can be enhanced with the following treatments:

- Traffic calming treatments may be appropriate to reduce motor vehicle speeds along bike boulevards. For more information on traffic calming techniques, see Chapter 7 of the MnDOT Bicycle Facility Manual.

Bicycle Boulevards

What are the advantages?

- Can be a low-cost solution to accommodating bicyclists and establishing bicycle networks
- Maintain low-stress bicycle access at busy cross streets.
- Typically allow bicyclists to share the lane with motor vehicle traffic.
- Can incorporate other traffic calming strategies to reduce roadway speeds, such as traffic circles.



Urban/suburban bikeway selection, Source: FHWA Bikeway Selection Guide

What are the challenges?

- Sometimes bicycle boulevards are associated with different type of trips, which requires balancing of transportation priorities and goals, such as an all ages and abilities bicycle network, and a full grid network for motor vehicles. This is not true of all bicycle boulevards.
- Reducing traffic volumes and speeds may require additional study to confirm that the desired street operating characteristics are achieved and maintained.
- Must ensure safe crossings at intersecting streets so that the bicycle boulevard or bicycle network can continue.

- Neighborhood traffic circles and mini-roundabouts used at minor intersections
- Crossing improvements at major streets, including traffic signals or beacons with bicycle detector/bicycle push buttons, median refuges, and curb extensions
- May incorporate shared use paths or other facilities to overcome discontinuous streets such as connecting cul-de-sacs and dead-end streets
- Traffic diverters discourage through motor vehicle traffic but still maintain local access. See Route Modifications section.

How much do they cost?

Many local/residential streets already have many of the desirable characteristics for bicycle boulevards. Revisions can involve moving STOP signs and adding guide signs, both of which could be done at very low cost. There may be some very low costs for new pavement markings. Where traffic volumes exceed the thresholds, traffic diverters can be constructed with flex posts or curbs. Where traffic speeds exceed thresholds, traffic calming techniques should be used. Other improvements may range from $15,000 to $30,000 for adding median pedestrian refuge islands, $5,000 to $10,000 for curb extensions, and $10,000 to $120,000 for RRFBs or traffic signals.

Bicycle Boulevards

Design Features

Bicycle boulevards can include the following design features:

- Improve bicycle mobility by limiting the times bicyclists are required to stop at neighborhood cross streets. Minimize use of stop signs by considering other forms of traffic control such as yield signs or mini-roundabouts in lieu of stop signs where practical.
- Wayfinding signs.
- Shared lane markings or other bicycle boulevard specific pavement markings.

Resources

- FHWA Bikeway Selection Guide: https://safety.fhwa.dot.gov/ped_bike/tools_solve/docs/fhwasa18077.pdf
- MnDOT Bicycle Facility Design Manual: http://www.dot.state.mn.us/bike/design-engineering.html
- https://nacto.org/publication/urban-bikeway-design-guide/bicycle-boulevards/



Bicyle boulevard sign, Minneapolis, MN



Bicycle boulevard, E 40th Street, Minneapolis, MN

Shared Use Paths

What is their purpose?

Shared use paths are bicycle facilities that are physically separated from motor vehicle traffic by an open space or barrier. Most shared use paths are designed for two-way travel and can serve a variety of nonmotorized users. They may be located within roadway right-of-way or an independent right-of-way. Shared use paths are sometimes referred to as trails, greenways, and sidepaths. In Minnesota, trails are facilities that may use a variety of surface materials, widths, and other standards, so although a shared use path might be called a trail, not all trails are shared use paths.

Are they a proven strategy?

Shared use paths are considered **PROVEN**. Shared use paths provide separation for pedestrians and bicyclists from motor vehicles. This separation increases road safety for all road users, particularly for pedestrians and bicyclists.

Wider shared use paths provide space to separate pedestrians and bicyclists from each other. Because of the lack of specific data for this measure, it is considered **TRIED**.

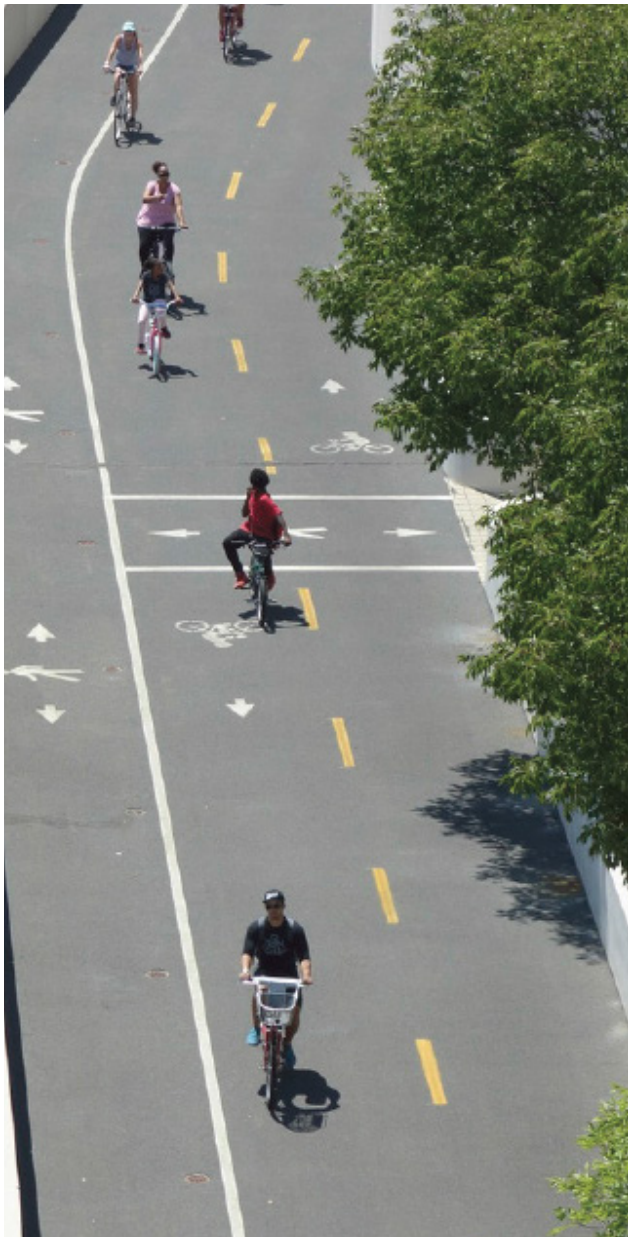
Where would we use them?

The FHWA Bikeway Selection Guide may be used as a reference. In general, shared use paths can be considered at the following locations:

- Where there is a greater mix of users, high user volumes, and a wide range of speeds between shared use path users
- When space is limited, shared use paths can be placed in lieu of separated bike lanes.
- Wider paths may be necessary where there are either large numbers of people bicycling or large percentages of other nonmotorized users that create frequent and inconsistent passing and meeting events. Crowded paths can result in delay, frustration, and collisions. Wider paths also better accommodate social cycling or walking (i.e. the ability to bike or walk side-by-side with another person)
- Geometric characteristics that may merit a wider shared use path include maintenance vehicle size, steep grades, curves, and stationary activities (such as fishing or scenic overlooks)

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine path maintenance. For example, a wider shared use path may be necessary to better suit available snow removal equipment. Shared use paths should be clear of debris, snow, and major cracks or potholes to accommodate users year round.



Shared use path with pavement markings separating bicycles and pedestrians

Shared Use Paths

What are the advantages?

- Separating bicyclists from motor vehicles is safer and more comfortable than shared lane facilities. Separating pedestrians from motor vehicles is also safer. Shared use paths are also more comfortable as motorist volumes and speeds increase.
- Shared use paths that separate users with a range of speeds (i.e., bicyclists and pedestrians) reduce crashes between shared use path users.
- When designed along corridors with minimal road interactions, such as routes following waterways, linear parks, and railroad or transit facility rights-of-way, shared use paths can increase safety and reduce travel times.

What are the challenges?

- Widening existing shared use paths may require modifications to existing drainage infrastructure.
- May require additional lighting for safety including for personal safety.
- Activities that create distractions or obstructions may require wider shared use paths to accommodate people standing. Standing areas for scenic overlooks or fishing, or benches and wayfinding kiosks, should be located beyond the functional area of the shared use path.
- The speed differential of users on wheels and walking can present safety challenges, thus the demand and user mix must be carefully considered when selecting a width and the ability to provide separate lanes, or spaces along the path (see FHWA's Shared Use Path Level of Service Calculator).
- Shared use path intersections should be carefully designed, particularly at intersections with other shared use paths and roadways. Grade separation may be appropriate to eliminate conflicts with railroads or motor vehicle traffic entirely. See Grade-separated Crossings section.
- A limiting factor to consider when widening a shared use path (or constructing a wider shared use path) is the available right-of-way. If necessary, the shared use path may still be widened but with narrower portions provided where right-of-way is constricted.



A shared use path

How much do they cost?

Typical costs for a shared use path range from $300,000 to $600,000 per mile.

Shared Use Paths

Shared Use Path Level of Service Look-Up Table, Typical Mode Split*											
Shared Use Path Peak Hour Volume	Shared Use Path Width (ft)										
	8	10	11	12	14	15	16	18	20	22	24
50	B	B	B	B	B	A	A	A	A	A	A
100	D	C	B	B	B	A	A	A	A	A	A
150	D	C	B	B	B	A	B	A	A	A	A
200	D	D	C	B	B	A	B	A	A	A	A
300	E	D	C	C	C	B	B	B	B	A	A
400	F	E	D	D	C	C	C	B	B	A	B
500	F	F	D	D	D	C	C	C	C	B	B
600	F	F	E	E	E	D	D	C	C	C	B
800	F	F	F	F	F	E	E	E	E	D	D
1,000	F	F	F	F	F	E	F	F	F	E	E
1,200	F	F	F	F	F	F	F	F	F	F	F
1,600	F	F	F	F	F	F	F	F	F	F	F
2,000	F	F	F	F	F	F	F	F	F	F	F

*Assumptions:

1. Mode split is 55% adult bicyclists, 20% pedestrians, 10% runners, 10% in-line skaters, and 5% child bicyclists.
2. An equal number of trail users travel in each direction (the model uses a 50% - 50% directional split).
3. Trail volume represents the actual number of users counted in the field (the model adjusts this volume based on a peak hour factor of 0.85).
4. Trail has a centerline.



Cedar Lake Trail, Minneapolis, MN

Shared Use Paths

Design Features

FHWA's Shared Use Path Level of Service Calculator can be used to determine whether a shared use path may require additional width to obtain an acceptable level of service. The calculation is based on four inputs: peak hour volumes, mode splits, shared use path width, and the presence of a centerline.

Additional information on how to use the Level of Service Calculator can be found in the FHWA Bikeway Selection Guide. MnDOT-specific design guidelines can be found in Chapter 5 of the MnDOT Bicycle Facility Design Manual. Noteworthy design features include the following:

- Typical shared use path widths range from 8' to 15', though they may be wider. A 15' shared use path is effectively a 10' bicycle path and 5' walkway, allowing for the separation of bicyclists and pedestrians.
- Shared use path users include adult bicyclists, child bicyclists, pedestrians, in-line skaters, roller skiers, runners, dog walkers, children in general, and people with disabilities.
- MnDOT requires all shared use paths that are funded by MnDOT, or within MnDOT right-of-way, to be ADA-accessible year-round. Required accessibility features include:
  - Ramps and detectable warnings at every shared use path intersection with a roadway
  - Accessibility to and from a roadway shoulder at the end of the shared use path
  - If the shared use path has a separate designated facility for walking, then it should be separated by a detectable edge.
- Walking and bicycling are inherently social activities. Designers should expect that people bicycling on shared use paths desire to ride side-by-side. Choosing an appropriate shared use path width depends on the mix of users, expected volumes, and land use context. Consider the following when determining a shared use path width:
  - User types (e.g. adult bicyclists, child bicyclists, runners, dog walkers)
  - User volumes and speeds, by type
  - Nearby land use context
  - Scenery
  - Distractions
  - Sight distance obstructions
  - Roadside hazards or conditions (fences, retaining walls, waterways)
  - Right-of-way availability
  - Maintenance, utility, or emergency services vehicle access

Resources

- FHWA Shared Use Path Level of Service Calculator: https://www.fhwa.dot.gov/publications/research/safety/pedbike/05138/
- FHWA Bikeway Selection Guide: https://safety.fhwa.dot.gov/ped_bike/tools_solve/docs/fhwasa18077.pdf
- MnDOT Bicycle Facility Design Manual
- MnDOT Land Use Context Memo: MnDOT Technical Memorandum 18-07-TS-05

Separated Bicycle Lanes

What is their purpose?

Separated bike lanes, also known as cycle tracks and protected bike lanes, are exclusive facilities for bicycling that are located within or directly adjacent to a roadway. They are physically separated from motor vehicle traffic by a vertical element such as flexible post delineators, channelizing curb, rigid bollards, raised medians, concrete barriers, parked motor vehicles, planters and landscaping, and/or other physical objects. The presence of this vertical element is what differentiates separated bike lanes from conventional and buffered bike lanes.

Unlike sidepaths and shared use paths, separated bike lanes are bike-only facilities. The buffer between the bicycle facility and the roadway is known as the street buffer; the buffer between the bicycle facility and sidewalk is known as the sidewalk buffer. Separated bike lanes can be:

- One- or two-way facilities
- On the left or right-hand side of a street
- At road-grade, at sidewalk-grade, or at an intermediate-grade between the roadway and sidewalk.



Capital City Bikeway, Jackson Street, Saint Paul, MN

Are they a proven strategy?

Physical separation of bicyclists from motor vehicle traffic promotes multimodal safety. The specific impact of separated bike lanes is not yet quantified, but has been shown to be more comfortable for people of all ages and abilities. Because of the lack of specific data for this measure, it is considered **TRIED**.

Where would we use them?

Separated bike lanes can be considered at the following locations:

- In areas with traffic volumes over 6,000 ADT or high motor vehicle speeds (over 30 mph)
- In areas with peak hour bicycle traffic over 100 per hour
- In areas with a wide range of user types and variety of speeds
- In areas that connect existing or planned biking networks
- Freight movements, delivery locations, on-street parking, accessible parking, pedestrian curb ramps, bus and transit access, and curb cuts must be carefully considered when designing separated bike lanes.

What are the maintenance impacts?

Partner with maintenance team members to discuss strategies and issues related to routine maintenance for separated bicycle lanes, in particular for debris in the spring and snow in the winter. Separated bicycle lanes typically require special equipment to remove snow. If adequate snow storage space is not provided in the buffer

Separated Bicycle Lanes

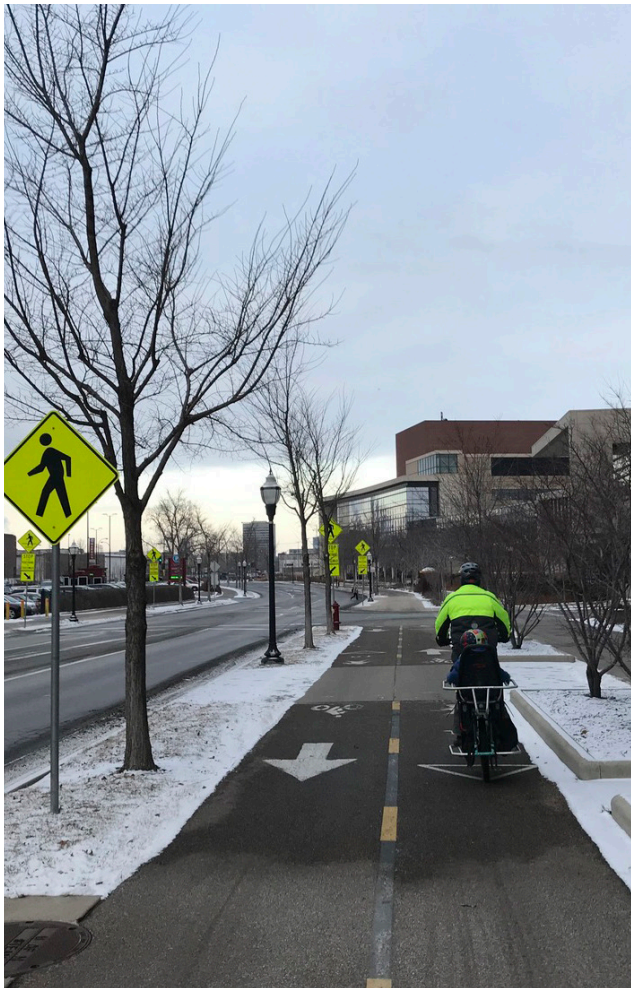
zone, snow removal may be needed. If delineator posts are used in lieu of curb separation, agencies should plan on replacing delineators that are damaged or destroyed during regular use; in high-traffic areas, this may require replacing up to 1/3 of delineators annually.

What are the advantages?

- Minimize bicyclist exposure and reduce the interaction between bicyclists and motor vehicles through the corridor.
- If a separated bike lane is at sidewalk- or intermediate-level through driveways and intersections, this design reduces the speed of motor vehicles at conflict points. This reduces bicycle crash severity.
- The street buffer provides space outside of the pedestrian accessible route space for roadway signs, utility poles, and parking meters. The street buffer can also provide space for snow storage.
- The sidewalk buffer can provide space outside of the pedestrian accessible route for trash receptacles, landscaping, benches, and/or pedestrian scale lighting.
- A buffer width of 5' or more can create the opportunity for additional landscaping or for providing stormwater best management practices.

What are the challenges?

- One-way separated bicycle lanes may attract wrong way riding if a separated bike lane is not provided in the opposite direction.
- Two-way separated bicycle lanes present unexpected conflicts between bicyclists and motorists at intersections and driveways because bicycles are riding against traffic.
- The design of the vertical separation must consider the drainage impacts.
- Consider freight movements and delivery locations when designing separated bike lanes.
- The design of the vertical separation will need to consider accessibility features, such as a space for paratransit needs since paratransit vehicles cannot park in bike lanes.



A separated bicycle lane in Minneapolis

How much do they cost?

Typical costs range from $16,000 per mile for restriping to $500,000 per mile for overlay to $5 million per mile for reconstruction.

Separated Bicycle Lanes

Design Features

- Coordinate with MnDOT ADA Group for guidance related to ADA needs and paratransit needs on roadways where separated bicycle lanes are proposed.
- For state specific design details, including preferred and minimum bike lane widths, see Chapter 5 of the MnDOT Bicycle Facility Manual.
- If a separated bike lane is at sidewalk-level, the design should allow the bicycle facility to continue at grade and while motor vehicles change grade to cross the facility.
- On two-way roadways, one-way separated bike lanes on each side of the roadway are typically preferred over a two-way separated bike lane on one side of the roadway.
- If motorists and bike/pedestrian movements are concurrent or uncontrolled at conflict points, sight lines on the intersection or driveway approach must be kept clear to maintain visibility between street users.
- Separated bike lanes can present some specific accessibility challenges that must be carefully thought through during the initial planning process.
- Protected intersections are commonly used with separated bike lanes. Refer to Separated Bicycle Lanes section.
- The MassDOT Separated Bicycle Lane Planning and Design Guide provides additional detailed guidance for Separated Bicycle Lanes.



A separated bicycle lane along Minnesota Avenue, Glenwood, MN

Resources

- FHWA Separated Bike Lane Planning and Design Guide: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/separated_bikelane_pdg/separatedbikelane_pdg.pdf
- MnDOT Bicycle Facility Design Manual, Chapter 5
- MassDOT Separated Bicycle Lane Planning and Design Guide: https://www.mass.gov/lists/separated-bike-lane-planning-design-guide



A separated bicycle lane along Minnesota Avenue, Glenwood, MN

Temporary On-Street Shared Use Paths

What is their purpose?

A temporary on-street shared use path discourages vehicles from entering into the shoulder space for bicyclists and pedestrians. These facilities are typically considered a temporary measure since the design retrofits the existing street width to provide an accessible route for pedestrians and bicyclists where a conventional sidewalk is not provided. These are not a recommended best practice and should be carefully designed to minimize the potential drawbacks.

Temporary on-street shared use paths may use delineator posts to separate the area from the roadway. There is often no curb, concrete barrier, or other continuous vertical element separating the space for bicycles or pedestrians from the space for motor vehicles. However, vertical elements can be provided to improve the detectability of the shared use path.



A temporary on-street shared use path

Are they a proven strategy?

There is little research or documentation on the efficacy of temporary on-street pedestrian accommodations. A variety of treatments have been tried in several locations across the country, including in Minneapolis, but are generally viewed as an interim solution until a more permanent bicycle/pedestrian facility is constructed. Therefore, this treatment is considered **EXPERIMENTAL**.

Where would we use them?

Temporary on-street shared use paths can be considered at the following locations:

- Areas where there is limited right-of-way
- Areas with limited bicycle or pedestrian demand
- Where missing links exist in the bicycle and/or pedestrian network

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to maintenance, especially regarding snow clearance. Since on-street shared use paths are retrofitted and temporary, they may have slopes that require additional maintenance to prevent melt and re-freeze. This is similar to retrofitted on-road bicycle lanes.

In addition, temporary shared use paths often repurpose space from existing shoulders, which may have been used for snow storage. Snow removal and storage must be carefully considered in the design.

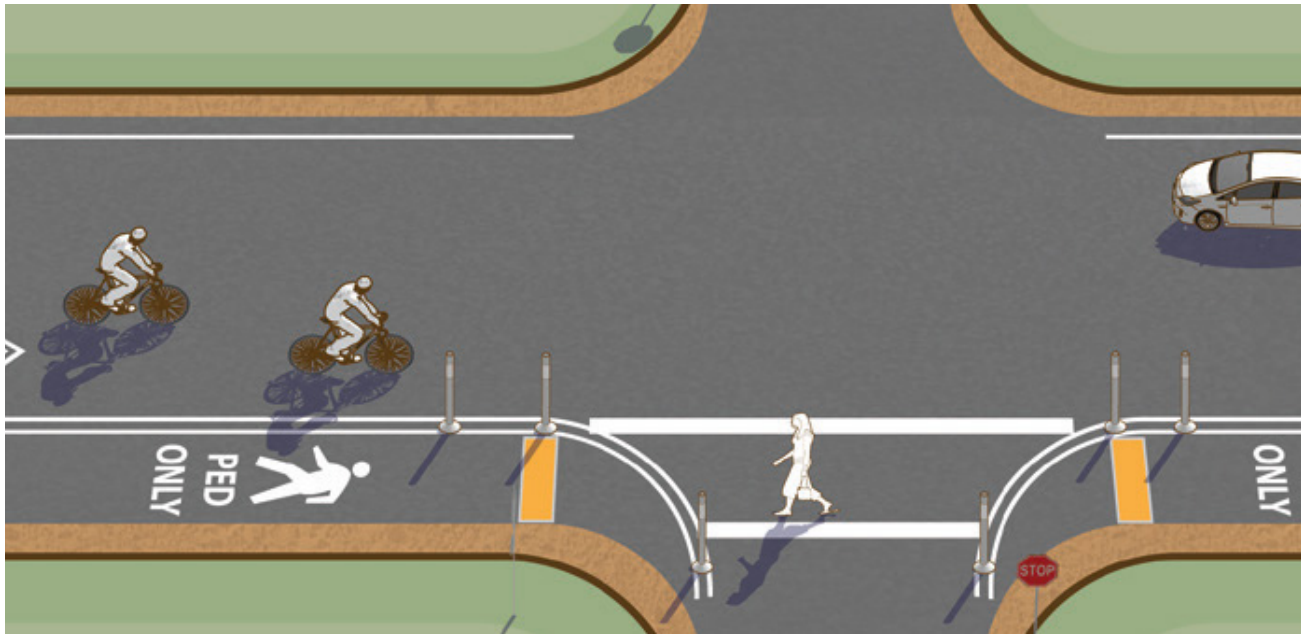
Temporary On-Street Shared Use Paths

What are the advantages?

- Can be implemented for a low cost.
- Can be used in areas where there is a desire to provide pedestrian and bicycle connections and separation from motor vehicle traffic but there is not enough space and/or resources to accommodate significant construction of a dedicated facility.

What are the challenges?

- Can present unique accessibility challenges because accessible routes typically have defined characteristics such as cross slopes of 2% or less.
- Should include detectable warning fields at intersections/ramps.
- Agencies should document any deficiencies with the on-street shared use paths and identify a plan to correct them in an ADA Transition Plan once a more permanent facility is constructed.



Pedestrian lane, Source: FHWA Small Town and Rural Multimodal Networks



A temporary on-street shared use path on 36th St, Minneapolis, MN

How much do they cost?

The cost of temporary on-street shared use paths will vary depending on the type, size and materials used.

Temporary On-Street Shared Use Paths

Design Features

Temporary on-street facilities should include a detectible edge whenever possible, such as the examples shown at right. If a dectectible edge is not provided, the installation should be for temporary use only until a long-term installation can be completed.

Examples constructed to date in Minnesota include truncated domes at intersections, and tube delineators to separate the path from the roadway.

Best practices

Important design features include the following:

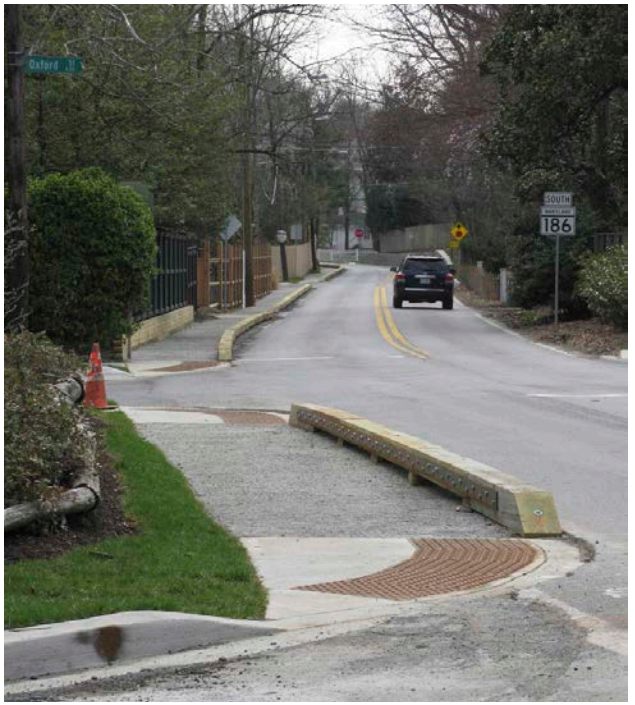
- In cases where it is not possible to provide an ADA-compliant facility, ensuring the cross slope matches the mainline may be acceptable as a temporary treatment. In rural situations, cross slopes greater than 2% but less than 4% may be acceptable.
- Temporary installation is defined as 5 years or less. Shorter durations for the installation are preferred.
- Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG) Guidance can be helpful when designing this type of facility for pedestrians. See Paved Shoulders section for more information.

Resources

- FHWA Small Town and Rural Multimodal Network Guide: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/small_towns/fhwahep17024_lg.pdf
- PROWAG (Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way) Guidance: https://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way



A temporary on-street shared use path



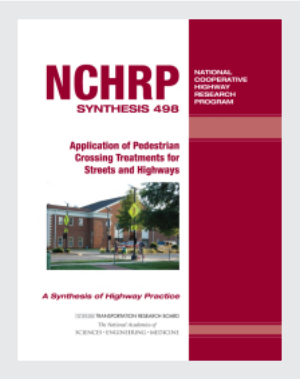
A temporary on-street shared use path


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NCHRP
SYNTHESIS 498

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Application of Pedestrian Crossing Treatments for Streets and Highways



A Synthesis of Highway Practice

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

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The authors wish to acknowledge the many individuals at state and local transportation agencies who contributed to this research by participating in the survey and contributing to in-depth case studies about their practices. In addition, the authors gratefully acknowledge the research panel members for their vision, guidance, and review of this report.

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FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice.*

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

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This synthesis summarizes the types of pedestrian crossing treatments being used in different places throughout the United States, and what policies and processes are used to select and prioritize treatments and treatment locations. The study was developed by (1) surveying state departments of transportation and local transportation agencies, (2) identifying and synthesizing effective practices and policies, and (3) performing a comprehensive literature review of safety evidence for more than 25 pedestrian crossing treatments. Case examples highlight more comprehensive pedestrian safety practices.

Libby Thomas, Nathan J. Thirsk, and Charles V. Zegeer, University of North Carolina–Chapel Hill, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

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CONTENTS

1 SUMMARY

5 CHAPTER ONE INTRODUCTION
- Background, 5
- Study Purpose, 6
- Study Approach, 6
- Content, Organization, and Use of This Report, 8

9 CHAPTER TWO POLICIES GUIDING SELECTION OF PEDESTRIAN CROSSING IMPROVEMENTS
- Complete Streets and Related Policies and Guidance, 9
- Toward Zero Deaths and Vision Zero, 11
- Examples of Effective Practices in Planning, Design, Land Use, Engineering, Operations, and Financing, 12

13 CHAPTER THREE GUIDANCE AND CURRENT PRACTICES REGARDING SELECTING AND PRIORITIZING PEDESTRIAN CROSSING IMPROVEMENTS
- Existing Resources for Identifying and Prioritizing Pedestrian Crossing Improvements, 13
- Current Practices, 25

35 CHAPTER FOUR RECOMMENDED APPLICATIONS, EFFECTIVENESS, AND CURRENT USE OF PEDESTRIAN CROSSING TREATMENTS
- Roadway Design Features, 36
- Traffic Control Devices, 47
- Summary of Application of Traffic Control Devices, 60

61 CHAPTER FIVE EXAMPLES OF GUIDANCE TOOLS AND ORIGINAL CASE EXAMPLES ON PROVISION OF SAFER PEDESTRIAN CROSSINGS
- Examples of State and Local Jurisdictions Crossing Treatment Guides, 61
- Original Case Examples, 66
- Case Examples—Innovative Treatments and Approaches from Other Sources, 80

83 CHAPTER SIX SUMMARY AND CONCLUSIONS
- Further Research Needs, 84
- Final Conclusions, 84

86 ACRONYMS AND TERMS USED IN THIS REPORT

88 REFERENCES

94 BIBLIOGRAPHY

95 APPENDIX A SURVEY QUESTIONNAIRE AND SUMMARY OF SURVEY RESPONSES

113 APPENDIX B DETAILED SYNTHESIS OF LITERATURE REVIEW OF TREATMENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

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APPLICATION OF PEDESTRIAN CROSSING TREATMENTS FOR STREETS AND HIGHWAYS

SUMMARY

Pedestrian safety and mobility in the United States are in a constant state of growth and change. Increasing national, state, and local priorities to increase walking generate an even greater need to improve safety for pedestrians. New traffic control devices, designs, research, and guidance continually emerge. In their efforts to encourage more walking, some jurisdictions may also consider a variety of goals such as energy conservation, congestion mitigation, community livability, and economic equity, whereas others have not embraced such goals. As a result, pedestrian safety policies and practices often differ widely among cities and states, with little uniformity and sometimes without optimal conditions for pedestrians.

This study compiles information on the state of existing practices regarding application of pedestrian crossing improvements, and does not produce new guidance. However, many key resources and tools, as well as examples of emerging state and local guidance and practices, are highlighted throughout the report. The study was carried out by (1) surveying state departments of transportation (DOTs) and local transportation agencies, (2) identifying and synthesizing current recommended practice and policy guidance, and (3) performing a comprehensive literature review of safety evidence for more than 25 pedestrian crossing treatments. For the survey, all 50 state transportation agencies and a select set of local (municipal and county) jurisdictions were asked about existing practices, what treatments are being applied by their jurisdictions, outcomes for different treatments, and continuing needs for information and tools to help in these processes. Forty states (80%), including the District of Columbia, responded to the requests to participate in the survey. Nineteen of the 39 targeted local city and county jurisdictions responded. The literature review and survey results were summarized and case examples were highlighted of more comprehensive pedestrian safety practices, as presented in chapter five of this report.

The study confirmed that a wide array of policies and practices exist with regard to application of crossing treatments, decision frameworks, and approaches used to create safer pedestrian crossings. In addition to policy requirements, a number of states and cities are also voluntarily adopting policies such as Complete Streets, and Toward Zero Deaths or Vision Zero frameworks to help meet community goals for safer and better-connected pedestrian networks. Many states and local jurisdictions—more than 700 in all, according to Smart Growth America—are committed to using Complete Streets approaches, to develop and retrofit urban and suburban streets in ways that will meet the needs of safe travel for all. Complete Streets is often considered an approach to providing a balanced transportation system. The National Association of City Transportation Officials (NACTO) has further developed principles and design guidance that demonstrate this collaborative organization's vision of how a safer, more accessible network and improved social and economic opportunities can be enhanced through design. A number of jurisdictions indicated that they are finding NACTO to be a valuable resource for their communities.

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At least 16 major cities have adopted a Vision Zero philosophy to address traffic safety. Vision Zero strategies place responsibility on the system designers and operators as well as the users of the transport system to minimize the possibility of people dying or becoming seriously injured on the nations' streets and highways. The cities that have adopted Vision Zero principles operate under the assumption that traffic fatalities are preventable, and that road owners and operators have an ethical responsibility to try to prevent them. Vision Zero programs generally include data-driven approaches to analyze problems and evidence-based methods to prioritize the use of resources to most effectively reduce pedestrian fatalities and injuries. In addition, some of these same cities are coordinating a wide variety of stakeholders, public processes, and program areas. Examples of comprehensive program areas include setting lower speed limits and enhancing enforcement through automated means, and implementing new designs and operational measures to reduce conflicts and pedestrian crashes. Vision Zero cities such as New York City and San Francisco are highlighted in this report.

At the same time, the survey results revealed that about 20% of states and 11% of local jurisdictions responding infrequently or never use crash data to help identify and prioritize locations for pedestrian safety improvements. However, a majority frequently or always use crash data to varying degrees. Public input and complaints are used at least as widely by states and even more so by the select local jurisdictions to identify locations that may need safety improvements. At least a few states (e.g., California, North Carolina) and a number of local jurisdictions (e.g., Seattle, Washington; Washington, D.C.; Boulder, Colorado) have also applied knowledge of systemic risks identified from research studies such as the *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations* to assess *locations* and identify improvements, and some are using *TCRP Report 112/NCHRP Report 562, Improving Pedestrian Safety at Unsignalized Crossings,* to help assess and home in on the right type of traffic control devices to use at currently unsignalized crossings.

When it comes to identifying the right treatments, research sponsors and jurisdictions have collaborated to develop an extensive body of safety evidence beyond the aforementioned reports, including some crash-based evidence, over the past couple of decades. However, the quality and quantity of crash-based and operational evidence vary for different treatments. The available information has been widely captured and interpreted in existing resources and expert-developed tools such as PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System (an interactive online resource), *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* [containing crash modification factors (CMFs) for pedestrian crashes], and a number of other guides including earlier NCHRP reports. However, a number of these guides are being used relatively infrequently to help select countermeasures. Instead, there appears to be greater reliance on locally tailored design and other guides, AASHTO and NACTO guides, and use of crash-based evidence such as from the CMF Clearinghouse and locally developed CMFs. Practitioners all expressed the need for more crash-based safety evidence for countermeasures.

Treatments of all types are also being applied in varied circumstances and in different combinations. Design treatments that are used sometimes by a vast majority (90% or more) of states and local jurisdictions surveyed include pedestrian median crossing islands and curb extensions. A majority of states also sometimes use raised median islands for pedestrian safety. Raised medians are typically applied on multilane roads (with speed limits as low as 25 mph). Pedestrian median islands may be installed at unmarked and some marked crosswalks on urban arterials where signalized intersections are infrequent. Both medians and median islands are used with marked crosswalks and signs, most often in conjunction with other treatments such as curb extensions, rectangular rapid flash beacons (RRFBs) or overhead and other flashing devices, and sometimes pedestrian hybrid beacons (PHBs). Street trees and context-sensitive designs were also mentioned. However, a few agencies qualified that their primary reason for using medians was for motor vehicle reasons, that this

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was the typical design for all arterial streets, or the treatment was applied when space and other circumstances allowed.

Curb extensions are most often used in downtown and urban settings or along main roads/trunk lines that pass through cities and towns. Issues mentioned included presence of a significant number of pedestrians and the need to shorten crossing distances or reduce exposure. Some agencies pointed out the need to have on-street parking present on the approaches, as best practice guides suggest. Some jurisdictions use curb extensions to help enforce parking restrictions to improve visibility at crossings. Cities such as Cambridge, Massachusetts, with Complete Streets priorities select designs including narrow radii, curb extensions, and raised pedestrian crossings to calm traffic, aiming to provide safer interactions in residential areas without relying extensively on traffic control devices and enforcement.

Other design treatments used by a majority of states include pedestrian overpass or bridge and underpass/tunnel (usually with restrictions to locations with significant barriers such as freeways or natural barriers), narrowed lane widths, reduced corner radii, and enhanced lighting. Less than half of states employ corridorwide speed calming or raised devices including raised crosswalks or speed tables. The main differences in application among the local jurisdictions surveyed were that most local jurisdictions also use raised crosswalks or speed tables, and a higher percentage also use corridorwide speed calming, while fewer use underpasses and tunnels; these differences may reflect in part the types of streets under state versus local management.

Although there is limited evidence of safety effectiveness, 100% of states use pedestrian warning signs, often in combination with other treatments, although some appear to preferentially try signs and pavement markings before other more extensive changes. Most local jurisdictions surveyed also use warning signs, again usually in combination with other treatments. Traffic signals with pedestrian countdown signals (PCSs) are also now being routinely used by almost all jurisdictions when signals are replaced or installed, as per *Manual on Uniform Traffic Control Devices* (*MUTCD*) guidance. This means that other potentially effective traffic control strategies such as protected left turns, exclusive pedestrian phases, more walk time, leading pedestrian intervals (LPIs), and right turn on red (RTOR) restrictions may be tried at appropriate locations when needed.

About two-thirds of states and three-fourths of the local jurisdictions use LPIs on occasion, with higher percentages sometimes using RTOR restrictions. These are often used on a case-by-case basis, either where complaints come in or where collision history, heavy turning traffic, dual turn lanes, or high pedestrian volumes suggest their use. Advance stop/yield bars and signs appear to have been taken up widely (by close to 90% of both types of jurisdictions), in keeping with evidence that these provide better stopping sight distance at multilane crossings. High-visibility crosswalk markings are also widely used—some jurisdictions use them at all types of crossings, whereas others tend to restrict their use to locations such as those with high pedestrian activity, high-priority intersections, or school-related crossings, or at midblock or uncontrolled locations.

Vision Zero policies and Complete Streets design priorities also are affecting treatment selection, with countermeasures and designs deemed to improve pedestrian safety and mobility sometimes being prioritized over those that may prioritize motorized mobility. For example, whereas three-fourths of states and a smaller percentage of local jurisdictions (65%) indicated that they have tried PHBs, San Francisco, a Vision Zero jurisdiction, mentioned preferring traffic signals to PHBs in its urban environment. Motorist yielding has, however, been uniformly high in evaluations of PHBs, and FHWA considers the device a proven safety treatment with respect to crashes. Eugene, Oregon, and others are sometimes shifting to PHBs where flashing warning devices including RRFBs might previously

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have been applied. Three-fourths of the states and 82% of the local jurisdictions have used RRFBs, with some jurisdictions having used them often.

Different jurisdictions also report different experiences and degrees of success with these treatments. For example, some jurisdictions are reporting significant use and success from applying RRFB devices where they might have used more traditional overhead and side-mounted flashing beacons in the past, including on multilane roads with higher speeds (40 mph and faster). Others restrict the use of RRFBs to lower-speed roads. Both RRFBs and PHBs are sometimes being used on multilane roads, at school crossings, and in other areas with significant pedestrian demand. There is also a trend away from using in-pavement flashing crosswalk lights and traditional flashing beacons, with some jurisdictions shifting to RRFBs instead. Warrant guidelines may also affect treatment selection because warrants do not have to be met for RRFBs. Different treatment outcomes likely relate to a variety of factors, including extent and history of use, variations in locations and other treatments, and differences in traffic law enforcement and driving culture, but these factors are not yet well understood.

Thus, both policy differences in treatment preferences and effectiveness differences when treatments are implemented in different jurisdictions suggest that there is no one-size-fits-all prioritization or decision matrix that can be universally applied, and engineering judgment remains an important aspect of existing practice. This situation appears to lead to some situations where practitioners are frustrated, believing that pedestrian needs are not being fully addressed under the current policy and practice environment. However, a number of local jurisdictions and some states have begun developing their own guidance that incorporates existing safety research, warrant information, and local experiences and priorities into decision tools to help assess locations, streamline processes, and improve consistency of outcomes when pedestrian needs do come to practitioners' attention. Several good examples are included in this synthesis report.

Ongoing research needs include quantifying crash effects of more pedestrian treatments, identifying the types of crashes most affected by different treatments, quantifying effects of multiple treatments, and helping sort through the contexts where certain treatments and combinations may be most effectively applied. Although some crash effect estimates are available for a number of treatments included in this guide, they are sometimes based on one or only a few studies, and, as mentioned, treatment effects may vary in practice. Jurisdictions also expressed a need for better information and more guidance or tools to help them proactively identify safety risks and thresholds for treatment, and for easy-to-apply pedestrian demand estimators to address the frequent lack of count data. Some also expressed a need for other, non-warrant-based decision criteria to help prioritize needs and applications to help address some of the current limitations.

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CHAPTER ONE

INTRODUCTION

BACKGROUND

Applications of treatments to improve pedestrian safety and mobility in the United States are in a state of growth and change. Increasing national, state, and local priorities to extend the opportunity to walk and increase the amounts of walking by people of all ages and abilities generate an even greater need to improve safety for pedestrians. These priorities, and for some jurisdictions, other goals related to livability, energy use, and sustainability of street networks, also affect the priorities and types of facilities provided.

Treatments that help provide safe access to all destinations as well as meet pedestrians' or would-be pedestrians' expectation of a safe crossing can eliminate potential barriers to walking. New and modified designs and traffic control countermeasures are continually emerging, but there is a research and learning curve on where and when different designs and treatments are most effective, if at all effective. Because safety and perceptions of safety are also key influences affecting the choice to walk, applications of treatments must also consider human responses, including responses of drivers. As described in *TCRP Report 112/NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings,* people may not walk if there are poor facilities or lack of sidewalks, a lack of a contiguous system of facilities (a connected network), concerns for personal safety, a lack of facilities connecting common origins and destinations, or poor lighting (Fitzpatrick et al. 2006a). Other considerations are pedestrian delay and comfort, sufficient space for pedestrian flows, and facilities and crossings that are accessible by all types and ages of people, including those with disabilities. Draft Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG) promote full accessibility for persons with disabilities in the public rights of way. Once the proposed or modified guidelines are adopted, compliance with the standards will become mandatory (United States Access Board n.d.). At the same time, many people prefer to walk (or cycle), do not own a car, or are unable to drive. According to data from the 2009 National Household Travel Survey, 8.7% of households had no motor vehicles available for travel, up from 8.1% in 2001 (Santos et al. 2011). Equitable access to jobs, schools, shopping to meet household needs, and recreation for these individuals is dependent on their being able to safely walk or bicycle to destinations or to transit stops.

National, state, and local policies also guide priorities and decision processes. Complete Streets policies and other voluntary policies are being increasingly adopted. Complete Streets are intended to ensure that streets are designed to provide safe access for all users, including pedestrians, bicyclists, transit users, and motorists, regardless of age or ability. According to the National Complete Streets Coalition, more than 700 jurisdictions across the United States have adopted Complete Streets policies (Smart Growth America 2015).

Furthermore, a majority of states are Toward Zero Deaths (TZD) states, and a growing number of local jurisdictions have committed to Vision Zero. Vision Zero considers that transportation system designers and users (including all parts of network design and operations, vehicles, users, and other safety stakeholders) have an ethical obligation to minimize the possibility of people dying as a result of traveling on the nations' streets and highways. According to the Vision Zero Network, at least 17 cities have adopted Vision Zero plans or strategies (Vision Zero Network 2016). There is more information on Vision Zero and other policy contexts in chapter two and in case examples in chapter five. These policy frameworks may alter usual decision processes according to jurisdictions, especially local jurisdictions, that provided information for this synthesis.

At the same time as these ambitious goals are being developed, there is a need for more information about the potential crash and injury effects of different treatments in varied land use and roadway contexts. The ability to identify crash risk relationships is also evolving but is still limited by the data typically available and what is measured in terms of risks and potential countermeasures effects. Availability and cost of appropriate treatments may also affect the prioritization of which locations will be treated and whether treatments will be sufficient. National and state guidelines and traffic control device warrants for pedestrian volumes, numbers of crashes, and other factors must also be taken into consideration for some treatments, but may be difficult to apply owing to a lack of available data. There is often a lack of data about where pedestrians are walking or estimates of pedestrian demand. Data on facilities locations or need, barriers to crossing, and other relevant conditions may also be unavailable.

Balancing the goals of improving safety and mobility for pedestrians as well as other road users, providing access for

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all, and doing so cost effectively and efficiently, all using a performance-based and transparent decision framework, are among the current challenges for states and local jurisdictions in the face of the previously mentioned and other concerns. Understanding the various policies, guidance documents, and philosophical frameworks used to shape applications of pedestrian crossing treatments by jurisdictions is therefore also key to understanding the state of current practice and measures of success.

STUDY PURPOSE

Given the wide variety of policy issues, priorities, and objectives for providing for the safety, mobility, and access for pedestrians, it is not surprising that a variety of practices currently exist with regard to application of pedestrian crossing treatments. Jurisdictions also differ with respect to geographic characteristics, including extent of urbanization, topography, miles and types of road network managed, network histories, data, and staff resources.

Evidence from various applications of newer and experimental traffic control devices in different jurisdictions is also constantly emerging, yet detailed answers of effectiveness and effective practices may still be unavailable for some treatments.

The purpose of this synthesis is to identify pedestrian crossing treatments being used in different places throughout the United States, and what policies and processes are used to select and prioritize treatments and treatment locations. This synthesis study is intended to

- Compile guidance and practices being used to prioritize treatments, including policies and related goals,
- Identify what is known about the intended and current uses and effects on pedestrian safety and mobility of various designs and devices that are being used to improve pedestrian crossings,
- Highlight examples of effective practices from around the country through case examples, and
- Identify gaps in knowledge and needs that state and local agencies have for further research, as well as improved information and tools that may be useful for decision making.

It is not the intent of the synthesis to create new guidance, although the synthesis of ideas being used, countermeasures evidence, case examples, and other resources should be valuable to help agencies that wish to improve their own practices.

STUDY APPROACH

The study encompasses a comprehensive literature synthesis and a survey that targeted all 50 state highway/transportation agencies and a select set of local (municipal and county) agencies. The next two sections summarize the literature review approach and the survey approach.

Literature Review

A comprehensive literature review of 25 pedestrian crossing treatments was undertaken (described in the next section about the survey) that identified and reviewed research and the current recommended practice guides to highlight in this synthesis, and identified and reviewed other key policies and practices that affect decision making.

For the review and assessment of countermeasures evidence, a recent comprehensive pedestrian research synthesis from the United States and abroad, *Evaluation of Pedestrian-Related Roadway Measures: A Summary of Available Research,* which covered research up to March 2014, was extensively relied on (Mead et al. 2014; available at http://www.pedbikeinfo.org/data/library/details.cfm?id=4872), along with other relevant synthesis reports. This information was updated by conducting a thorough search for recent evaluations of pedestrian crossing treatments and countermeasures, focusing on the select group of treatments mentioned in the survey section, but also searching for terms that would capture all types of crossing treatment safety studies. International evidence was included, if articles were in English and were identified through the searched databases listed here. In addition, information developed for an international assessment that is documented in an FHWA report on *Delivering Safe, Comfortable, and Connected Pedestrian and Bicycle Networks: A Review of International Practices* (Thomas et al. 2015a) was used.

The following databases were searched for research reports and articles, guides, and policy documents on determining and selecting appropriate pedestrian crossing safety improvements published between January 2014 and March 2015, and later for comprehensive guidance documents:

- National Transportation Library
- TRB's Transport Research International Documentation database
- Web of Science
- TRB abstracts of presentations at the 2015 TRB Annual Meeting
- Other conference proceedings during the period from January 2014 to March 2015.

Comprehensive search terms and a few specific terms were used to capture studies pertaining to treatment evaluations or studies on any type of controlled or uncontrolled crossing. The study titles and abstracts were screened and relevant studies were reviewed. In this case, original studies were consulted when these had not already been summarized for earlier reports cited in this synthesis, or if

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additional information was needed. The effects of specific treatments were summarized for each countermeasure evaluation study, including study details, treatment location descriptions (when available), measures of effect, and study findings. Peer-reviewed research that is published by government agencies or in peer-reviewed journals or conferences was focused on, because such evidence is most valuable for assessing generalizable treatment effects.

In addition, key guidance documents, including PEDSAFE, NCHRP reports, and pedestrian facility design guides by AASHTO, the National Association of City Transportation Officials (NACTO), and others, were identified and used to describe the current recommended state of practice regarding treatment applications. The literature review did not cover general pedestrian or pedestrian safety plans or transportation plans, although these may touch on the relevant topics.

In addition, key policies to include in the synthesis were identified. This was done based on survey responses, and through follow-up targeted website searches of key agencies and organizations such as FHWA, AASHTO, NACTO, and other policy organizations to document information about current policies.

Survey

The second focus of the study is a survey that targeted transportation agencies responsible for streets and highways in all 50 states and Washington, D.C., and a select number of city and county jurisdictions. In all, 40 states, including the District of Columbia, responded to the request for information. However, only 37 states provided detailed information in response to the questionnaire. The other states indicated that they did not have time to respond (one state), or did not have many practices in place with respect to pedestrian crossing improvements (two states).

In addition to large metropolitan areas that may be leading the way in pedestrian safety processes, cities and counties targeted by the survey were selected on the basis of study team and panel knowledge of relevant experiences in implementing treatments to improve safety at pedestrian crossings. Efforts were also made to gather input to represent agencies of different sizes and from geographic regions across the United States. The initial target group included 39 city and county jurisdictions. A few more were recruited in response to additional information obtained from states. In total, 19 local jurisdictions, nearly half of those recruited, provided responses to the questionnaire.

The survey was intended to gather information about current policies, practices, and research needs with regard to identifying locations and selecting and applying pedestrian safety crossing improvements. An Internet questionnaire was developed, tested, and used for these purposes.

Survey Process

The pedestrian coordinators or equivalent were initially contacted by e-mail for all 50 states and Washington, D.C., and the select local jurisdictions to request their assistance with obtaining a survey response for their state or local jurisdiction. The e-mail described the purpose of the survey and provided a unique link to the Internet-based questionnaire. The description of the survey indicated that multiple people might be needed to complete the survey and that it was possible for different people to enter data into the online questionnaire before submittal.

A follow-up request was sent to state representatives to the AASHTO Standing Committee on Highways, Subcommittee on Safety Management for those states that did not respond to the initial or follow-up requests.

Survey Content

As already mentioned, the survey was intended to capture information about overarching policies, guidance, and recommended practices that agencies are using to prioritize crossing improvements, as well as information on if and how the treatments of interest are currently being implemented. The first part of the survey asked about

- General pedestrian policies or guidance documents used by the jurisdictions (federal/national, state, and local guides used),
- How locations needing improvement are identified,
- How treatments are selected, and
- What other types of resources are needed to assist with these processes.

The second part of the questionnaire asked agencies specifically about their use of different design and traffic control measures to improve crossings for pedestrians. In particular, the survey asked about the situations or location types where or when each treatment is typically used, and if there are other treatments typically used in conjunction with the treatment in question. In addition, the questionnaire asked whether the treatments had been evaluated (by or for the responding jurisdiction). The questionnaire is provided in Appendix A Survey Questionnaire and Summary of Survey responses.

Although it is desirable in such a survey to have quantifiable answers, there were other considerations in developing the questionnaire for this effort. Because of the large number of treatments under consideration in the present synthesis, and the diversity of decision criteria or location types where such treatments might be applied, an open-ended approach was used to obtain some types of information. This approach makes it more difficult to quantify similarities and differences in practices, but it also captured the diversity of approaches or primary considerations that jurisdictions have

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in applying treatments, and allowed for detailed responses by jurisdictions, which provided useful information.

The final list of treatments addressed in the questionnaire included 11 design or infrastructure measures and 14 types of traffic control applications (e.g., beacons, signs, signals, and markings) as follows:

Infrastructure and Design Features

- Raised median with crossing
- Pedestrian median crossing island
- Raised crosswalk or speed table
- Curb extension/bulb-out
- Reduced corner radius
- Road diet
- Narrow lane width
- Pedestrian overpass/bridge
- Pedestrian underpass/tunnel
- Corridorwide speed calming
- Enhanced illumination at pedestrian crossings.

Traffic Control Devices

- High-visibility crosswalk markings
- Advance stop/yield bars and signs
- Traffic signal without pedestrian countdown signal
- Traffic signal with pedestrian countdown signal
- Pedestrian hybrid beacon [PHB; formerly called high-intensity activated cross walk (HAWK) signal]
- Rectangular rapid flash beacon (RRFB)
- Overhead or roadside-mounted flashing beacon
- Pedestrian-only crossing phase/pedestrian scramble
- Leading pedestrian interval to pedestrian walk phase (traffic signal)
- Right turn on red restrictions
- In-roadway "Yield to Pedestrians" signs
- Pedestrian warning signs
- Parking restrictions
- In-pavement flashing lights (associated with crosswalks).

The questionnaire also asked jurisdictions to provide links or information about state or local guidelines, countermeasure selection guides, or evaluation studies for any of the crossing treatments they had implemented locally. The results were analyzed and current practices summarized from the survey by state and local jurisdictions.

CONTENT, ORGANIZATION, AND USE OF THIS REPORT

This report focuses on policies and prioritization and countermeasure selection practices, and on 25 specific crossing treatments that are widely used to help improve safety for pedestrians at intersections with signal or stop controls, at uncontrolled intersection approaches, or at midblock controlled or uncontrolled crosswalks. The report provides a synthesis of countermeasures safety evidence that could be useful to practitioners, as well as an overview of policy guidance and current recommended practice guidance resulting from research. The report also serves as a valuable reference resource to existing guidance and safety studies.

Although the study identified crossing treatments being used at any type of location, the study did not focus in detail on roundabouts (at the panel's request) nor on other specialized crossings, such as at single-point urban interchanges or freeway interchange ramps, unless evaluations of the treatments included in the study were undertaken at such specialized locations. Although no particular peer-reviewed evaluation studies were identified, a few state-of-practice reports have emerged that are described in chapter three. Many of the treatments and effective practices discussed in this report are also applicable to those types of junctions, but as yet, there is not much research evidence available for those specific types of locations. There may also be other specialized treatments and considerations that are uniquely applicable to those locations and that were outside the scope of this study.

The summary provides an overview of the synthesis study approach, the practices, and key findings regarding provision of safe pedestrian crossings, as well as ongoing research needs.

Chapter two provides a summary of policies that may affect how jurisdictions prioritize pedestrian safety crossing improvements.

Chapter three summarizes current knowledge resources and practices regarding identifyng locations and selecting appropriate improvements.

Chapter four sumarizes 25 specific design treatments and traffic control countermeasures and how states and a select group of local jurisdictions are using these treatments.

Chapter five provides six new case examples of effective practices being applied by jurisdictions and replicates four case studies from other sources. The chapter also provides several good examples of treatment application guidance that have been developed by state and local agencies.

It should be noted that many other jurisdictions have or are developing their own guidance documents, but not all could be represented in detail this report. Call-out references to some of the other notable practices are, however, distributed throughout the report at appropriate locations.

Chapter six provides a summary of the findings, including an overview of countermeasures effectiveness, and a summary of other practices, as well as highlights needs for future research or resource development.

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CHAPTER TWO

POLICIES GUIDING SELECTION OF PEDESTRIAN CROSSING IMPROVEMENTS

This chapter summarizes some of the overarching policies that frequently provide a decision framework for creating safer access for pedestrians. According to the FHWA Office of Human Environment, all federal-aid highway projects must consider all users, regardless of whether they are National Highway System routes. The 2000 policy Accommodating Bicycle and Pedestrian Travel: A Recommended Approach (FHWA HEP 2012a), and the 2010 policy U.S. Department of Transportation Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations (FHWA HEP 2010) detail how to incorporate safe and convenient walking and bicycle facilities into transportation projects. Note that both policies are still in effect; supplementary guidance to the 2000 policy is provided in a supplemental Memorandum (FHWA HEP 2012b).

In addition, U.S. Code requires each state to develop a statewide transportation plan and a statewide transportation improvement program for all areas of the state. "The statewide transportation plan and the transportation improvement program developed for each state shall provide for the development and integrated management and operation of transportation systems and facilities (including accessible pedestrian walkways and bicycle transportation facilities) that will function as an intermodal transportation system for the state and an integral part of an intermodal transportation system for the United States" (23 USC § 135(a)(2)).

Although there are many other national, state, and local policies, priorities, and requirements, the following policies and guides are notable at present in terms of providing a decision framework or guiding philosophy for provision of pedestrian facilities. Complete Streets approaches have been widely adopted, and are being strengthened by the adoption of Vision Zero approaches in many large cities.

COMPLETE STREETS AND RELATED POLICIES AND GUIDANCE

Complete Streets are streets designed to provide safe access for all users, including pedestrians, bicyclists, transit users, and motorists, regardless of age or ability (Smart Growth America 2015). According to Smart Growth America, more than 700 jurisdictions across the United States have adopted Complete Streets policies. Policies may be enacted through laws, ordinances, executive order, plans, or new design manuals, but regardless of the method used, there are key aspects of a successful policy, according to the national coalition.

According to the National Complete Streets Coalition, these are the 10 key traits of an ideal Complete Streets policy:

- Includes *a vision* for how and why the community wants to complete its streets;
- Specifies that "*all users*" includes pedestrians, bicyclists, and transit passengers of all ages and abilities, as well as trucks, buses, and automobiles;
- Applies to *both new and retrofit projects*, including design, planning, maintenance, and operations, for the entire right of way;
- Makes *any exceptions* specific and sets a clear procedure that requires high-level approval of exceptions;
- Encourages *street connectivity* and aims to create a comprehensive, integrated, connected network for all modes;
- Is adoptable by *all agencies to cover all roads;*
- Directs the use of the *latest and best design criteria* and guidelines while recognizing the need for flexibility in balancing user needs;
- Directs that Complete Streets solutions will *complement the context* of the community;
- Establishes *performance standards* with measurable outcomes; and
- Includes *specific next steps* for implementation of the policy.

A number of state and local jurisdictions have begun to redefine street purposes that aim to meet multiple goals for modern living through such policies and guidelines as Complete Streets, Main Streets, and others. Although a variety of policies and guidance were mentioned by state and local jurisdictions, Complete Streets was among the more common answers for the type of overarching policies or guidance used to direct pedestrian programs among the states. Nearly one-third of states (30%) that participated in the survey for this report mentioned having state Complete Streets policies or guidance; several also coordinate with local jurisdictions that have Complete Streets policies or plans.

In keeping with this trend, more jurisdictions are adopting use of design guides that support a Complete Streets

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vision. Of the states, 35% mentioned they use the AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities* (2004). However, a number of states, including Colorado, Connecticut, Massachusetts, Washington, and Wisconsin, have also begun consulting NACTO design guidance. A number of local jurisdictions surveyed also referred to state or local Complete Streets guidance; NACTO guidance was mentioned as being used as a resource by 42% of the local jurisdictions surveyed, a higher percentage than the AASHTO pedestrian design guide.

NACTO is a nonprofit organization and coalition of large city transportation departments with 20 member cities, 18 affiliate members, and four international members. NACTO is committed to raising the state of practice for urban street design to provide space where people can safely walk, bicycle, drive, take transit, and socialize. The organization provides two design guides—the *Urban Street Design Guide*, which articulates a vision and road map for complete streets, and the Urban Bikeway Design Guide. NACTO also supports peer-exchange and regular communication among member cities to improve practices (NACTO n.d.).

FHWA also promotes the provision of complete, safe, and comfortable pedestrian networks (Biton et al. 2014), and has recognized changing needs for providing Complete Streets through policies such as Design Flexibility. This FHWA policy memorandum endorses the use of NACTO and other bicycle and pedestrian facility design guides, which the agency views as building on the "flexibilities provided in the AASHTO guides" (Shepherd et al. 2013). The memorandum goes on to state that the *Manual on Uniform Traffic Control Devices* (*MUTCD*) allows, or does not preclude, many of the treatments illustrated in NACTO and other design guides, and encourages pilot testing of innovative, noncompliant treatments through the *MUTCD* experimental process (Shepherd et al. 2013). NACTO guides and other design resources are described in chapter three. FHWA also has promoted enhancing transportation equity for access to jobs, schools, and economic centers, while driving down fatalities and serious injuries (Biton, Daddio, and Andrew 2014; Ladders of Opportunity n.d.; Toward Zero Deaths 2015). The Toward Zero Death initiative is described in the next section.

Oregon described the lack of a Complete Streets approach when planning and designing new or reconstructed roads:

> While we've been quite successful deploying medians, curb extensions, rapid rectangular flashing beacons and the like, we continue to favor roadway cross-sections that we know are difficult for pedestrians to cross. I think our favorite is the five-lane section with two way center turn lane. Because there is no REQUIREMENT to provide a high quality ped(estrian) crossing at regular intervals these features are not included in initial construction. Then local agencies are forced to seek limited grant funding to retrofit for pedestrian crossings.

Some states and communities have also adopted environmental, livability, social equity, and other economic sustainability goals. 8 80 Cities is one nonprofit organization that provides services and resources to such communities and has a "pedestrians first" vision in the focus areas of parks and public spaces, sustainable and healthy mobility, inclusive community engagement, and open streets programs (8 80 Cities n.d.). Eugene, Oregon, is a smaller city that has embraced inclusive community engagement in efforts to provide streets that encourage more walking as well as improve safety. See the case example for Eugene in chapter five. Massachusetts has both a project development and design guide, and a Healthy Transportation Policy Directive, which it adopted in 2013.

Although design guides may not help prioritize where retrofit improvements are most crucial, as roads are rebuilt or new ones are developed, design guides may be used as models for what Complete Streets might look like, and to help develop a network that is *self-explaining* and *self-enforcing* and provides cues for the type of streets and interactions that are to be expected.

Finally, FHWA also encourages planning and environment linkages that represent

> a collaborative and integrated approach to transportation decision making that 1) considers environmental, community, and economic goals early in the transportation planning process, and 2) uses the information, analysis, and products developed during planning to inform the environmental review process. (USDOT n.d.)

Implications for Practice

In addition to funding priorities, jurisdictions with aims to provide Complete Streets and increase walking for livability, environmental, health, and economic reasons may place greater weight on public preferences as part of their pedestrian safety program because there are goals to increase mobility and access in addition to safety. See the case example from Cambridge, Massachusetts, in chapter five for an example of a community using a design approach to achieve Complete Streets, along with public outreach and feedback as part of the evaluation process.

Complete Streets is often defined as a process that aims to balance multimodal transportation objectives. In addition to Complete Streets designs and planning processes, more public input about preferences or level of service (LOS) approaches that use inputs from prior research into pedestrian preferences may be used, in conjunction with safety evidence, to help guide decisions in these cases. However, quantifiable pedestrian LOS measures are fairly limited in the United States at present, but include the pedestrian and multimodal LOS models in the *Highway Capacity Manual 2010.*

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Because of the limitations of current LOS models in addressing pedestrian concerns, some jurisdictions have developed quality of service (QOS) approaches in efforts to take pedestrians' perceptions of safety into account when attempting to achieve balanced street designs. See Chu and Baltes (2003) for a description of Florida's effort to apply a theoretical framework, planning needs, and data to QOS assessment. Some LOS tools have also been developed by international jurisdictions, including the Australasian Pedestrian Facility Selection Tool prepared by Austroads (Abley et al. 2015). However, more study is needed to know whether such tools could be transferred or adapted for use in a U.S. context. Care should also be taken to balance actual safety evidence with stated preferences.

At present, according to survey results, neither pedestrian LOS tools nor QOS assessments appear to be much used by states or local jurisdictions—either to assess current locations or to help assess how improvements may change LOS. There are, however, some exceptions, including New York City. One state mentioned wanting more guidance about effects on vehicular LOS from pedestrian treatments; in a Complete Streets approach, pedestrian mobility would be considered as well. There is more information about the processes and tools that are being used in chapter three.

TOWARD ZERO DEATHS AND VISION ZERO

"The National Strategy Vision [of TZD] is a highway system free of fatalities" (*Toward Zero Deaths* n.d.). The Toward Zero Deaths national safety strategy was outlined and supported by two NCHRP projects and multiple national partners to further develop a national strategy and marketing plan for a TZD initiative (Toward Zero Deaths: A National Strategy on Highway Safety 2015). According to FHWA's website, "The Toward Zero Deaths (TZD) vision is a way of clearly and succinctly describing how an organization, or an individual, is going to approach safety—even one death on our transportation system is unacceptable" (FHWA Office of Safety 2015).

The idea that zero is the "acceptable" number of deaths on the nation's road network was adapted from Sweden's "Vision Zero" framework. To achieve zero deaths, it is necessary to use a data-driven, interdisciplinary approach similar to those FHWA, NHTSA, and NCHRP have been promoting for many years, but with an increased priority on safety. The TZD approach targets areas for improvement and employs proven countermeasures, integrating application of education, enforcement, engineering, and emergency medical and trauma services as well as a shift in safety culture among road users (*Toward Zero Deaths* 2015). The National TZD Strategy outlines strategies for five key areas: safer vulnerable users, safer vehicles, safer infrastructure, enhanced emergency medical services, and improved safety management and data (*Toward Zero Deaths* n.d.). According to a 2012 survey of state highway safety programs by the University of Minnesota Center for Excellence in Rural Safety, 30 states have adopted a Toward Zero Deaths or Vision Zero decision-making approach or language (*Rural Transportation Safety: A Summary of Useful Practices* 2012). However, states did not tend to explicitly mention TZD as having a role in their pedestrian safety practices.

Implications for Practice

Vision Zero, in contrast, was mentioned by a number of local jurisdictions. Vision Zero is the term preferred by many cities, and, as described in the introduction, places responsibility on the system designers, as well as the users of the system, to minimize the possibility of people dying as a result of traveling on the nations' streets and highways. System designers include all those responsible for roadway infrastructure and operations, enforcement, education, and emergency response. According to the Vision Zero Network (2016), at least 17 cities have adopted Vision Zero goals. Many others are considering committing to this framework.

A Vision Zero framework typically changes how decisions are made, because the usual assignment of "costs" to lives is no longer used in a tradeoff with mobility or other transport objectives; safety is considered paramount. However, as mentioned in the preceding paragraph, to achieve the goal of zero deaths, it remains crucial to use a data-driven approach to prioritize projects and effective treatments to achieve the greatest savings in lives and injuries.

A zero deaths vision and policy framework may affect decision making for providing pedestrian facilities in other ways. Because pedestrians and bicyclists are overrepresented among those killed and injured in traffic crashes, such a framework might provide greater impetus for improving safety at crossings for pedestrians (and improving safety for all modes) as it has for New York City and San Francisco, as described in the case examples. A Vision Zero framework tends to give greater weight to measures such as lower speed limits, traffic-calming measures, and enforcement that lowers vehicle speeds in built-up areas where pedestrians are expected. Other measures that lower the chances of severe injury or provide more separation in time or space between pedestrians and motorists, thereby reducing potential conflicts, might also be prioritized where crossing amenities are needed.

A Vision Zero framework not only involves addressing locations where pedestrian crashes and injuries have already occurred, but also suggests using a proactive systematic approach to implementing improvements at locations with a high potential for pedestrian crashes and injuries (FHWA, Office of Safety n.d.). As described in the definitions of terms, a systemic approach is a method of identifying locations that may have high potential for future crashes based on

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similarities with locations that have had high crashes in the past and that may benefit from a similar treatment approach, even if crashes have not yet occurred. A systemic approach is especially useful for pedestrian and bicycle crashes, which tend to occur in relatively low numbers at any one location. NCHRP Project 17-73, "Systemic Pedestrian Safety Analyses," scheduled for completion in July 2017, is under way to assist with a systemic approach to pedestrian safety.

In chapter five, case examples are presented that describe how Vision Zero has shaped the analysis, outreach, and provision of pedestrian safety improvements in San Francisco and New York City. Another case example from Eugene, Oregon, a smaller jurisdiction that is in the process of adopting a similar approach, describes how decisions are being affected.

EXAMPLES OF EFFECTIVE PRACTICES IN PLANNING, DESIGN, LAND USE, ENGINEERING, OPERATIONS, AND FINANCING

In recognition of the complex interplay between policies, designs, and other environmental factors in creating successful pedestrian environments, *NCHRP Synthesis 436: Local Policies and Practices That Support Safe Pedestrian Environments* identified and summarized practices that help jurisdictions be more successful in providing for the safety and mobility needs of pedestrians (Walsh 2012). In the report, more than 40 practices were summarized, and four in-depth case examples were developed. The examples were categorized into the following six categories to highlight particular aspects of each area of practice:

1. Public right-of-way engineering and geometric measures,
2. Design guidelines,
3. Architectural and urban design guidelines,
4. Planning and land development regulations,
5. Financing mechanisms, and
6. Operations, maintenance, and enforcement measures.

Many other policies and local values may also guide pedestrian programs. For example, Safe Routes to School programs and community priorities on providing safer routes for children and families to walk and bike to and from school may lead to identification of needs and prioritization of treatments in such areas. These may in turn lead to application of successful measures to other locations that serve key destinations such as parks and recreation centers, employment centers, and transit locations. See more about Safe Routes to School guidance in chapter three.

Jurisdictions are also challenged to accomplish safety and mobility goals while improving innovation, efficiency, transparency, and environmental sustainability in project development (MAP 21—Moving Ahead for Progress in the 21st Century 2012). Thus, states and local jurisdictions have their work cut out for them. A data-driven approach (defined in the definitions of terms) is the primary method recommended by federal agencies to achieve all of these goals. The remainder of this synthesis highlights not only data available about safety effects of treatments to help agencies make good decisions, but also some of the tools available and processes being used to help apply the knowledge to create safer, more sustainable, and economically and environmentally viable communities and cities.

Innovative policies and practices from Europe, Canada, Australia, and Japan are also documented in a recent report for FHWA, *Delivering Safe, Comfortable, and Connected Pedestrian and Bicycle Networks: A Review of International Practices,* on how these countries measure and complete pedestrian and bicycle networks (Thomas et al. 2015a).

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CHAPTER THREE

GUIDANCE AND CURRENT PRACTICES REGARDING SELECTING AND PRIORITIZING PEDESTRIAN CROSSING IMPROVEMENTS

Federal and national documents such as the *MUTCD* and AASHTO green books provide guidance on design and traffic control devices. However, these national guides alone provide insufficient information on identifying where crossings should be placed and how crossings are to be improved appropriate to the location type, road type, traffic volumes, pedestrian needs, and other concerns.

A number of agencies have undertaken to fill some of the gaps. This chapter describes key state-of-the-practice guides and resources that have been developed to help jurisdictions understand issues related to pedestrian crossing needs, traffic and roadway factors that affect the safety effects of treatments, and how to select appropriate countermeasures. In addition, some examples of guides developed by state and local agencies are highlighted in this chapter and in case examples in chapter five.

As described in chapter two, safety decisions are not made in a vacuum. Policies and local values and public interests, as well as local experiences with treatments, guide decision priorities, and local guides have been tailored to address such concerns. As documented by responses from jurisdictions, not all locations have the same successes with the same treatments, and they likewise do not want to approach pedestrian safety with the same toolbox used by other locations.

This chapter describes practices and resources actually being used by jurisdictions to help make decisions. State and local jurisdictions also described some of their challenges in delivering safer pedestrian crossings. Among the challenges jurisdictions face are that safety barriers can hinder network access for pedestrians; consequently, there may be low crashes and low pedestrian numbers (and difficulty meeting traffic control device warrants), but significant latent demand and need for improved mobility and safety. A further challenge is the lack of crash-based evidence for some types of treatments, or details on where certain treatments are most effective. As discussed in the introduction, these and other issues sometimes make it difficult to determine or justify treatment priorities and to perform cost–benefit types of assessments to prioritize resources.

The following two major sections of this chapter cover effective practice resources available, followed by a summary of practices and guidance resources being used.

EXISTING RESOURCES FOR IDENTIFYING AND PRIORITIZING PEDESTRIAN CROSSING IMPROVEMENTS

It is clear that crossings cannot be provided everywhere pedestrians may potentially cross a street. However, at certain locations, pedestrians need assistance from designs or traffic control devices or both to create sufficient gaps in traffic, to reduce speeds or conflicts with motor vehicles and exposure to potential crashes, and to reduce unnecessary delay for a level of safety and service that motorists typically expect.

The guides highlighted here each offer information or process guidance that can help jurisdictions improve their practices. A number of the guides may be used in several ways, because they may provide information important for screening and identifying risks (in a systemic approach), as well as processes and safety evidence needed to identify and prioritize appropriate treatments.

Other guides are also available and used by some agencies, but are not included here, either because they are more out of date or are not evidence based.

The first resource described provides a model process and prioritization tool that any type of jurisdiction may apply to plan and prioritize any type of pedestrian or other multimodal transportation projects. NCHRP Project 07-17 developed a flexible model process that can be applied to identifying and prioritizing any types of pedestrian or bicycle improvements for existing roads.

Prioritization Tool

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

Available at http:/onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_803.pdf

In 2014, researchers for NCHRP Project 07-17 created the ActiveTrans Priority Tool (APT) in an effort to provide the first national model pedestrian and bicycle prioritization tool that can be used by agencies with a wide spectrum of resources and capabilities. The tool is "a flexible, and

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data-driven approach to prioritizing pedestrian and bicycle improvements along existing roads; and is designed to work for agencies at all levels of government with different prioritization purposes and different levels of technical capacity, available data, and experience" (Lagerwey et al. 2015). The APT tool consists of a guidebook and a programmed spreadsheet with preloaded prioritization factors, associated variables, and functions intended to save users time.

The APT can be used for prioritizing a variety of location types, including road segments, intersections, and corridors. It also addresses facility types such as sidewalks and curb ramps. It consists of 10 steps and two phases. Phase I comprises an initial scoping effort to define the purpose, determine how community or agency values could be expressed through factor selection and weighting, select variables to represent the chosen factors, and assess data availability and technical resources. Phase II comprises the mechanics of calculating prioritization scores and developing a ranked list of improvement locations.

Phase I starts at a high level and is used to tailor the tool to the specific agency's goals and safety priorities. It includes six steps from defining the purpose to assessing data and technical resources (Figure 1). The steps proceed in a linear fashion but are also iterative.

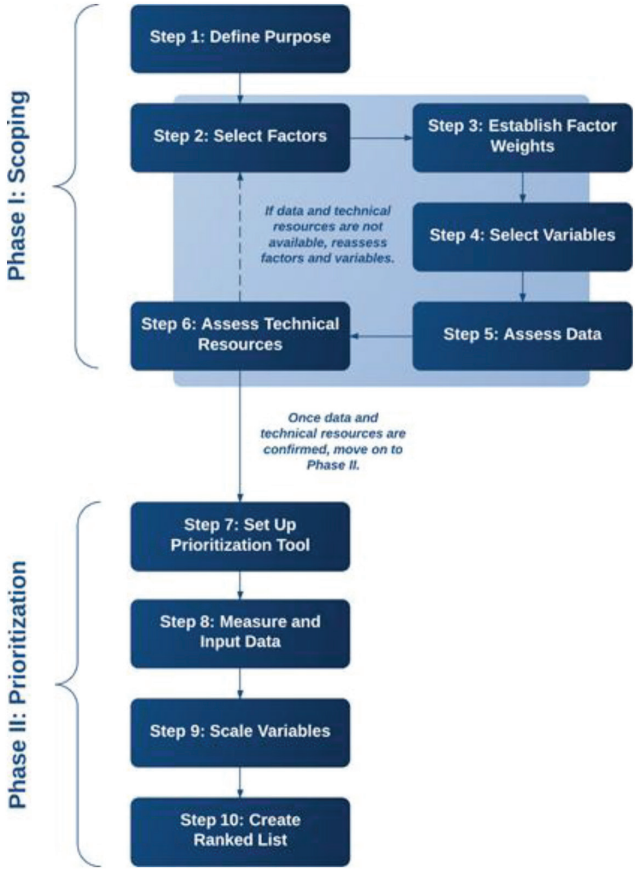


FIGURE 1 ActiveTrans Priority Tool general process. *Source*: Lagerwey et al. (2015).

Phase II then calculates the scores for each improvement location based on the purpose, factors, weights, variables, and technical resources identified (Figure 1). The ultimate output of Phase II is a ranked list of priority pedestrian or bicycle improvement locations, along with a well-documented process for how the list was developed.

Through extensive multiagency and jurisdiction pilot testing, the APT was further refined and found to be useful in multiple planning processes, including master transportation plans; multimodal plans; Complete Streets plans; statewide needs and assessments; bicycle, pedestrian, and sidewalk master plans; Americans with Disabilities Act (ADA) transition plans; districtwide or citywide Safe Routes to School plans; pedestrian and bicycle crash reduction plans and safety audits; and transit access plans (Lagerwey et al. 2015).

Identifying Problems and Problem Locations

A typical reactive assessment process might begin with crash analysis, community complaints, or public input during plan development that flags a problem location, whether controlled or lacking any existing facilities. From there, agencies will likely investigate the site, crash history, and multimodal traffic characteristics and volumes to determine what actions, if any, to take. However, a more proactive approach could incorporate other types of systematic processes. Following are descriptions of tools available to help in various steps of the problem identification and prioritization process. In addition, some tools that have recently been developed by state and local jurisdictions are highlighted in chapter five. Additional guides for uncontrolled crossings have been highlighted separately following this section.

Crash Analysis Tools

Analyzing where crashes occur as well as the types of crashes occurring are ways to identify areas that may need improvement (Zegeer et al. 2009). The crash type provides information on the movements and actions of the motorist and pedestrian leading up to a collision that can help in selecting appropriate treatments to reduce the type of conflict that led to the crash. This information is often lacking in many state crash databases for pedestrian crashes. The spatial location of crashes is crucial to identify in a systemic way land use and other characteristics of streets and the built environment that may be associated with crashes or to identify high crash/crash rate locations that may merit further investigation. Coding crash locations in geographic information system (GIS) or other spatially linkable format (if spatial data are not already available from the state or other transportation agency) is a key to knowing where collisions occur. Analyzing crash types can aid in identifying the types of treatments that may help remedy the problems.

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The Pedestrian and Bicycle Crash Analysis Tool (PBCAT) software was created to help agencies type their pedestrian crashes if crash type information is lacking in their existing crash databases, as it is for many (Harkey et al. 2006). PEDSAFE (further described later) is a companion tool with a matrix to help select countermeasures based on crash types or other performance objectives. Hundreds of agencies have downloaded the PBCAT software. Jurisdictions known to type and analyze their pedestrian crashes to help identify countermeasures include North Carolina; Wisconsin; and Boulder, Colorado.

Once the database is developed, the *Highway Safety Manual* (*HSM*) (AASHTO 2010) provides guidance on a variety of crash-based screening approaches, depending on the types of data available, that might be used to identify locations potentially needing safety improvements. However, pedestrian crashes are relatively rare events and may not occur in concentrations at many particular locations. High crash locations also tend to move around over time. Agencies may want to apply systemic or proactive approaches to identify risks patterns and appropriate treatments to apply across many locations to maximize safety benefits.

Systemic Screening Tools and Approaches

At present there are a few tools and resources to help jurisdictions identify high risk locations before crashes occur, but an active NCHRP project (17-73) aims to develop a systemic pedestrian safety process. Two resources that are currently available include the following:

- *Pedestrian and Bicyclist Intersection Safety Indices (PedISI): User Guide* (Carter et al. 2006, 2007), available at https://www.fhwa.dot.gov/publications/research/safety/pedbike/06130/06130.pdf.
- *Pedestrian Road Safety Audit Guidelines and Prompt Lists* (Nabors et al. 2007), available at: http://www.pedbikeinfo.org/cms/downloads/PedRSA.reduced.pdf.

The PedISI proactive screening tool is available to help prioritize intersection crossings that may need further in-depth assessment (Carter et al. 2006). The index is a model equation and is applied at the crossing level (Figure 2). The index was developed from expert safety ratings and observed pedestrian and motorist interactions and conflicts data. The tool allows users to identify intersection crossings that may be priorities for in-depth pedestrian safety assessments. Observable characteristics such as number of lanes, area type, and type of traffic control, are used to produce a safety index score.

Another way to diagnose problems more fully and help to narrow down potentially appropriate treatments is a road safety audit (RSA). RSAs are a formal, but qualitative, on-site safety assessment of streets, intersections, or other areas, and is conducted by an interdisciplinary, unbiased team of experts. It is important that pedestrian issues be addressed in any RSA, but pedestrian-focused RSAs can be conducted to focus on pedestrian safety issues and characteristics and suggest potentially appropriate remedies. RSAs can also be applied proactively, such as to certain types of corridors or a main thoroughfare through a small community, or even systemically, such as throughout an area.

FHWA's *Pedestrian Road Safety Audit Guidelines* and *Prompt Lists* provide more information on conducting an RSA to be used either proactively to identify locations that

Ped ISI = 2.372—1.867**SIGNAL**—1.807**STOP** + 0.335**THRULNS** + 0.018SPEED + 0.006(**MAINADT*SIGNAL**) + 0.238**COMM**

Where:

Ped ISI	Safety index value (pedestrian	
SIGNAL	Signal-controlled crossing	0 = no 1 = yes
STOP	Stop-sign controlled crossing	0 = no 1 = yes
THRULNS	Number of through lanes on street being crossed (both directions)	1, 2, 3, ...
SPEED	Eighty-fifth percentile of speed of street being crossed	Speed in miles per hour
MAINADT	Main street traffic volume	ADT in thousands
COMM	Predominant land use on surrounding area is commercial development (i.e. retail, restaurants)	0 = not predominantly commercial area 1 = predominantly commercial area

FIGURE 2 FHWA Pedestrian Intersection Safety Index model equation and index values. Reproduced from Table 1 in Carter et al. (2006).

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may have safety issues, or reactively, once locations have been identified through crash data analysis, complaints, or other public or stakeholder input (Nabors et al. 2007). Public safety officials as well as engineering staff often provide input about problem areas, and can participate in RSAs.

RSAs can also be conducted at any stage of the new project development process, preferably as early in the process as possible, to identify issues that could be addressed by the project, or even during the project (such as work zone design).

Public input and complaints are other commonly used methods of identifying areas of concern that may need treatment and could be considered part of a systemic approach to address problems before they become crash statistics.

A Resident's Guide for Creating Safer Communities for Walking and Biking was created as a resource for community stakeholders to get involved in helping to make their communities safer for pedestrians and bicyclists (Sandt et al. 2015). This resource also highlights 12 case examples of community-oriented programs that have helped achieve success in implementing pedestrian and bicycle safety improvements. Several of these examples highlight methods of effectively engaging all types of residents, including communities that are often underrepresented in more standard public processes. Also see Thomas et al. (2015a) for more information on public outreach methods used internationally.

See case studies from Cambridge, Massachusetts, and New York City in chapter five on public outreach approaches used to assess satisfaction with traffic calming measures (Cambridge), and to engage the community about pedestrian safety needs and culture change (New York City).

The tools described in the next section can be used to help assess uncontrolled locations for application of potential crosswalks and other treatments.

Guides for Assessing Risks and Selecting Treatments at Uncontrolled Crossings

The *MUTCD* does not establish clear warrants on when to place crosswalks at uncontrolled locations, but does indicate that crosswalk markings at nonintersection locations legally establish the crosswalk. However, a legal crosswalk alone may be insufficient to obtain motorist stopping or yielding to crossing pedestrians and achieve a high level of safety. The *MUTCD* further states, "In conjunction with signs and other measures, crosswalk markings help to alert road users of a designated pedestrian crossing point across roadways at locations that are not controlled by traffic control signals or STOP or YIELD signs." The *MUTCD* also advises that an engineering study is needed before marking crosswalks at uncontrolled approaches and advises that the engineering study consider the number of lanes, presence of a median, distance from signalized intersections, pedestrian volumes and delay, average daily traffic, speed limit or 85th percentile speed, location geometry, possible consolidation of crossing locations, availability of street lighting, and "other appropriate factors" (FHWA 2009, rev. 2012, pp. 383–384). The consideration of many of these elements is, however, left open to interpretation.

Relating to speed and geometry, stopping sight distance is among the factors that should be considered in deciding where to install (or not install) a marked crosswalk (Zegeer et al. 2005). For example, agencies should not mark a crosswalk where sight distance is poor, such as on or near a horizontal or vertical curve. The sidebar reproduces stopping sight distances as a function of speed from the 2009 *MUTCD* (FHWA 2009), and is provided in conjunction with work zone guidance.

Sight triangles and potential visual obstructions, such as buildings, parking, and landscaping, should be considered in conjunction with stopping sight distance in selecting locations or providing other treatments to mitigate issues. In addition to stopping sight distance for motorists, pedestrians also need adequate sight distance to select a gap and have time to cross at uncontrolled locations, known as pedestrian sight distance (Pedestrian Crossings: Uncontrolled Locations 2014).

As mentioned by survey respondents for this study, establishing demand or need for crosswalks and other improvements is a challenge owing to a lack of pedestrian count data or models to estimate latent demand. Block lengths, street connectivity, and transit access are other factors that can vary locally and by jurisdiction that may affect the need to provide supplemental crossings at uncontrolled locations. Beyond establishing the need for a crosswalk, there are warrants for some treatments—in particular traffic signals and pedestrian hybrid beacons—that may affect the ability to provide a safe crossing because many locations require more treatments than simply striping crosswalks. All of these factors, in addition to differing policies and priorities, help explain why jurisdictions may adopt a variety of practices with regard to providing safer crossings at uncontrolled crossing points.

The next two resources described focus on additional safety risks and potential treatments to provide safer crossings at uncontrolled locations when community needs and engineering studies suggest locations merit crossing improvements. In addition to counting pedestrians crossing at locations along a segment, soliciting public input, consulting pedestrian plans, and assessing land uses and pedestrian generators, transit access, and distance to nearest controlled crossings are some of the ways that communities can identify where crossing improvements may be needed (see e.g., Lagerwey et al. 2015). The existence of pedestrian crashes, particularly more severe injury crashes, may also suggest a need for crossing enhancements.

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Stopping Sight Distance as a Function of Speed (Reproduced from FHWA 2009, Table 6E-1).

Speed*	Distance
20 mph	115 ft
25 mph	155 ft
30 mph	200 ft
35 mph	250 ft
40 mph	305 ft
45 mph	360 ft
50 mph	425 ft
55 mph	495 ft
60 mph	570 ft
65 mph	645 ft
70 mph	730 ft
75 mph	820 ft

*Posted speed, off-peak 85th-percentile speed, or the anticipated operating speed

FHWA's *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines* (Zegeer et al. 2005)

Available at http:/www.fhwa.dot.gov/publications/research/safety/04100/.

This study examined safety factors related to providing crosswalks at crossings with no stop or signal controls in place. The guidelines suggested in this report emerged from a study of 1,000 marked and 1,000 unmarked crosswalks at similar locations in 30 cities. The study reported that higher vehicle traffic volumes, higher pedestrian volumes, and a greater number of lanes were all associated with higher rates of pedestrian crashes. Raised medians and pedestrian crossing islands were associated with lower pedestrian crash rates (Zegeer et al. 2005).

The study found that the presence of a marked crosswalk alone at uncontrolled locations on two-lane and low-volume, multilane roads showed no effect on pedestrian crash rates

TABLE 1

MATRIX OF RECOMMENDATIONS FOR INSTALLING MARKED CROSSWALKS AND OTHER NEEDED PEDESTRIAN IMPROVEMENTS

Roadway Type (number of travel lanes and median type)	Vehicle ADT ≤ 9,000			Vehicle ADT > 9,000 to 12,000			Vehicle ADT > 12,000 to 15,000			Vehicle ADT > 15,000		
	Speed Limit*											
	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)
Two lanes	C	C	P	C	C	P	C	C	N	C	P	N
Three lanes	C	C	P	C	P	P	P	P	N	P	N	N
Multilane (four or more lanes with raised median)**	C	C	P	C	P	N	P	P	N	N	N	N
Multilane (four or more lanes without raised median	C	P	N	P	P	N	N	N	N	N	N	N

Note: Reproduced from Zegeer et al. (2005) Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations, Table 11, p. 54. These guidelines include intersection and midblock locations with no traffic signals or stop signs on the approach to the crossing. They do not apply to school crossings. A two-way center turn lane is not considered a median. Crosswalks should not be installed at locations that could present an increased safety risk to pedestrians, such as where there is poor sight distance, complex or confusing designs, a substantial volume of heavy trucks, or other dangers, without first providing adequate design features or traffic control devices or both. Adding crosswalks alone will not make crossings safer, nor will they necessarily result in more vehicles stopping for pedestrians. Whether or not marked crosswalks are installed, it is important to consider other pedestrian facility enhancements (e.g., raised median, traffic signal, roadway narrowing, enhanced overhead lighting, traffic-calming measures, curb extensions), as needed, to improve the safety of the crossing. These are general recommendations; good engineering judgment should be used in individual cases for deciding where to install crosswalks.

* Where the speed limit exceeds 64.4 km/h (40 mph), marked crosswalks alone should not be used at unsignalized locations.

** The raised median or crossing island must be at least 1.2 m (4 ft) wide and 1.8 m (6 ft) long to serve adequately as a refuge area for pedestrians, in accordance with *MUTCD* and AASHTO guidelines.

ADT = Average daily traffic.

C = Candidate sites for marked crosswalks. Marked crosswalks must be installed carefully and selectively. Before installing new marked crosswalks, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review may be sufficient at some locations, while a more in depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, and other factors may be needed at other sites. It is recommended that a minimum utilization of 20 pedestrian crossings per peak hour (or 15 or more elderly or child pedestrians) be confirmed at a location before placing a high priority on the installation of a marked crosswalk alone.

P = Possible increase in pedestrian crash risk may occur if crosswalks are added without other pedestrian facility enhancements. These locations should be closely monitored and enhanced with other pedestrian crossing improvements, if necessary, before adding a marked crosswalk.

N = Marked crosswalks alone are insufficient, since pedestrian crash risk may be increased by providing marked crosswalks alone. Consider using other treatments, such as traffic-calming treatments, traffic signals with pedestrian signals where warranted, or other substantial crossing improvement to improve crossing safety for pedestrians.

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compared with unmarked crosswalks at similar locations. However, on multilane roads with traffic volumes above about 12,000 vehicles per day, a marked crosswalk alone was associated with higher pedestrian crash rates than similar locations with no marked crosswalks.

Table 1 reproduces a matrix from the FHWA study, with guidelines on the number of lanes, volumes, and speed limits to guide considerations for implementing crosswalks. The guidelines further offer some suggestions for additional treatments to consider for locations that fall into the P (possible increase in crashes may occur if crosswalks are used without other improvements) or N (marked crosswalks alone are insufficient) categories in the matrix. The report indicates that engineering assessment and judgment is still required before marking any crosswalk, as conditions such as sight distance or populations using the crosswalk may vary from one location to another.

For example, the study also found that older pedestrians had higher crash involvement relative to their crossing exposure. In locations with significant older pedestrians, as well as school children or other special populations, the study cautions that treatments may need to be adjusted accordingly. There may be other local factors that can be diagnosed only from assessments of local data and through site evaluations such as a road safety audit.

The study recommends that marked crosswalks alone (i.e., without traffic-calming treatments, traffic signals and pedestrian signals when warranted, or other substantial crossing improvement) are insufficient (N category) and should not be used under the following conditions:

- Where the speed limit exceeds 40 mph (64.4 km/h),
- On a roadway with four or more lanes without a raised median or crossing island that has (or will soon have) an average daily traffic (ADT) of 12,000 vehicles or greater, or
- On a roadway with four or more lanes with a raised median or crossing island that has (or soon will have) an ADT of 15,000 or greater.

The report goes on to highlight some of the types of additional improvements that may help make uncontrolled crossings safer on higher-volume, multilane roads. The findings from the FHWA report are not intended to deter agencies from placing crosswalks at currently uncontrolled locations on multilane, higher-speed, higher-volume roads where pedestrians need to cross, but to carefully assess the location through engineering studies and, if a crossing is needed, to consider what treatments should be used to make it a safe one.

See the case example description of Seattle, Washington's Pedestrian Crosswalk Inventory and Improvement Program in chapter five. Seattle used the guidelines developed by the FHWA crosswalk study to assess all of the city's midblock/uncontrolled crosswalks and develop a treatment implementation plan. Also, see how the District of Columbia adapted the guidance from this study for its lower speed conditions and identified appropriate treatments to provide crossing enhancements for different types of streets.

TCRP 112/NCHRP 562: Improving Pedestrian Safety at Unsignalized Crossings (Fitzpatrick et al. 2006a)

Available at http:/onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_562.pdf

This study focused in particular on traffic control devices at unsignalized crossings. The study had two main objectives:

(1) to recommend selected engineering treatments to improve safety for pedestrians crossing high-volume, high-speed roadways at unsignalized intersections, in particular those served by public transportation; and

(2) to recommend modifications to the *Manual on Uniform Traffic Control Devices for Streets and Highways* (*MUTCD*) pedestrian traffic signal warrant. (Fitzpatrick et al. 2006a)

The guide does not cover school crossings. As suggested, the focus of this study was on traffic control devices, not design treatments. The study collected information on pedestrian volume, street crossing width, and traffic volume and speed and examined four possible crossing treatment categories: marked crosswalk; enhanced, high-visibility or "active when present" devices; red signal/warning device or warning beacon device [primarily pedestrian hybrid beacons (PHBs) and rectangular rapid flash beacons (RRFBs)]; and conventional traffic control signals. Although significant additional research on the effects of PHBs and RRFBs has been conducted by these and other authors since this publication, there are still valuable insights that agencies may want to consider when weighing whether to use signs, signals, and beacons such as PHBs and RRFBs.

The inputs into the study and summary of ongoing research needs were developed through a review of literature, surveys of practitioners and pedestrians, assessments of pedestrian crossing designs, assessment of current pedestrian signal warrants, and additional research including field studies of pedestrian and motorist behaviors such as pedestrian walking speeds and motorist yielding.

Among other findings from practitioners, the surveys found that across agencies,

- A wide variety of treatments were being used,
- Local agencies were more apt to experiment with innovative treatments and to seek modifications to current warrant requirements than were states,

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- Practitioners were concerned that traffic signal warrants then in place were too high to meet,
- Treatment effectiveness varied by environment, and
- Some practitioners interviewed at the time interpreted the findings from FHWA's *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations* report recommendations as supporting a "mark versus do not mark" decision rather than a "mark versus more substantial treatment" decision.

Interviews with pedestrians revealed that the most common pedestrian concerns were

- Unpredictability of motorists, in particular whether they will stop or yield at marked crosswalks;
- Traffic volume (particularly turning traffic); and
- Vehicle speeds.

Pedestrians also typically felt safer with greater levels of vehicle control (i.e., traffic signals or red signal/beacon devices compared with warning beacons and marked crosswalks alone) (Fitzpatrick et al. 2006a).

Other findings that could be considered regarding the placement (and enhancement) of crossings were the distances pedestrians were willing to go out of their way to cross at a signalized intersection. The authors reported on these findings in the web-only companion document (Fitzpatrick et al. 2006b). When pedestrians at a midblock crossing were asked "if this crossing was not here, would you walk to the next intersection (point to intersection of interest)?," about half of pedestrians indicated they would walk to the signalized intersection when the nearest was 200 ft away; and only about 25% of the respondents would walk to the nearest signalized intersection when it was located 550 ft (168 m), 950 ft (290 m), or 1,000 ft (305 m) from where they were crossing. At one site, a much higher percentage, 65% of pedestrians interviewed, indicated that they would be willing to walk to a signalized location 600 ft away, but at that site there were six lanes and high speed and high volume of traffic, and the only treatment at the midblock crossing was a marked crosswalk (Fitzpatrick et al. 2006b).

New investigations were also conducted into the effects of three general types of treatments, including (1) high-visibility devices, which included high-visibility crosswalk markings and fluorescent yellow-green pedestrian crossing signs, in-street pedestrian crossing signs, and pedestrian crossing flags as well as other devices (in-pavement flashing crosswalk lights) and signs that attempted to draw attention to the crosswalks; (2) "active when present" warning-type flashing beacons; and (3) red signal/beacons [traffic signals, pedestrian hybrid beacons (HAWK signals) and, half signals]. In addition, the study included sites with median crossing islands. Six measures of effectiveness for pedestrian treatments were considered, including motorist compliance (yielding/stopping for pedestrians when required to do so), pedestrian delay, pedestrian compliance with the crosswalk, pedestrian visual search, pedestrian–motor vehicle conflicts, and pedestrian walking speed.

Results of evaluations of the specific devices are reported in the detailed literature review and summarized in the relevant treatment sections in chapter four, along with many other studies. However, in general, Fitzpatrick et al. (2006a) concluded that motorist crosswalk compliance was consistently quite high—94% or above at all sites tested—with an average of 97% or higher for each of the signal control/beacon-type devices. Results were more mixed for the high-visibility devices and warning flashing-when-activated types of beacons (yellow-only indicators). The study also determined that compliance rates for high-visibility and "flashing when present" types of devices were always better for any of the treatments used on two-lane roadways compared with four-lane roadways. (None of the signal treatments in the study were applied to two-lane streets.) Flags, pedestrian median islands, and high-visibility markings all had higher compliance rates on lower-speed roadways.

Based on all of their findings, including the inputs from practitioners and pedestrians, and other research available at the time, the researchers developed Guidelines for Pedestrian Crossing Treatments, as Appendix A to the report. This guidance splits primarily along speed limits (at 35 mph), with additional worksheets providing assistance for assessing roads with limits of greater than 35 mph, and another for streets with lower speed limits (see flowchart reproduced in Figure 3). The report developed recommendations for new guidelines for various pedestrian crossing measures. An Excel worksheet was also developed that combines Worksheets 1 and 2 from Appendix A of the report, and allows practitioners to enter inputs to identify recommended treatments based on the recommendations developed in the study. (The Excel worksheet for pedestrian crossing treatments selection guidance from *TCRP Report 112 / NCHRP Report 562* can be accessed at http://www.pedbikeinfo.org/data/library/details.cfm?id=4949.)

Countermeasure Selection Tools

There are also a number of resources available to identify potentially appropriate countermeasures, once locations needing improvement have been identified. The Pedestrian and Bicycle Clearinghouse regularly updates information on pedestrian countermeasure evaluations and case examples, and reviews new evidence and practices through its White Paper series and other resources. In addition, the PEDSAFE and BIKESAFE countermeasure selection tools were updated (in 2013 and 2014, respectively) with new countermeasures and case examples. PEDSAFE may also be used proactively to address more systemic goals and performance objectives.

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Inputs for PEDSAFE Countermeasure Selection Tool

1. In what type of area is the roadway located?
2. What is the functional class of the roadway?
3. Is the problem at an intersection or midblock (roadway segment) location?
4. What is the vehicle volume at this location [expressed in terms of average daily traffic (ADT) for the primary roadway]?
5. Is vehicle speed low or high?
6. What is the number of through travel lanes (both directions)?
7. Is a traffic signal present, being considered, or not an option?
8. Is the roadway on a transit line/route (bus or rail)?
9. Is the roadway in a school zone or a school crossing?
10. Does the roadway contain a railroad crossing?
11. Is the roadway in a work zone?

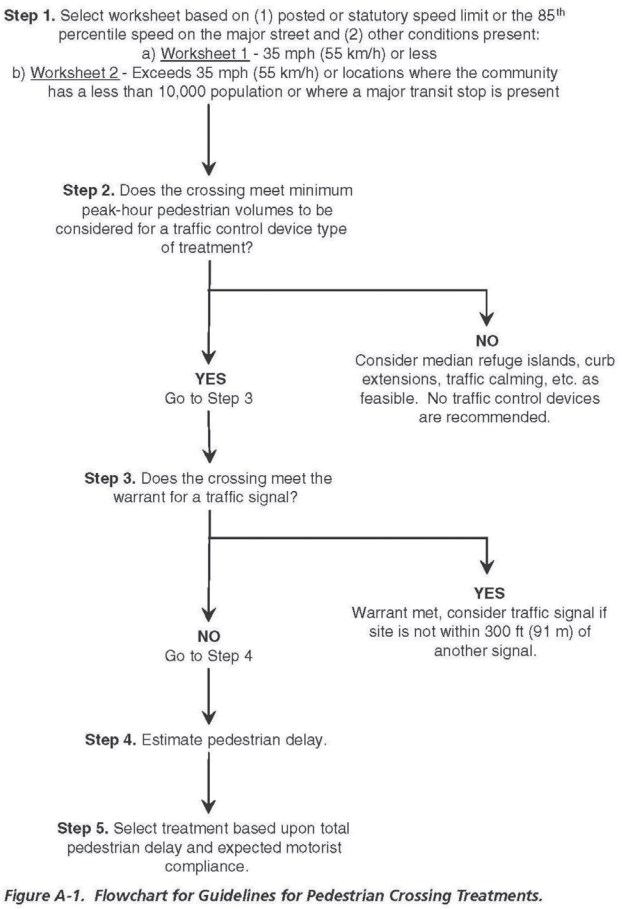


Figure A-1. Flowchart for Guidelines for Pedestrian Crossing Treatments.

FIGURE 3 Flowchart for Guidelines for Pedestrian Crossing Treatments at Unsignalized Crossings. *Source*: Figure A-1 in Fitzpatrick et al. (2006a).

PEDSAFE: Pedestrian Safety and Countermeasure Selection System (Zegeer et al. 2013)

Available at http:/pedbikesafe.org/PEDSAFE/index.cfm

Once a location or a systemic risk pattern or approach to treatment has been identified, the PEDSAFE countermeasure selection system can be used to help identify potential countermeasures for any type of crossing location.

PEDSAFE can be used to identify potential treatments for particular crash-type problems through the crash-type matrix or countermeasure selection tool, or in a more systemic approach using safety performance objectives or roadway descriptors or both in the objectives matrix or selection tool. This interactive Internet-based resource provides descriptions of 67 engineering, education, and enforcement countermeasures (Zegeer et al. 2013). The selection tool allows the user to input characteristics of the street or intersection of interest to help narrow down the potentially appropriate countermeasures for the context or crash-type pattern.

A companion document to PEDSAFE summarizes the existing safety research: *Evaluation of Pedestrian-Related Roadway Measures: A Summary of Available Research,* published by the Pedestrian and Bicycle Information Center (PBIC) (Mead et al.) in April 2014. (This document was also used as a primary source for this synthesis, as previously mentioned.)

PEDSAFE likely provides the most up-to-date research and expert-based guidance to practitioners for an initial identification of potentially appropriate countermeasures. In addition, PEDSAFE includes numerous case studies describing how agencies have used various treatments to help address pedestrian safety problems. Each countermeasure description also provides a link to the safety research summary provided in the companion document.

*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashe*s (2013)

Available at http:/www.pedbikeinfo.org/collateral/PSAP%20Training/gettraining_references_pedToolboxofCountermeasures2013.pdf

This toolbox documents 30 signalization, geometric, sign, marking, and operational measures that have crash-based estimates of effectiveness for pedestrian safety. The publication was last updated in February 2013 for FHWA. This publication resulted from reviews of crash-based evaluations of a wide range of roadway and engineering countermeasures related to enhancing pedestrian safety. The effect estimates are presented in the form of crash modification factors (CMFs), and the study references are provided. The signal-related measures that have safety benefits—that is, a CMF estimate of less than 1—include the following:

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- Exclusive pedestrian signal phasing
- Improved signal timing, including increasing pedestrian walking period
- Replacing traditional pedestrian signals with those with countdown timers
- Modifying signal phasing to include a leading pedestrian interval
- Removing unwarranted signals on one-way streets
- Converting permissive or permissive/protected left-turn signal phasing to protected-only phasing
- Using the pedestrian hybrid (HAWK) signal
- Installing traffic and pedestrian signals when warranted.

Geometric treatments that were found to have a significant benefit to pedestrian crashes include the following:

- Converting unsignalized intersections to a roundabout
- Installing a pedestrian underpass or overpass
- Installing raised medians at unsignalized crossings
- Installing a raised pedestrian crossing
- Installing raised refuge islands (pedestrian median islands)
- Installing sidewalks or paved shoulders
- Narrowing the roadway cross-section from four lanes to three lanes (two through lanes with a center turn lane).

Sign, marking, and operational improvements having beneficial crash effects include:

- Adding intersection lighting (applies to nighttime crashes)
- Adding roadway section lighting (applies to nighttime crashes)
- Improving pavement friction
- Increasing enforcement
- Prohibiting right turns on red
- Prohibiting left turns
- Restricting parking near intersections (to off street)
- Providing high-visibility crosswalks
- Providing high-visibility crosswalks in school zones.

Estimates documented in this toolbox are included in the Tables of Countermeasures Effectiveness in chapter four.

Other Pedestrian Safety Resources

Safe Routes to School Guide (Pedestrian and Bicycle Information Center, et al. 2015)

Available at http:/www.saferoutesinfo.org/

The *Safe Routes to School Guide* provides support for communities interested in increasing opportunities for children of all abilities to safely walk and bicycle to school. The Safe Routes to School (SRTS) concept began in Denmark in the 1970s. In 1997, the New York City borough of the Bronx, and the state of Florida both introduced pilot programs. In 2000, the U.S. Congress funded two SRTS pilot projects through the National Highway Traffic Safety Administration. Many other grassroots SRTS efforts began throughout the United States within a year of the launch of the pilot programs. The federal-aid Safe Routes to School Program was established by Congress in 2005 through comprehensive transportation legislation. Subsequent transportation legislation, including Moving Ahead for Progress in the 21st Century (MAP 21) passed in 2012 and makes SRTS activities eligible to compete for funding alongside other pedestrian and bicycle programs as part of a new program called Transportation Alternatives (Pedestrian and Bicycle Information Center, et al. 2015).

The *Safe Routes to School Guide* (online) summarizes current recommended practices, mainly in regard to processes. However, it also provides guidance and numerous case studies demonstrating engineering treatments that have been implemented in school walking areas and crossings (http:/guide.saferoutesinfo.org/case_studies/engineering.cfm). The guide outlines five principles for engineering solutions to improving the built environment for school-age pedestrians:

- The physical environment often determines whether many children walk or bicycle to school. To safely walk or bicycle to school along a street or separate path, or to cross a street along the way, children need well-designed, well-built, well-maintained, and accessible facilities.
- Accessibility is required. An important aspect of enabling children with disabilities to walk and bicycle to school is provision of accessible infrastructure.
- The relationship of school buildings to sidewalks and street crossings can determine the level of comfort and safety a pedestrian or bicyclist experiences. All elements are interconnected: the street is connected to the sidewalk and the sidewalk is connected to the building. Getting this relationship right is critical.
- Focus first on implementing easy and low-cost solutions first to build momentum. Then identify and prioritize longer-term improvement needs.
- Engineering treatments are matched to the type of problem (Pedestrian and Bicycle Information Center, et al. 2015).

The guide also provides information on school route maps; understanding and improving the areas immediately around the school, along the school route, and at street crossings (see Crossing the Street page at http:/guide.saferoutesinfo.org/engineering/crossing_the_street.cfm); slowing down traffic; and links to other resources.

The guidance is developed from existing research, although many treatments lack specific evaluation in school

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areas. However, with the assistance of examples and case examples, the guidance is tailored to be appropriate for implementation in school walking routes, school zones, and other areas near schools. In addition, the guide notes that newer treatments, such as PHBs and RRFBs or raised intersections, may be tried in a community first in a school zone, where child safety is a prime concern. As such treatments gain acceptance, they may be used in other locations (Seth LaJeunesse, National Center for Safe Routes to School at the University of North Carolina Highway Safety Research Center, personal communication, Aug. 20, 2015).

NCHRP Report 500, Volume 10: A guide for reducing collisions involving pedestrians (Zegeer et al. 2004)

Available at http:/onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v10.pdf

AASHTO, in cooperation with FHWA, sponsored a series of reports (Report 500 series) to help state transportation agencies in safety planning and implementation. The series was designed to help agencies develop plans and strategies to address key road safety problems to help meet their strategic safety objectives. The guide to reduce pedestrian crashes was released in 2004 (Zegeer et al. 2004). Although the report is somewhat dated in terms of evidence regarding traffic control devices and other treatments, it provides guiding safety principles, as well as significant information on considerations for applications of comprehensive treatments (e.g., engineering, enforcement, and education and public information) that are still relevant.

In addition to planning guidance, the report outlines four major objectives for reducing collisions between motor vehicles and pedestrians. The four strategies include the following:

1. Reduce pedestrian exposure to vehicular traffic.
2. Improve sight distance and visibility for motor vehicles and pedestrians.
3. Reduce vehicle speed.
4. Improve pedestrian and motorist safety awareness and behavior.

Proven, tried, or experimental but promising strategies are outlined under each of the four objectives. The strategies for objective 1—Reduce pedestrian exposure to vehicular traffic—include the following:

- Providing sidewalks and curb ramps and protective barriers as needed (proven);
- Providing median islands and raised medians (proven);
- Adding or upgrading pedestrian signals, such as adding right-turn-on-red restrictions, pedestrian countdown signals (PCSs), and automated pedestrian detection (proven, tried, and experimental, respectively);
- Providing grade-separated crossings (proven); and
- Restricting or reducing traffic (proven and tried, respectively).

Cautions, considerations, and keys to success are also described for each treatment. For example, continuous medians may not be appropriate for all circumstances and may sometimes result in higher speeds by reducing friction along sections.

Strategies under objective 2—Improve sight distance and visibility for motor vehicles and pedestrians—include providing crosswalk enhancements (proven and tried). Crosswalk enhancements encompass a variety of engineering and enforcement measures, including improving conspicuity, enforcement campaigns, school route improvements, narrowing measures, installing and upgrading traffic signals, pedestrian islands, and others.

The purpose of adding crosswalks at appropriate locations is to guide pedestrians to the best location to cross, with enhancements such as high-visibility markings, raised crosswalks, lighting, and other physical roadway enhancements that reinforce the crosswalk or reduce vehicle speeds or both. This report also summarizes the FHWA crosswalk study findings, with appropriate cautions about not using only markings in the absence of other improvements on multilane, high-volume, higher-speed roads.

Other measures mentioned include

- Crosswalk illumination/lighting (proven for nighttime crashes);
- Eliminating visual obstructions/screening (tried); and
- Signals to alert motorists that pedestrians are crossing (tried and experimental at the time), and improved reflectorization/conspicuity of pedestrians (tried).

Measures identified under objective 3—Reduce vehicle speed—include road-narrowing measures through lane reductions, and lane width reductions by extending sidewalks or landscaped areas through curb extensions (tried). Since publication of this report, there is evidence that reductions in numbers of lanes through road diets often result in reduced traffic speeds and reduced crashes. Other measures to reduce vehicle speed include

- Traffic-calming measures for sections such as serpentine streets and chicanes, chokers or roadway narrowing through a portion of a section, speed tables and humps, and low-speed shared streets (tried; e.g., Woonerfs or living streets);
- Raised traffic-calming measures to lower speeds and crashes (proven); and

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- Narrowing measures such as bulb-outs/curb extensions (tried).

For intersections, measures include
- Mini traffic circles, such as those widely used in Seattle, which had been found to significantly reduce crashes there (tried);
- Speed tables/raised crosswalks and raised intersections, which in some cases had improved motorist yielding to pedestrians (proven);
- Roundabouts (tried);
- Curb radius reductions and curb extensions, expected to reduce turning speeds at intersections (tried); and
- School route improvements, such as design of the pick-up/drop-off areas, parking restrictions, school warning signs and school zone speed limits, walking route maps, and adult crossing guards (tried).

Educational and outreach measures are discussed in objective 4—Improve pedestrian and motorist safety awareness and behavior—because the approach taken by these guides is intended to be comprehensive. However, these measures are not covered in depth by this synthesis.

Other sources include regularly updated information on countermeasures safety effects and proven countermeasures. Additional sources that may aid pedestrian safety practitioners include those described below.

FHWA's Proven Safety Countermeasures Bulletins and Related Guidance Documents (FHWA 2015)

Available at http:/safety.fhwa.dot.gov/provencountermeasures/

The most relevant pedestrian safety measures currently included among FHWA's proven countermeasures are road diets, medians and pedestrian crossing islands, pedestrian hybrid beacons, and roundabouts. Estimates for crash effects are described in the countermeasures descriptions in chapter four and the literature review.

Crash Modification Factors (CMF) Clearinghouse

Available at http:/www.cmfclearinghouse.org/

The CMF Clearinghouse contains a regularly updated searchable database of countermeasures with documented crash effects, including CMFs that were incorporated into the *Highway Safety Manual* (2010). The CMFs are quality rated using a star system that incorporates study design; sample size including years of data, diversity, and number of sites; size of the standard error compared with the CMF; control for potential sources of bias; and data sources (number and diversity of states). The star rating, standard errors, and descriptions of the crash types, road types, and area types applicable to the CMF provide information to help users determine the potential validity of the CMF to their situation.

As new pedestrian crash (and other) CMFs are developed, they will be added to the clearinghouse.

Countermeasures That Work (Goodwin et al. 2015)

Countermeasures That Work describes major strategies and countermeasures and their effectiveness, costs, and implementation issues that state highway safety offices and their partners can use to help select effective behavioral countermeasures for traffic safety problems. This reference work covers nine major topic areas, including pedestrians, bicycles, and speeding and speed management (Goodwin et al. 2015).

Speed Management Toolkit (see Thomas et al. 2015b)

Available at http:/safety.fhwa.dot.gov/speedmgt/ref_mats/docs/speedmanagementtoolkit_final.pdf

Speed is an important consideration for pedestrian safety, with risk for adult pedestrians rising rapidly with impact speeds above approximately 25 mph (Rosén and Sander 2009). The *HSM* (2010) provides CMF estimates for total fatal and total injury crash effects expected for changes in average operating speed for a road. Because pedestrians are more vulnerable to injury than motor vehicle occupants when involved in a crash, reductions in speed might be expected to yield even greater safety benefits to pedestrians than for total crashes as predicted by the HSM.

FHWA's *Speed Management Toolkit* for speed-related countermeasures (Tables 9 and 10 of the toolkit) reproduces the estimates of total (not pedestrian) fatal and injury crash effects from the *HSM* (see Thomas et al. 2015b). Other speed- and crash-reducing countermeasures are also described in this toolkit, and companion documents provide examples of speed management action plans. Also see other FHWA speed management resources, including *Engineering Speed Management Countermeasures: A Desktop Reference of Potential Effectiveness in Reducing Speed* (2014) for tables of speed and crash-reduction effects for traffic-calming and other measures from prior studies.

Methods and Practices for Setting Speed Limits (Forbes et al. 2012)

Available at http:/safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa12004/

This report discusses four methods for setting speed limits, including an injury minimization approach that is commonly used in Vision Zero countries.

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New York City, a Vision Zero city, has taken an assertive approach to managing speed, described in the case example in chapter five.

Design Resources

Although many of the previously mentioned resources describe design or geometric-based countermeasures and also touch on the importance of good design generally, the resources described here are the key national resources available to guide pedestrian facility design.

If good design principles are followed, including providing adequate separation of pedestrians from motorized traffic or designing for slower motor vehicle speeds, safety would be improved for both pedestrians and other users (Zegeer et al. 2004, p. V-2; NACTO n.d.). Good design may reduce the need for additional countermeasures to solve problems in the future.

Design Resource Index (Pedestrian and Bicycle Information Center et al. 2015)

Available at http:/www.pedbikeinfo.org/planning/facilities_designresourceindex.cfm

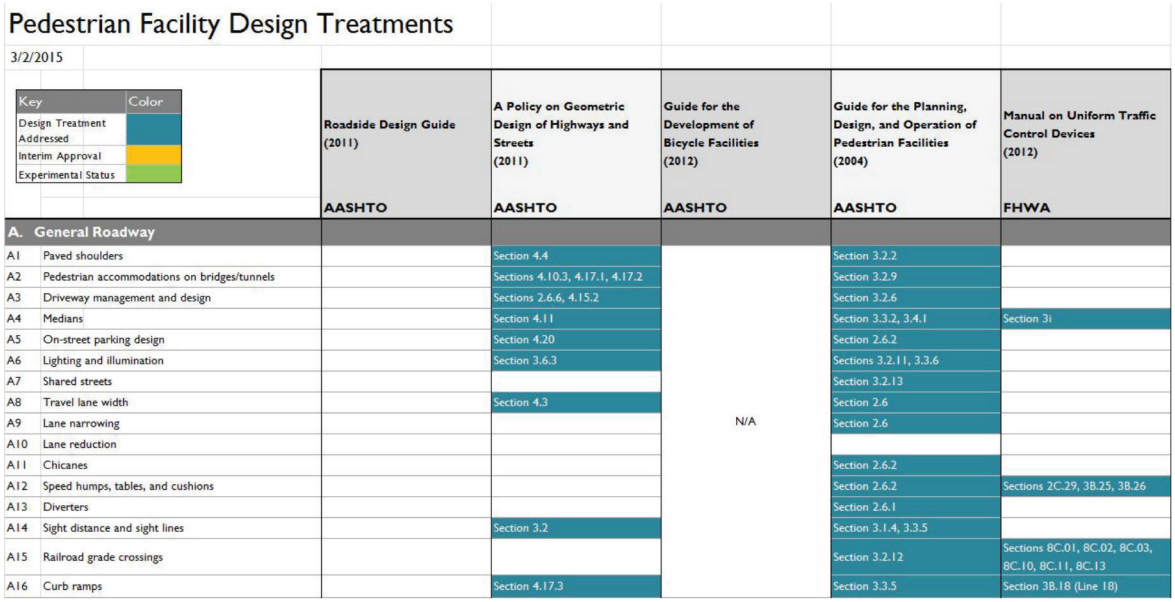
The Pedestrian and Bicycle Information Center released an index prepared for FHWA that documents specific sections or page numbers where pedestrian-related design and traffic control features are treated in key national manuals (see Figure 4 for an example of some of the listings). There are also indices for on-street bicycle facilities and for shared-use paths, as well as a master list.

The following nine resources (plus two other bicycle-oriented resources) were reviewed for the design index, and have information on pedestrian facilities listed in the Index:

- *Roadside Design Guide*—AASHTO (2011)
- *A Policy on Geometric Design of Highways and Streets*—AASHTO (2011)
- *Guide for the Planning, Design, and Operation of Pedestrian Facilities*—AASHTO (2004)
- *Manual on Uniform Traffic Control Devices* (*MUTCD*)—FHWA (2009, with 2012 revision)
- *Designing Walkable Urban Thoroughfares*—ITE and Congress for the New Urbanism (2010)
- *Recommended Design Guidelines to Accommodate Pedestrians and Bicycles at Interchanges*—ITE (2014)
- *Traffic Control Devices Handbook*—ITE (2013)
- *Urban Street Design Guide*—NACTO (2013)
- Draft Guidelines: PROWAG, Shared Use Path Guidelines—U.S. Access Board, as of 2014 (Pedestrian and Bicycle Information Center, Design Resource Index n.d.)

The index makes it much easier for practitioners to consult and cross-reference information from the most important guidance resources regarding particular designs or devices.

PROWAG provides the most up-to-date guidance for accessible pedestrian facilities and crossings, although still in draft form. Once adopted in present or modified form, PROWAG guidance will provide required standards for accessible facilities.



Pedestrian Facility Design Treatments

3/2/2015

Key	Color
Design Treatment Addressed	
Interim Approval	
Experimental Status	

		Roadside Design Guide (2011) AASHTO	A Policy on Geometric Design of Highways and Streets (2011) AASHTO	Guide for the Development of Bicycle Facilities (2012) AASHTO	Guide for the Planning, Design, and Operation of Pedestrian Facilities (2004) AASHTO	Manual on Uniform Traffic Control Devices (2012) FHWA
A.	**General Roadway**					
A1	Paved shoulders		Section 4.4		Section 3.2.2	
A2	Pedestrian accommodations on bridges/tunnels		Sections 4.10.3, 4.17.1, 4.17.2		Section 3.2.9	
A3	Driveway management and design		Sections 2.6.6, 4.15.2		Section 3.2.6	
A4	Medians		Section 4.11		Section 3.3.2, 3.4.1	Section 3i
A5	On-street parking design		Section 4.20		Section 2.6.2	
A6	Lighting and illumination		Section 3.6.3		Sections 3.2.11, 3.3.6	
A7	Shared streets				Section 3.2.13	
A8	Travel lane width		Section 4.3		Section 2.6	
A9	Lane narrowing			N/A	Section 2.6	
A10	Lane reduction					
A11	Chicanes				Section 2.6.2	
A12	Speed humps, tables, and cushions				Section 2.6.2	Sections 2C.29, 3B.25, 3B.26
A13	Diverters				Section 2.6.1	
A14	Sight distance and sight lines		Section 3.2		Section 3.1.4, 3.3.5	
A15	Railroad grade crossings				Section 3.2.12	Sections 8C.01, 8C.02, 8C.03, 8C.10, 8C.11, 8C.13
A16	Curb ramps		Section 4.17.3		Section 3.3.5	Section 3B.18 (Line 18)

FIGURE 4 Image of partial listing of designs and coverage in guidebooks for pedestrian facility design in Design Resource Index, developed by the PBIC for FHWA. *Source*: PBIC (2015).

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Of the other design guides mentioned earlier, the AASHTO guides are widely used by state and local jurisdictions. The *MUTCD* is a key resource for most agencies.

NACTO's Urban Street Guide (n.d.)

This guide bears additional mention because a number of cities, in particular, are reporting use of this guide. See the Complete Streets section in chapter two for information on FHWA's policy statement sanctioning use of NACTO and other (non-AASHTO) design guides.

The *Urban Street Design Guide* articulates a Complete Streets vision, principles, and approaches to design, and provides design examples for how to make different types of streets and intersections function safely for pedestrians. The guide articulates "design controls" that counter approaches from the past that were based largely on moving cars efficiently through rural highways, but have had unforeseen consequences on traffic speed and safety when applied in urban areas (NACTO n.d.).

Guidance Focusing on Special Types of Crossings or Populations

ITE, NCHRP, TCRP, FHWA, and other agencies have produced many reports over the years focusing on pedestrian safety, traffic calming, and particular engineering challenges.

Several design guides focus on unique types of crossings or special populations. The following three reports were developed to provide guidance regarding crossings at interchange ramps, of rail/transit lines, and to provide guidance on installation of accessible pedestrian signals for visually impaired persons. Many others are also available, and state and local agencies often create their own design guides.

- *Recommended Design Guidelines to Accommodate Pedestrians and Bicycles at Interchanges: An ITE Recommended Practice* (Mitman and Ridgway 2015)

This guide, included in the Design Index, fills an important gap in shared knowledge on designing for pedestrians and bicyclists at interchanges. A number of the same treatments described in this synthesis are recommended for use by the guide. General design principles and current recommended practices were identified through a series of workshops involving ITE members (Mitman and Ridgway 2015). Some of the principles include

- Minimizing the number of conflict points;
- Slowing ramp speeds until past crosswalks;
- Placing crosswalks before the location where drivers will be looking for conflicting traffic from the left;
- Highlighting conflict areas with high-visibility markings, lighting, and so forth; and
- Using advance stop/yield lines.

A number of design examples for different scenarios are also provided.

- *TCRP Report 175: Guidebook on Pedestrian Crossings of Public Transit Rail Services* (Fitzpatrick et al. 2015)

Available at http:/www.tcrponline.org/PDFDocuments/tcrp_rpt_175.pdf

This guidebook, too recent to be included in the Design Index, assesses current practices in pedestrian rail treatments, and discusses issues associated with pedestrians (including special groups such as older pedestrians, child pedestrians, and people with disabilities) crossing public rail transit lines (Fitzpatrick et al. 2015).

Treatments discussed in the guidebook include channelization, barriers, design, traffic control treatments (signs, signals, and warnings), other infrastructure including crossing gates and audible warning devices, and operational measures such as reduced train speed and outreach programs.

There is also information on railroad crossings in PEDSAFE, which links to additional resources.

- *NCHRP Web-Only Document 117A: Accessible Pedestrian Signals: A Guide to Best Practices* (Harkey et al. 2007)

Available at http:/www.apsguide.org/

This web-only NCHRP publication addresses most-effective practices for accessible pedestrian signals. The web content was developed from the report for NCHRP research project 3-62. The guide from this study is also available for download in pdf form from TRB's online publications (Harkey et al. 2007).

CURRENT PRACTICES

In addition to reviewing the literature, the survey of states and local jurisdictions asked about practices and processes currently being used to prioritize pedestrian crossing improvements. These practices are summarized in the next three sections.

Identifying Locations in Need of Improvement

A number of different processes are used in conjunction with various types of programs and funding to identify locations in need of pedestrian crossing improvements.

General Processes Used by States to Identify Locations

Most states described multiple methods and processes, project types, and stakeholders that are used to identify locations

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in need of pedestrian crossing improvements. These processes often included analysis of crash data and complaints, which are considered reactive processes—that is, they react to existing problems. A few states and local agencies are also using, or interested in using, more proactive systematic approaches to identifying locations in need of crossing improvements. About half of states indicated use of crash data, with such data playing a major role for many. Several states have developed crash-based screening processes or use processes similar to those for all types of crashes. RSAs and scoping/plan reviews are also used to help prioritize locations or opportunities by some state and local jurisdictions.

In its survey response, California's Department of Transportation (Caltrans) described a screening process:

> We first look at marked crosswalks across uncontrolled roadways where the speed limit exceeds 40 mph and the roadway has four or more lanes of travel and an ADT of 12,000 vehicles per day or greater.
>
> We also do a screen of fatal or injury collisions to look independently for pedestrian fatalities or injuries and investigate the locations that meet the parameters of the screen.

Several states rely mostly or partly on local governments to initiate the process and identify specific needs, at least for part of the network. In Virginia, a twofold process is used, as described in the state's survey response:

> For Cities who maintain their roadways, we rely on their inventory, crash, and volume information. They may submit for HSIP [Highway Safety Improvement Program] funds based on the risk based documentation of purpose and need. For the VDOT [Virginia DOT] maintained system (~85% of centerline miles) our network screening analysis for bike and ped crashes is done at the county route segment (length) level. A jurisdiction ranked listing of injury crash counts by severity and percentile range color coded maps . . . is generated each year. VDOT districts are then asked to define specifics for identifying and prioritizing safety improvements, using local knowledge and input, field reviews, and more detailed crash analysis when warranted.

Oregon also described its process in its survey response:

> We don't have a formal process. Needs are evaluated on a project-by-project basis. Public and local agencies request crossing improvements frequently. If money is available and the location meets the criteria in the *Oregon Traffic Manual*, a crossing is provided.

About 15% of states indicated that they consult with local jurisdictions on transportation, multimodal, pedestrian, or land use plans when they exist; several states, including Arkansas, North Carolina, and Oregon, have statewide pedestrian plans that incorporate public input. Arkansas indicated the following:

> One of the ways we identify these locations is through our Statewide Pedestrian Master Plan. It identifies 31 recommended projects across the state. These improvements were identified through a review of existing conditions; GIS analysis of safety, connectivity, mobility, and pedestrian-oriented populations considerations; and stakeholder input (from the public, DOT staff, and other agency staff).

Florida DOT (FDOT) indicated that many locations are identified by public requests, which initiate an engineering evaluation: "FDOT has also systematically identified the top 20 pedestrian crash locations in each district, with the focus of reducing crashes at those locations." FDOT currently bases prioritization on safety conditions including crash history and *MUTCD* warrants, but is working toward a "context-based system to supplement crash-based and warrant based."

North Carolina DOT said the following:

> Candidate Pedestrian Crossing Safety locations are identified much like traditional safety location efforts—through a wide array of both information/evidence-driven corrective (historical black spot and network screening) mechanisms and approaches, as active project (new location and retrofit) efforts, general systemic (system modernization/infrastructure and connectivity improvement) efforts, community complaints/concerns and perceived risk, Pedestrian Plan-identified needs/deficiencies, safety audits/review recommendations, development activities, and general statewide efforts aimed at improving modal accommodations and accessibility.

In addition, North Carolina mentioned a wide variety of projects, programs, and agencies that participate in their efforts from the initial identification stage through programming and evaluation.

Pennsylvania DOT uses a Bicycle & Pedestrian Checklist to assess bicycle and pedestrian needs on all construction projects, but the checklist does not yet apply to resurfacing projects.

Washington State DOT (WSDOT) indicated that crash evaluations and operational reviews are used for identifying potential needs, but that design criteria are also used for identification of needs. Planning documents and community requests are also used. Among the design guidance resources the state of Washington references are "Complete Streets, NACTO design guide, Context Sensitive Design, Practical Design, WSDOT design manual, and modal system plans, along with *Guide for the Planning, Design, and Operation of Pedestrian Facilities* and accessibility guidance."

General Processes Used by Local Jurisdictions to Identify Locations

Similarly, a variety of types of processes were mentioned by local jurisdictions, including these by Santa Barbara, California:

1—Locations identified in annual high collision locations

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2—Public requests for investigation

3—Locations identified as part of a plan

4—Locations identified using Safety Effects of Marked versus Unmarked Crosswalk criteria

5—Observation by Traffic Engineering or Police.

Milwaukee, Wisconsin, described the following:

1. Preliminary engineering studies associated with large-scale capital improvement projects/paving
2. Land use developments
3. Complaints or requests from citizens
4. School operations, including new facilities
5. Changes in traffic patterns
6. Control needs and types identified through MUTCD warrant analysis and local policies
7. Prioritization based on federal fund or grant availability (i.e., HSIP, Transportation Alternatives Program, and Federal Aid Paving) and city capital improvement program fund allocation
8. Political influences.

See the case example on San Francisco's data-driven approach, using crash locations and collision profiles, to identify and prioritize intersections for improvement and to aid selection of low-cost countermeasures.

Specific Tools/Methods Used by States to Identify Locations

States were also asked about which specific procedures or tools they used to identify locations in need of pedestrian crossing safety improvements. The specific types of procedures reported used most often (*frequently* or *always* used) by states include the following:

- A majority of states (83%) indicated they frequently or always review for ADA compliance, using PROWAG or ADA Accessibility Guidelines guidance.
- A majority (72%) also reported frequently or always assessing the need for pedestrian crossing improvements in conjunction with all types of projects (reconstruction, repaving, operations, and spot safety).

However, in regard to measures that would help to identify and treat existing problems,

- Half of responding state DOTs (50%) indicated that they frequently or always conduct pedestrian crash analysis to help identify locations in need of improvements , and
- Nearly half (47%) solicit and review public complaints (Table 2).

Lower percentages of states *frequently* or *always* use the other types of procedures, including the following:

- Review existing pedestrian plans—39%
- Conduct road safety audits/assessments (RSAs)—36%
- Collaborate with district or neighborhood assessments—28%
- Solicit public input for specific project needs—25%
- Perform multimodal level of service (LOS) or quality of service (QOS) assessments—5.6%
- Perform pedestrian LOS or QOS assessments—2.8%.

Table 2 summarizes the results for the states. The last column in Table 2 shows the weighted average of use of different procedures (shown in descending order) with points assigned as follows: never used = 0 points; infrequently used = 1; sometimes used = 2; frequently used = 3; and always used = 4. These results show that assessment for ADA compliance comes closest, on average, to being always used (4 = *always used*) by all states reporting. Use of pedestrian level of service or quality of service assessments was the lowest, with a weighted average of < 1 (1 = *infrequently used*). ("Unable to determine" and missing answers were excluded from the weighted average calculations; if these had been included, with an assumption of "nonuse," then the weighted averages of "use" would be considerably lower for those methods with a high missing response rate.)

A variety of other types of analyses are frequently or always used by 25% of states to identify problem crossing locations. These include review of crash histories/crash reports (two states), and crash or warrants review plus site visits (two states).

Other singular responses included analysis of pedestrian count data, analysis of pedestrian generators, priority routing for school-related projects, conducting combined pedestrian/bicycle RSAs, general road safety analysis that includes pedestrians as well as every other type of crash for patterns that can be addressed, and engineering and safety/crash investigations in response to complaints/concerns from the community and officials.

Only one state (California) mentioned using a more systemic risk assessment approach in that it "look[s] for specific roadway and operational characteristics (multilane, intersections, higher volume, higher speed)" to identify locations that may need crossing safety improvements. (It should be

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noted that only what the states indicated can be reported, and states may not have mentioned all the processes in use.)

Other methods are also used by 14% of states to gather information for identifying locations. These include gathering comments from public meetings; looking at access in and around major train stations and transit stops (Maryland); Safe Routes to School funding evaluation and plan overview (Wisconsin); other types of planning processes, including Transportation System Plans (Oregon), Strategic Highway Safety Plan collaboration (California), and fatal crash investigations.

Specific Tools/Methods Used by Local Jurisdictions to Identify Locations

There is a tendency for the local jurisdictions that responded to the survey (a select, nonrandom group) to use more procedures more often to identify locations for improvements. In particular, methods relating to planning and public input are used more often by local jurisdictions than by the states. Differences in processes and emphases between states and local jurisdictions were expected, because there are many differences in the size and scope of responsibilities, particularly with regard to planning and public input between most local jurisdictions compared with most states. The procedures used *frequently* or *always* by a majority of the local jurisdictions surveyed include the following:

- Assess the need for pedestrian crossing improvements in conjunction with all types of projects (reconstruction, repaving, operations, and spot safety)—83%
- Solicit and review public complaints—83%
- Review ADA compliance—78%
- Review existing pedestrian plans—67%
- Collaborate with district/neighborhood evaluation—56%
- Solicit public input regarding specific project needs—56%
- Conduct crash analysis—56% (Table 3).

The other methods asked about specifically are used frequently or always by fewer than half of the local jurisdictions that responded, including the following:

- Road safety audits/assessments—28%
- Multimodal level of service (LOS)/quality of service (QOS)—11%
- Pedestrian LOS/QOS—11%.

Other types of analysis, used by 22% of local jurisdictions, include the following:

- Gaps assessment (three of 18 localities)

TABLE 2
TYPES OF PROCESSES USED TO IDENTIFY LOCATIONS IN NEED OF IMPROVEMENTS—SUMMARY OF RESULTS FOR STATES

Process or Method	Proportion—Frequently (3) or Always (4)	Proportion—Sometimes (2)	Proportion—Infrequently (1) or Never (0)	Proportion—Unable to Det./No Answer	Weighted Average (excluding missing answers)[1]
Review—ADA	83.3%	8.3%	5.6%	2.8%	3.4
Review for all types projects	72.2%	19.4%	5.6%	2.8%	2.9
Crash analysis	50.0%	30.6%	19.4%	NA	2.4
Solicit/review complaints	47.2%	38.9%	11.1%	2.8%	2.5
Review existing pedestrian plans	38.9%	36.1%	19.4%	5.6%	2.3
RSA	36.1%	41.7%	19.4%	2.8%	2.2
Collaborate with district/neighborhood evaluation	27.8%	47.2%	19.4%	5.6%	2.1
Solicit public input—specific project needs	25.0%	22.2%	47.2%	5.6%	1.8
Multimodal LOS/QOS	5.6%	16.7%	61.1%	16.7%	1.4
Pedestrian LOS/QOS assessment	2.8%	13.9%	72.2%	11.1%	0.8
Other type analysis	25.0%	13.9%	16.7%	44.4%	NA
Other methods	13.9%	8.3%	8.3%	69.4%	NA

Note: Thirty-seven states responded to the question.
NA = not available.
[1] "Unable to determine" and missing answers were excluded from the weighted average calculations; if these had been included, with an assumption of "nonuse," then the weighted averages of "use" would be considerably lower for those methods with a high missing response rate.

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- Safe Routes to School or school audits (two localities)
- Engineering analysis (one locality)
- Warrants analysis (signals, crosswalk, midblock crossing) (one locality mentioned).

Other methods of obtaining information to identify locations, used by 17% (three) of local jurisdictions, include the following:

- Staff observations/knowledge (one locality)
- Community requests (one locality)
- Public input for all major projects (one locality)
- Tracking locations where a specific treatment (one widely used and known about in the community) is requested.

Identifying Countermeasures

States Countermeasure Selection Procedures

With two exceptions, less than half of the states reported frequently or always using any particular resources or tools to help select pedestrian countermeasures. This may reflect, in part, the relatively few treatments or designs with crash-based safety evidence for various location types, but there are no data to support this conjecture. In addition, the responses may reflect a lack of awareness of the existing tools that could be used to help select potential countermeasures. However, jurisdictions were not asked about their reasons for using or not using the tools, including prior awareness of the tools, only whether they used them. Reasons for lack of use may also vary across jurisdictions.

The procedures used most often (*frequently or always used*) by states (Table 4) include the following:

- A majority of states (81%) report that they frequently or always assess ADA compliance during the countermeasure identification process.
- The second most often used method was to solicit public input (53% frequently or always used).
- Internal design resources were used frequently or always by 42% of states.
- The CMF Clearinghouse was used frequently or always by 36% of states responding.
- Of the states, 39% reported that they use cost–benefit assessment to help select countermeasures, whereas 44% indicated that they infrequently or never do. This finding may relate, as already mentioned, to difficulties in estimating crash effects for measures for which there are only behavioral data or no data.

Other resources were less commonly consulted on average. Again, the weighted average column reflects the average level of use on a four-point scale from "never used" (0) to "always used" (4) (Table 4).

TABLE 3
TYPES OF PROCESSES USED TO IDENTIFY LOCATIONS IN NEED OF IMPROVEMENTS—SUMMARY OF RESULTS FOR LOCAL JURISDICTIONS

Process or Method Used	Proportion—Frequently (3) or Always (4)	Proportion—Sometimes (2)	Proportion—Infrequently (1) or Never (0)	Proportion—Unable to Det./No Answer	Weighted Average (excluding missing answers)
Review for all types projects	83.3%	16.7%	0	0	3.3
Solicit/review complaints	83.3%	11.1%	5.6%	0	3.3
Review—ADA	77.8%	11.1%	11.1%	0	3.2
Crash analysis	55.6%	27.8%	11.1%	5.6%	2.6
Review existing pedestrian plans	66.7%	5.6%	27.8%	0	2.6
Collaborate with district/neighborhood evaluation	55.6%	33.3%	11.1%	0	2.6
Solicit public input—specific project needs	55.6%	16.7%	27.8%	0	2.4
RSA	27.8%	33.3%	38.9%	0	1.9
Multimodal LOS/QOS	11.1%	11.1%	66.7%	11.1%	1.4
Pedestrian LOS/QOS assessment	11.1% [1]	27.8%	55.6%	5.6%	1.2
Other type analysis	22.2%	5.6%	11.1%	61.1%	N/A
Other methods	16.7%	5.6%	0	77.8%	N/A

Note: Eighteen cities and counties responded to this question.
[1] No agencies reported always using pedestrian LOS or QOS.

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A few other methods were also mentioned as being used, including engineering judgment; coordination (by states) with local governments; web search of measures implemented in other states and cities; in-service evaluation of similarly treated sites; and other internal policies, procedures, and plans.

Other external countermeasures resources mentioned by state agencies included the *HSM* (California), and a "case-dependent" approach, described by North Carolina as follows: "Depends on the case, and we will attempt to find relevant sound research that pertains to the countermeasure and intended candidate application."

Other external design resources used include

- Staff knowledge, including specialized staff or work team—three states;
- State guidance for pedestrian crossing treatments—two states (at least one additional state has guidance under development or in the training phase); and

TABLE 4
RESOURCES AND TOOLS COMMONLY USED BY STATES TO HELP SELECT COUNTERMEASURES

Tool or Resource Used	Proportion—Frequently (3) or Always (4)	Proportion—Sometimes (2)	Proportion—Infrequently (1) or Never (0)	Proportion—Unable to Det./No Answer	Weighted Average (excluding missing answers)
ADA guidelines	80.6%	16.7%	0	2.8%	3.2
Solicit public input	52.8%	33.3%	8.3%	5.6%	2.6
Internal design resource	41.7%	16.7%	11.1%	30.6%	2.5
Cost-benefit analysis	38.9%	8.3%	44.4%	8.3%	1.8
Crash Modification Factors Clearinghouse	36.1%	36.1%	25.0%	2.8%	2.1
FHWA's *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations*	27.8%	47.2%	16.7%	8.3%	2.1
External design resources	22.2%	30.6%	13.9%	33.3%	2.2
FHWA *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes*	22.2%	52.8%	22.2%	2.8%	2.0
Internal counter-measures resource	19.4%	33.3%	16.7%	30.6%	2.0
NCHRP Report 562, Improving Pedestrian Safety at Unsignalized Crossings	19.4%	41.7%	25.0%	13.9%	1.9
Consult other original research	19.4%	0	30.6%	50.0%	1.7
Use other methods	19.4%	2.8%	11.1%	66.7%	N/A
PEDSAFE	13.9%	25%	58.3%	2.8%	1.2
Pedestrian LOS/QOS assessment	8.3%	11.1%	66.7%	13.9%	0.9
Other external countermeasure selection tools	5.6%	19.4%	25.0%	50.0%	1.2
Multimodal LOS/QOS	5.6%	5.6%	69.4%	19.4%	0.8

Note: Figures showing detailed distributions of responses to how locations are identified by states and the local jurisdictions that participated are provided in Appendix B.
N/A = not available.

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- Other state manuals and technical guidance, including traffic engineering manual—two states.

One state each mentioned the following resources:

- State pedestrian (or bicycle) safety implementation plan
- State guidelines for installation of marked crosswalks
- CMFs with local data
- State project development and design guidance
- Operations policy directives.

Regarding ADA compliance, a plurality of states (12) mentioned using PROWAG guidelines. Several also use internal policies or design guides. Some also have specialists within the department to assist with ensuring ADA compliance.

Other external design resources consulted by states to help identify appropriate treatments most often include the AASHTO (pedestrian facilities) guide, used by six states (17% of responding states).

Other guidance used included the following:
- NACTO guidance
- ITE *Traffic Control Devices Handbook*
- Nonspecific NCHRP reports
- Nonspecific FHWA guidance
- Boulder crosswalk guide and FHWA crosswalk study, both used by New Hampshire
- Vermont state guidelines (*VTrans 2015 Guidelines for Pedestrian Crossing Treatments*).

Thirteen states in all referenced using various internal highway or road design guides, manuals, standard drawings, policies, or bulletins, while one mentioned a traffic control device manual and one mentioned a pedestrian streetscape guide.

Local Jurisdictions Countermeasure Selection Procedures

Local jurisdictions also frequently solicit public input to help select countermeasures (68% of those responding to the survey). In addition, seeking ADA guidance is also widely used (63%), but to a somewhat lower extent than states reported (Table 5).

Oakland, California, adopted a policy in 2015 for selecting pedestrian treatments at signalized intersections. The methodology was based on a review of current practices implemented by other cities (on NACTO's distribution list), and the types of pedestrian–motor vehicle conflicts, intersections, and land use features present.

Other measures often used are

- Consulting the FHWA study on the safety effects of marked versus unmarked crosswalks (47%), and
- Consulting internal countermeasures resources (42%).

A number of local jurisdictions (53% at least *sometimes*) also refer to *TCRP Report 112/NCHRP Report 562* on pedestrian safety at unsignalized crossings described in chapter three.

Only 16% of local jurisdictions *frequently* perform cost–benefit assessments, with another 26% *sometimes* doing so.

PEDSAFE was not often consulted by this set of jurisdictions. Only 16% consulted it frequently or always, with another 16% sometimes using this resource. The PBCAT tool for typing crashes, which can be used alone or in conjunction with PEDSAFE, also was not mentioned by state or local jurisdictions as a resource to help identify appropriate countermeasures, although the survey did not inquire specifically about this tool.

The FHWA *Toolbox of Countermeasures containing* CMFs for pedestrian crashes was consulted frequently by about 32% of those responding, with another 21% consulting it *sometimes*. Again, LOS/QOS tools were not frequently used by many agencies (about 10% each, with similar percentages using these methods *sometimes*).

Finally, a little over half of the local jurisdictions (56%) and exactly half of state jurisdictions responded that they use a formal design or treatment selection review process. When jurisdictions did have such a process, some of them appeared to be more "front end" processes such as collision analysis and warrants assessment, but were sometimes followed up with design quality assessment reviews. One agency mentioned that the processes included review by citizen committees and that sometimes issues did not turn up in the initial plans and scoping reviews, but were identified later. New York City involves a wide variety of partner agencies or divisions in reviewing significant treatment plans.

Additional Resources or Needs Identified by Jurisdictions

Perhaps some of the most helpful information came from asking the jurisdictions what type of additional guidance or resources they require. State and local jurisdictions were asked several questions about the need for additional guidance to identify problem locations or appropriate solutions.

When asked,

Does your jurisdiction need additional guidance on how to identify locations for pedestrian crossing improvements?

only two (11%) of the selected local jurisdictions responding to the question indicated they needed additional guidance on identifying locations for crossing improvements.

- Both of those identified needs related to numbers of users—one was a desire to be better able to quantify

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TABLE 5
RESOURCES AND TOOLS COMMONLY USED BY LOCAL JURISDICTIONS TO HELP SELECT COUNTERMEASURES[1]

Tool or Resource Used (local)	Proportion Frequently (3) or Always (4)[2]	Proportion Sometimes (2)	Proportion Infrequently (1) or Never (0)	Proportion Missing/ Unable to Answer	Weighted Average (excluding missing answers)
Solicit public input.	68.4%	10.5%	10.5%	10.5%	2.9
Consult ADA guidelines.	63.2%	5.3%	15.8%	15.8%	2.8
Consult internal design resource.	57.9%	5.3%	10.5%	26.3%	2.9
Consult FHWA *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations.*	47.4%	15.8%	15.8%	21.1%	2.6
Consult internal countermeasures resource.	42.1%	5.3%	15.8%	36.8%	2.4
Consult NCHRP 562, *Improving Pedestrian Safety at Unsignalized Crossings.*	36.8%	15.8%	26.3%	21.1%	2.1
Consult external design resources.	31.6%	10.5%	15.8%	42.1%	2.4
Consult FHWA *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes.*	31.6%	21.1%	31.6%	15.8%	1.9
Consult other external countermeasure selection tools.	26.3%	10.5%	26.3%	36.8%	1.8
Consult Crash Modification Factors Clearinghouse.	26.3%	5.3%	42.1%	26.3%	1.5
Perform cost–benefit analysis.	15.8%	26.3%	42.1%	15.8%	1.5
Consult PEDSAFE Countermeasure Selection Tool.	15.8%	15.8%	47.4%	21.1%	1.3
Consult other original research documents.	10.5%	15.8%	10.5%	63.2%	2.0
Perform pedestrian LOS or QOS assessment.	10.5%	10.5%	52.6%	26.3%	1.1
Perform multimodal LOS or QOS assessment.	10.5%	15.8%	52.6%	21.1%	1.0
Use other methods.	5.3%	0.0%	5.3%	89.5%	2.0

[1] Eighteen local jurisdictions responded to the question.
[2] Numbers in parentheses represent the answer weight in the weighted average in the right-most column.

latent demand at some locations, and the other related to deriving costs and benefits of threshold numbers (both vehicle and pedestrian volumes) for midblock crosswalks.
- Another need mentioned by one of these jurisdictions was for additional guidance about channelized islands, including thresholds and benefits.

In contrast, 57% of the states responding indicated that they could use additional guidance on identifying locations in need of crossing improvements. Most often (nine states), the focus was on means of prioritizing among locations needing treatment as opposed to initial identification of locations (Table 6). An illustrative answer from North Carolina was,

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> It should be noted that certainly far more candidate locations than could ever be treated can be readily identified through existing data-driven and systemic mechanisms/approaches—but what *is helpful are decision support tools that help apply limited resources to the most beneficial locations/sites that are best utilized.* Additional spatial analysis and analytic-based tools would be of value.

The North Carolina Department of Transportation (NCDOT) currently uses an expert team to estimate crash effects for treatments that currently lack such estimates. Other jurisdictions such as San Francisco have applied similar approaches. See the case example on San Francisco's data-driven approach to prioritize improvements in chapter five.

TABLE 6
SUMMARY OF STATE RESPONSES TO TYPE OF GUIDANCE NEEDED FOR IDENTIFYING LOCATIONS FOR PEDESTRIAN CROSSING IMPROVEMENTS

Type of Guidance Needed	No. of States
Prioritization-related information/guidance (with specific mentions of economic and health valuations; identifying generators and receptors; incorporating community goals; using crowd-sourced data for public input; need for CMFs; use of tools such as spatial analysis, United States Road Assessment Program, warrants other states are using)	9
Proactive/systemic approach to identifying risks (versus waiting for crashes to happen), including one mention of context-based guidance	7
Coordinating with other planning (e.g., nonmotorized, Complete Streets) or project processes (i.e., integrating needs early in project scoping)	2
Crosswalk/rural crosswalk guidance	2

The second most common need expressed was for proactive systematic approaches to identify locations, as opposed to relying only on crashes to do so (mentioned by at least seven states).

Other needs mentioned related to coordinating with other planning or project processes, or guidance on implementing crosswalks (in general, or in rural locations).

When asked,

What type of resource that does not already exist would be most beneficial to help your jurisdiction select pedestrian crossing improvements?

answers focused most commonly on a need for tools and resources to help with prioritization, including better crash-based (CMFs) evidence, and perhaps the need for better "packaging" of the *information that* (may) *already exists* to enhance cost-effective and *context-appropriate* decision making.

A few answers from states are as follows:

> A guideline that address(es) [sic] when to use various devices (as to what to look for when assessing the problem location) relative to the realistic expectations each device or treatment can address. It should provide some uniform basis for making the decision to install it and when to augment it with another treatment/device or when to consider something different.

> A tool that analyzes the network and conditions where crossing improvements should be installed and then suggests a countermeasure and prioritizes the locations, such as USRAP [United States Road Assessment Program], cloud-based public comments, etc.

> In some ways it appears that much of the information is available but not very conducive to being readily compiled. Better organization of the knowledge and tools would be helpful as would more decision support/expert-type tools. Tools that better focus efforts toward locations with greatest need and most potential for improvement/public benefit from investment of limited safety resources.

Additional warrants or guidance for countermeasures that are not signals was mentioned, but the respondent clarified that warrants were not necessarily what was needed:

> For example, in our developing guidance document we are considering a "warrant" for marked and signed, nonsignalized crosswalks based on sight distance and the ability of the pedestrian to cross the roadway and clear the roadway based on available sight distance of the approaching vehicles. Signal installations have clear thresholds currently and hopefully simple signed/marked crosswalks will also have clear thresholds. Then we have room for flexibility in countermeasures for crossings that don't meet either that range from prohibiting crossings using barriers (for locations where a significant generator is not too far from a designated crossing), to moving generators (such as bus stops or sidewalks leading from developments, to installing some type of enhanced sign or signal treatment. [Many of the pedestrian treatments are determined based on engineering judgment. It would be helpful to provide some more guidance but not necessarily warrants.]

More information or guidance about when to use HAWKS and PHBs was mentioned several times, including ways to assign the right type of project to the right level of risk. The respondent went on to address the need for incorporating latent demand: "Provide warrants that account for latent demand (many pedestrian situations are like the chicken and the egg … pedestrians can't cross so they don't try), clearer warrants for large investments such as signals and HAWKS [PHBs]."

Others pointed out this need as well:

> We are always in need of tools to help predict usage on facilities that don't currently exist. We have many corridors that do not currently have pedestrian facilities (such as sidewalks, shared use paths, etc.) so it is difficult to either justify where a facility is needed or determine what type of usage may occur to determine which type of facility would be most appropriate.

A local jurisdiction also mentioned the need for a latent demand predictive model.

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A state and a local jurisdiction also mentioned the need for improvements in guidance or improvements in practice relating to the balance of vehicular LOS with pedestrian needs. Responses include the following:

> Sometimes pedestrian crossings are not installed because movement along the roadway is prioritized. Some people in the community feel a Complete Streets policy could overcome this bias in mode choice (driving versus walking). I don't think pedestrian crossings should be as onerous to install as they are. Traditional engineering practice places a lower value on walking than on driving and maintaining an effective LOS.

> Guidance related to acceptable reductions in vehicular LOS in order to benefit nonmotorized mobility and safety.

One state mentioned the need for "low-cost methods to count pedestrians or determine exposure."

A local jurisdiction expressed the need for more information on effects of FHWA's proven countermeasures in an urban environment.

NACTO, in addition to local and other design guidance, has become a useful tool for Charlotte, North Carolina.

One jurisdiction mentioned the needs for the following:

> Widespread general pedestrian engineering education. Hands-on field studies.

> Knowledge of the availability of documents and training in some of the primary resources being made available locally, and without excessive costs.

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CHAPTER FOUR

RECOMMENDED APPLICATIONS, EFFECTIVENESS, AND CURRENT USE OF PEDESTRIAN CROSSING TREATMENTS

This chapter summarizes practices regarding applications of 25 specific pedestrian crossing treatments. The next sections describe the treatments and their intended uses as described by the current recommended practice documents summarized in chapter three, provide a summary of effectiveness from the literature synthesis, and characterize uses of the treatments reported by states and select local jurisdictions.

There are numerous publications, guides, and web resources that are useful in selecting the most appropriate types of pedestrian crossing treatment(s) for a given location. Some of these, including the PEDSAFE Countermeasure Selection Tool, were described in chapter three. PEDSAFE provides guidance for selecting appropriate measures and using the most up-to-date safety research and expert knowledge available, and provides numerous case studies demonstrating how jurisdictions are applying treatments to specific types of locations. PEDSAFE describes more than 60 types of pedestrian treatments, most of which are appropriate at pedestrian crossing locations. The *Safe Routes to School Guide*, also described in chapter three, summarizes engineering countermeasures that may be appropriate for crossings near schools or along school walking routes. Comprehensive measures such as adult crossing guards, enforcement, Walking School Buses, and other programs to supplement engineering improvements in school zones and along school walking routes are also described in resources on the SRTS website (http:/www.saferoutesinfo.org/).

As mentioned in chapters one and two, there are a variety of issues and other policy frameworks that may also affect decision making. For example, a number of cities have recently embraced a TZD or Vision Zero framework in which zero traffic deaths are acceptable. In a Vision Zero framework, wherever pedestrians are expected, they should be provided safe and convenient access to all destinations, with designs and traffic controls in place to minimize the chances of serious harm in the event that road users make mistakes. Measures that unnecessarily delay pedestrians in favor of motorized mobility may also be considered generally inappropriate, and may lead to safety problems because pedestrians may choose to cross without a safe gap or at less-safe locations. In addition to countermeasures safety resources, a number of jurisdictions also use design guidance such as NACTO's *Urban Street Design Guide*, or locally produced design and countermeasures guidance to aid contextually appropriate decision making and development of a self-explaining and self-enforcing network of streets.

Traffic speed and driver expectation—two measures that are often unavailable in existing studies—are other factors that may play roles in treatment selection. Midblock and uncontrolled approaches to intersections tend to have higher severity outcomes when crashes occur—these more severe outcomes may relate to both of those issues, driving speed and a lack of expectation of pedestrians at such locations—as well as lighting and other factors. Speed is often indicated as a consideration for selecting appropriate treatments, particularly at uncontrolled locations [as in the FHWA crosswalk study by Zegeer et al. 2005, *TCRP Report 112/NCHRP Report 562 Improving Pedestrian Safety at Unsignalized Crossings* (Fitzpatrick et al. 2006a), and PEDSAFE (Zegeer et al. 2013)]. Fitzpatrick et al. (2006a) also reported that speed is a primary concern of pedestrians in perceiving whether a location is safe to cross. In a Vision Zero or Toward Zero Deaths approach, speed is a major consideration for how much separation to provide users (through either designs or traffic controls).

Studying the safety effects of treatments to improve conditions for pedestrians is especially challenging because of the low number of pedestrian crashes at most locations, and also a widespread lack of data on pedestrian volumes or counts. This condition affects both the application of treatments and the study of treatment effects because the amount of exposure (measures such as the numbers of crossing pedestrians and auto traffic volume) typically have a large effect on pedestrian safety. Because crashes also tend to migrate from one "hot spot" to another, partly by chance, many jurisdictions are also looking for more proactive ways to assess risks and provide safety improvements that may lead to more widespread benefits (systemic approach).

In the following summaries of safety effects, bear in mind that it is challenging to incorporate enough treated and control locations in either before–after or cross-sectional studies to assess the safety impacts of the treatments of interest, and to isolate what factors or site conditions may affect the outcomes in a positive or negative direction. The many variations in conditions from site to site or before and after treatments often overwhelm the pedestrian–motor vehicle crash numbers, and especially more severe crashes,

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so that generalizable conclusions about safety effects can be difficult to reach. Therefore, other measures of effectiveness (MOEs) are often utilized in lieu of crash- and injury-based measures. MOEs often used include motorist yielding, pedestrian–motor vehicle conflicts, and measures of mobility effects (pedestrian delay, gap analysis, etc.). Motorist speed could also be used more often as a measure of safety impact. Operating speed is a measure that has well-established relationships with safety, including several studies that developed risk curves for pedestrian fatalities related to preimpact or impact speeds (Leaf and Preusser 1999; Rosén and Sander 2009; Tefft 2011). All have found the same general relationship, with a sharp rise in risk at increasing speeds. The Rosén and Sander study estimated fatality risk for impact speeds of 50 km/h to be twice as high as the risk at 40 km/h and more than five times higher than the risk at 30 km/h. Thus, the results of studies of behavioral/operating measures are quite useful for helping select appropriate treatments when sufficient crashes are unavailable or require too long or too many sites to evaluate.

These measures may be observed in before-to-after assessments or cross-sectional studies of treatment and comparison locations. Before–after behavioral assessments may be somewhat more rigorous for identifying effects of treatments. Ideally, these assessments are performed under similar conditions and times. Comparison locations can be used to assess whether behaviors or crashes may be changing over time for other reasons such as changes in the level of enforcement, traffic or pedestrian volumes, distraction, communications or educational campaigns, or other factors. However, in practice, many of these potential confounders are often not considered or data are unavailable to control for them in real-world research designs.

If before period data are unavailable, cross-sectional studies, either behavioral, or crash based, may be used. These types of studies also have limitations, because it is challenging to identify comparison sites that are comparable to the treated location(s), except for the treatment of interest. However, studies that at least attempt to control for potentially important factors by using similar comparison locations are better than those that do not. Also, in order to detect factors that may affect the degree of success, it is important to have a number of sites and comparison sites that do vary with respect to those traits. Consistent findings from multiple studies also provide more support for the direction and degree of effects.

This chapter summarizes the safety effectiveness evidence available for each countermeasure or treatment. Tables showing study information, site characteristics, outcome measures, and references are provided in Appendix B. As other details of studies can help in understanding how and where treatments have been applied and evaluated, the reader is also referred to the comprehensive literature review by Mead et al. (2014), which summarizes most of the studies included (through at least 2013).

> "When available, we have reported crash effect estimates (CMFs). However, users are cautioned that crash effect estimates should be developed or at least calibrated using local data, that actual effects may vary, and specific site conditions should always be investigated before any treatment is implemented."

ROADWAY DESIGN FEATURES

Eleven different design elements were investigated through the literature as well as the survey of practices. Following are results from the literature synthesis.

Narrow Lane Width

Description and Purpose of Treatment

Narrowing lane widths, or a lane diet, can provide multiple benefits, including reducing crossing distance and time that pedestrians are exposed to motor vehicle traffic (Figure 5). Depending on how they are implemented (such as through rechannelization or extending the curb line), narrower lanes may also provide space for other uses such as wider sidewalks, enhanced buffers, or space for bike lanes, which can also provide a buffer for pedestrians from adjacent traffic (Zegeer et al. 2013, PEDSAFE Lane Narrowing countermeasure). By shortening crossing distance, the delay to motorists may also be reduced. If lanes are narrowed to add buffers for sidewalks, bike lanes, or shoulders, the added space can also provide an additional buffer between motorized traffic and pedestrians waiting to cross the street or walking along the roadway. Also see the section on Curb Extension/Bulb-Out countermeasure below, on another way to narrow lanes at crossing locations.



FIGURE 5 Lane diet on Harvard Avenue in Boston, Massachusetts. *Source*: PEDSAFE/Bill Schultheiss, Toole Design Group.

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NACTO's *Urban Street Design Guide* indicates that lane widths of 10 ft are appropriate in urban areas and have a positive impact on a street's safety without affecting traffic operations. NACTO also mentions that some cities may want to consider 11-ft lanes (versus 10) on routes used by trucks and buses, and that turn radii at intersections also be considered.

Summary of Effects

Although no studies were identified that specifically evaluated effects on pedestrian safety of narrowing lane widths, literature suggests that there are negligible operational (capacity) or safety differences for motorists between lane widths from 10 to 12 ft (Petritsch n.d.). The *HSM* is silent on the effects of lane width in safety performance. Narrower lanes have been associated with lower speeds on suburban/urban streets (Fitzpatrick et al. 2003), but results have been mixed when lanes were narrowed using different techniques and at different types of locations. The evidence thus far is also mixed regarding crash effects of narrowing lanes. The variable results may relate, in part, to the purpose of the lane-narrowing project. For example, Harwood found that when the purpose of lane narrowing was to increase the total number of through lanes on an arterial street, intersection crashes increased, but there was no effect on segment crashes. When narrower lanes were created to provide space for installation of a center two-way left-turn lane, total crashes were generally reduced by 24% to 53% (Harwood 1990). The effects of lane diets on speeds and crashes may depend on interactions with shoulder width and type, and number and width of other adjacent lanes as well as other environmental cues and design speed factors (Boodlal et al. 2015).

Use of Narrower Lanes

In terms of using narrower lane widths, 67% of the states and 78% of the select local jurisdictions responding to the survey indicated that they use this measure to improve safety conditions for pedestrians at crossing locations. The range of widths considered "narrow" by different jurisdictions varied from 9 ft to less than 12 ft.

Local jurisdictions responding to the survey for this study most often reported using widths of 10 ft or less (nearly 80% of those answering the question). Ann Arbor, Michigan, uses 9 ft for turn lanes and 10 ft for through lanes. Cambridge, Massachusetts, uses 10 ft for major roads and 9 ft for minor. A few other cities, including Eugene, Oregon, and Charlotte, North Carolina, use 9-ft lanes on occasion.

The most common width considered "narrow" among states was 11 ft or less; but at least seven states would use 10 ft or less in some situations. North Carolina DOT indicated that it depends on the context and that generally a lane at or under 10 ft wide would be considered "narrow" for most nonresidential conditions. Three states indicated that anything at or less than 12 ft is considered narrow.

Road Diets

Description and Purpose of Treatment

A road diet is a reallocation of road space cross-section through reduction in the number of motorized traffic lanes (also known as road conversions) (Figure 6). Road diets are of interest to communities that may be seeking to reallocate space for other uses, smooth traffic flows and reduce traffic speeds, improve access management, reduce crashes, improve safety and accessibility for pedestrians or bicyclists, improve parking utilization, improve economic function of the street, or gain space for other uses more compatible with the purposes of the street (Thomas 2013).



FIGURE 6 Before (left) and after (right) road diet on Edgewater Road, Orlando, Florida. *Source*: PEDSAFE.

The most common road diet configuration involves converting a four-lane, undivided two-way road to three lanes, with one travel lane in each direction and a center two-way left-turn lane (TWLTL). It is important that a traffic analysis be conducted to assess the feasibility of a road diet, which is generally considered feasible from lower volumes up to about 25,000 ADT in some cases [Zegeer et al. 2013, PEDSAFE, Lane Reduction (Road Diet) countermeasure description].

FHWA released a *Road Diet Informational Guide* (Knapp et al. 2014) that summarizes the history of road diet conversions, safety effects, and other uses and benefits. According to the guide, road diets or reallocation of the roadway cross section may be used to create pedestrian median islands, bike lanes, transit stops, or parking. Pedestrians also have fewer motorized lanes to cross, and medians and median islands may further be used to shorten crossing distances. If bike lanes are added, these create an addition buffer between motorized traffic and pedestrians on walkways (Knapp et al. 2014).

Summary of Effects

A study of road diets at 460 sites in New York City found that road diets have contributed to a trend of fewer pedestrian crashes between intersections, and decreases in total and injurious crashes at segments and intersections abutting the road diet segments. The range of expected effects on total crashes is from 19% to 47% reduction. The expected effects are in the lower range in large urban areas, and in the higher range for main roads passing through smaller towns

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and suburban areas. An average 29% reduction (CMF of 0.71) for total crashes across all sites was estimated (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Harkey et al. 2008). Road diets have also been found to reduce motor vehicle operating speeds, which are also associated with expected reductions in injury and fatal crashes.

Use of Road Diets

Similar percentages of states (78%) and the select local jurisdictions in the survey for this study (72%) have used road diets to improve crossing conditions for pedestrians. Most of the jurisdictions using the treatment mentioned applying a road diet where volumes allow or there is excess capacity, or to allocate space for bike lanes or improve conditions for pedestrians. Road diet conversions are also used if the current cross section is not operating well, the local community has pushed for the change, or there is a change in function from highway to local collector. High speeds were mentioned as one of the issues of concern. North Carolina mentioned taking care to address transitions on either end of a road-dieted section with regard to driver expectation, lane continuity, positive guidance, proper advance signs, and markings.

A number of state and local jurisdictions mentioned implementing bike lanes and median islands with road diets. Fewer mentioned parking. New York City implements medians, median islands, and curb extensions with road diet conversions. Eugene, Oregon, implements bike lanes and median islands. Others use two-way, center two lanes. Three jurisdictions mentioned they will implement RRFBs in conjunction with road diets (Nevada; Portland, Oregon; and Davis, California). Davis also adds a center median and marked crosswalks. A few jurisdictions mentioned installing sidewalks and lighting.

Raised Median and Pedestrian Median Islands

Description and Purpose of Treatment

Medians with pedestrian crossings, and pedestrian median islands—sometimes referred to as center islands, refuge islands, or pedestrian islands—are raised areas intended to help protect pedestrians who are crossing the road at either intersections or midblock locations (Figure 7). The presence of a median island in the middle of a street or intersection allows pedestrians to focus on one direction of traffic at a time as they cross and gives them a place to wait for an adequate gap between vehicles before finishing the second leg of the crossing (Figure 8). Islands are appropriate for use at both uncontrolled and signalized crosswalk locations. According to PEDSAFE, where the road is wide enough and on-street parking exists, center islands can be combined with curb extensions to further reduce the crossing distance (Zegeer et al. 2013, PEDSAFE, Crossing Islands).

Summary of Effects

The available evidence suggests that medians and median crossing islands provide a protective effect for pedestrians (as well as motorists) with regard to crashes by reducing pedestrian exposure to traffic. A CMF of 0.75 (25% reduction) for pedestrian crashes was estimated from a Florida study (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Gan et al. 2005). CMF estimates of 0.54 (46% reduction) for raised median with a marked crosswalk at unsignalized intersection, and 0.61 (39% reduction) for raised median with unmarked crosswalk at unsignalized intersection were estimated from the FHWA crosswalk study (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Zegeer et al. 2002).



FIGURE 7 Landscaped, raised median with pedestrian crossing. *Source*: Zeeger et al. (2013), citing PBIC (n.d)

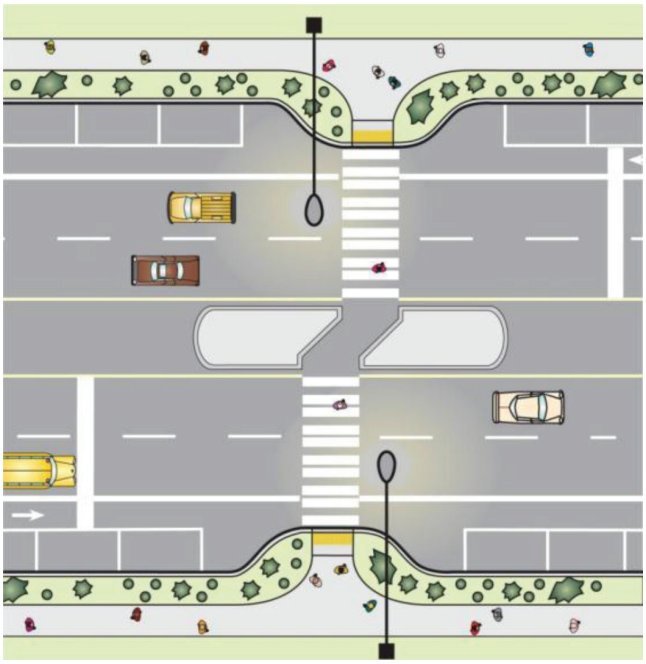


FIGURE 8 Midblock pedestrian crossing island with curb extensions, high-visibility crosswalks, advanced stop lines, lighting, and angled cut-through. Note that a cut-through must include detectable warnings. *Source: Oregon Bicycle and Pedestrian Design Guide: Oregon Highway Design Manual* (2011).

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Studies for *NCHRP Report 562* found that motorist yielding rates varied widely across sites with median islands and marked crosswalks. Some of the explanatory variables included the number of through lanes and posted speed limit (Fitzpatrick et al. 2006a). Other treatments may be needed to improve yielding at uncontrolled locations or improve pedestrian access and safety at multilane uncontrolled road crossing locations, particularly with higher volumes or speeds or both (see the matrix in chapter three). Treatments recommended by Zegeer et al. (2005) and Fitzpatrick et al. (2006a) include advance stop/yield lines and signs, beacon signals with a red (stop) indication (such as PHBs), and signs and flashing beacons, although the latter have tended to have a wider range of effectiveness.

Use of Raised Medians

Raised medians were used by 89% of states responding and 67% of local jurisdictions. The most common reasons or situations mentioned by state or local agencies (44 responses in total) for using raised medians to improve pedestrian crossing safety were to manage access/reduce conflict points. Raised medians are frequently used on multilane, wide, or arterial roadways, or on higher-speed and higher-volume roads, and may be used where there is a need for a midblock crossing. Raised medians are also used to provide a pedestrian refuge, and to reduce conflicts and crashes at intersections.

Two state agencies mentioned that they sometimes used medians in conjunction with fencing as a means to discourage pedestrians from crossing or "jaywalking," but there was no further description of the type of roads or land uses where this type of treatment was applied.

Some other issues mentioned include whether there was sufficient width, and Scottsdale, Arizona, mentioned that a raised median is a design criterion for all arterials, whereas Portland uses raised medians on any four-lane road with a speed limit higher than 25 mph.

The most common other treatments used in addition to raised medians were the following:

- Marked crosswalks (and signs) are used most often in conjunction with other treatments, but sometimes alone or with signs only.
- RRFBs or overhead or other flashing devices are used by Oregon, Utah, and Minnesota, which will also incorporate striping, curb extensions, and pedestrian countdown timers at signals.
- Tucson, Arizona, will consider a PHB (HAWK) or PELICAN (PEdestrian LIght Control ActivatioN system, a type of two-stage pedestrian crossing) for multilane roads with a median. Delaware will also consider midblock crosswalks enhanced by a PHB, whereas Florida may implement a pedestrian signal and markings.
- Washington uses street trees and context-sensitive design in conjunction with raised medians.
- Scottsdale, Arizona, will implement a pedestrian refuge and raised crosswalk in conjunction with some medians.

Three states mentioned that median fencing or barriers are sometimes installed in conjunction with raised medians but were not more specific about the context or type of road.

Use of Pedestrian Median Islands

Pedestrian median islands are used by 97% of states and 94% of the select group of local jurisdictions to provide enhancements for pedestrian crossings. There appear to be two basic approaches to providing median refuges. Many jurisdictions consider the characteristics of the street that may cause pedestrians to need a refuge—such as high speed, high volume, width, and multiple lanes—in their decisions. Most of the answers were along these lines, with one jurisdiction (Portland, Oregon) indicating that it might apply a pedestrian refuge on "any four-lane road with a speed limit higher than 25." Another indicated it might on "most three- and five-lane roadways." A few jurisdictions mentioned that they use such refuges at unmarked and some marked crosswalks on urban arterials where signalized intersections are infrequent. A couple of other jurisdictions mentioned they would use refuges at urban arterial signalized intersections, at nonintersection path crossings, or where there is a high volume of pedestrian–vehicle conflicts.

Other jurisdictions take a somewhat different approach, at least as reflected in their survey responses. These jurisdictions described a more opportunistic approach and mentioned criteria, such as "already-existing median, sufficient width or space, TWLTL designs, when four- to three-lane road diets are implemented," or "crossing with storage/refuge area—ample sight distance, good spacing from adjacent intersections and conflicts" that would lend themselves to implementation of pedestrian refuge islands. Others mentioned both pragmatic concerns and needs.

Raised Crosswalk/Speed Table

Description and Purpose of Treatment

According to PEDSAFE, raised pedestrian crossings are a type of vertical traffic control measure that can reduce vehicle speeds, reduce the need for curb ramps (though truncated domes should still be included), and enhance the pedestrian crossing environment (Figure 9). A raised pedestrian crossing is similar to a raised intersection, but it is only the width of a crosswalk, usually 10 to 15 ft. Construction involves providing ramps on each vehicle approach, which elevates the entire crosswalk to the level of the sidewalk. The crosswalks can be built with a variety of materials, including asphalt, concrete, stamped concrete, or brick pavers (Zegeer et al. 2013, PEDSAFE, Speed Tables, Raised Pedestrian Crossings countermeasures).

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A speed table is a long, broad speed hump or a flat-topped speed hump typically used to reduce vehicle speeds on residential roads. Speed tables can be used in combination with curb extensions where parking exists. Speed tables are paved (usually asphalt) and approximately 3 to 4 in. high at their center, and extend the full width of the street with height tapering near the drain gutter to allow unimpeded bicycle travel. Speed tables should not be confused with the speed "bump" that is often found in mall parking lots. There are several designs for speed tables. The traditional 12-ft table has a design speed of 15 to 20 mph, the 14-ft table has a design speed of a few mph higher, and the 22-ft table has a design speed of 25 to 30 mph. The longer tables are much gentler for larger vehicles (Zegeer et al. 2013).



FIGURE 9 Raised crosswalk in Salt Lake City, Utah. *Source*: http://www.pedbikeimages.org, Dan Burden.

Speed tables are used to slow vehicular traffic at two-way path crossings in Canberra and Yarra, Australia, and Malmö, Sweden, and help enforce path user right-of-way priority (Thomas et al. 2015a).



Image source: Thomas et al. 2015a, Alistair McDonald.

Speed humps in Helsinki, Finland, were implemented in advance of similar, two-way path crossings, and an evaluation found that drivers were slowed on the approach and scanned in both directions more often before driving across the path after the speed humps were installed (Thomas et al. 2015a; citing Summala et al. 1996).

Existing guidance suggests that raised pedestrian crosswalks or speed tables (most often flat-topped, but may also be parabolic) may be applied at midblock locations on low-speed local streets, collector roads, and other locations such as airport drop-off and pick-up zones, campus settings, and shopping centers. Typically, they function as an extension of the sidewalk (per AASHTO guidance), but may have gaps to allow bicycles and motorcycles to pass through (AASHTO Guide 2014; Fitzpatrick et al. 2006a). Because raised crosswalks create a vertical displacement of the vehicle as it drives over the devices, lower speeds are expected if they are designed for speeds slower than initial operating speeds. Because vertical displacement can also cause discomfort and noise issues (especially with larger vehicles) as well as potential drainage issues, PEDSAFE recommends that these devices go through a public process that involves emergency response agencies. However, raised devices such as speed tables and speed humps tend to be consistently effective at lowering speeds (FHWA 2014) and at lowered total and injury crashes of all types, as demonstrated in a study from the United Kingdom (Mountain et al. 2005). They are also thought to call increased attention to pedestrian crossings.

Summary of Effects

In research conducted for the *HSM*, CMF estimates of 0.70 (30% reduction) for all crashes and 0.64 (36% reduction) for fatal injury crashes were developed, although the CMFs were not ultimately included in the *HSM* (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Bahar et al. 2007). The effects of raised crossings on motorist yielding and on pedestrian crashes are not well-documented. However, lower speeds, and potentially improved search behaviors (see sidebar), should reduce severe crashes according to *HSM* estimates of effects of lower speeds. Speed reductions for speed tables have been documented in five studies cited by FHWA (*Engineering Speed Management Countermeasures* 2014).

Use of Raised Crosswalk/Speed Table

Only 17% of states indicated they use raised crosswalks or speed tables. In contrast, 72% of the local jurisdictions responding indicate that they do.

Cases where raised crosswalks have been implemented include when a street is "functionally" classified as a local street, most frequently mentioned in association with residential areas or new residential developments. Speed tables have also been used near schools, parks, or other pedestrian traffic generators. The devices are used to slow traffic for midblock crossings, and also used at signalized locations with a "free" or yield-controlled right turn. Speed tables are also considered on a case-by-case basis, although the treatment is not normally used on state roads according to some state agencies.

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The only treatments often mentioned in survey responses as being used in conjunction with raised crosswalks/speed tables were signs and pavement markings.

Curb Extension/Bulb-Out

Description and Purpose of Treatment

Curb extensions are installations at intersections or mid-block locations that extend the sidewalk or curb line into the street or parking lane, thus reducing the street width and crossing time. It is essential that they not extend into bicycle travel lanes or shoulders (Zegeer et al. 2013, PEDSAFE, Curb Extensions) (Figure 10).

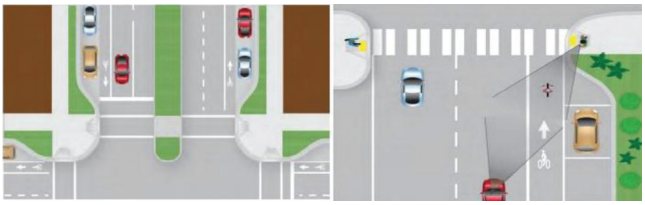


FIGURE 10 Integrating curb extensions and on-street parking into the sidewalk corridor decreases pedestrian exposure and enhances the walking experience. *Source*: PEDSAFE, Michele Weisbart.

Curb extensions have the potential to enhance pedestrian safety in several ways: by making pedestrians and motorists more visible to each other; when used at intersections, by keeping motor vehicles from parking too close to the intersection and blocking sight lines; by reducing crossing distance (which may also allow less signal time to be devoted to the pedestrian phase at signalized locations); and by narrowing radii at intersections, which may slow turning traffic. Curb extensions also tend to allow for better placement of curb ramps and prevent ramps from being blocked by vehicles that park at the corner. They are useful in conjunction with parking restriction policies, such as daylighting.

Current guides suggest that curb extensions, also known as bulb-outs and neck-downs, are appropriate only where there is on-street parking, and may not be desirable where the street is too narrow or the extension would interfere with a bicycle lane (*Guide for the Planning, Design, and Operation of Pedestrian Facilities* 2004; Knapp et al. 2014; Zeeger et al. 2013).

Summary of Effects

Although curb extensions are expected to have safety benefits based on exposure and design principles, behavioral or crash effects of curb extensions have not been widely studied, as yet.

Curb extensions may be effective at improving motorist yielding as part of a larger package of treatments or designs (including crosswalks with advance stop/yield lines and median islands). As mentioned, curb extensions are expected to slow turning speeds by narrowing the effective turn radius, and to improve sight lines between pedestrians and motorists (but this depends on implementation; for example, tall shrubs are not to be used as part of landscaped areas). They may also help lower overall crash severity based on a New York City study that attempted to measure crash effects at six locations (King 1999).

Use of Curb Extensions/Bulb-Outs

Of the states and local jurisdictions surveyed, 94% use curb extensions/bulb-outs in certain situations.

Jurisdictions most often mentioned using this treatment in downtown and urban settings, or along main roads/trunk lines that pass through towns and cities. Other criteria mentioned were high-pedestrian locations, and the need to shorten crossing distances/reduce pedestrian exposure. Several jurisdictions mentioned on-street parking as a requirement, which is consistent with the current recommended practice guides. One jurisdiction mentioned the need to consider drainage issues.

Treatments mentioned most often as used in combination with curb extensions or bulb-outs include the following:

- Marked crosswalks were mentioned 10 times in total, seven of those times in combination with additional other treatments including pedestrian signals, signs, RRFBs, LPIs, and lighting. Oregon mentioned a comprehensive list of treatments used *sometimes,* with curb extensions, including marked crosswalks, LPIs, pedestrian countdown signal heads, RRFBs, and lighting.
- High-visibility crosswalk markings were mentioned by three jurisdictions, one of those times in conjunction with pedestrian crossing warning signs.
- ADA curb ramps were also mentioned by several jurisdictions.

Treatments mentioned only once include landscaping, back-in parking, and water harvesting.

Reduce Corner Radius

Description and Purpose of Treatment

Large curb radii facilitate high-speed turns for vehicles (Figure 11). Curb radius reduction forces sharper turns, thus reduced turning speeds. Curb radius reduction also creates larger waiting areas for pedestrians wishing to cross. Curb radii sizes are normally based on design vehicle types, often for large emergency vehicles. By reducing radius sizes, emergency vehicles may find navigating the turn more difficult.

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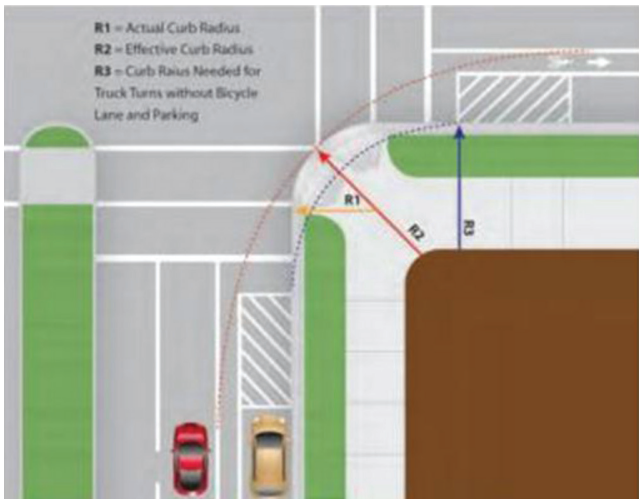


FIGURE 11 The effective corner radius controls turning speeds and the ability of large vehicles to turn. *Source*: PEDSAFE, Michele Weisbart.

However, the distinction between the actual and effective curb radius is important when designing the intersection. The actual curb radius is the radius of the curb itself whereas the effective radius is determined by the path of a turning vehicle, which is increased by the presence of on-street parking, bicycle lanes, or striping advance stop lines on the destination street of multilane roadways. An actual curb radius of 5 to 10 ft, where possible, is recommended. For the effective curb radius, 15 to 20 ft on urban streets with high numbers of pedestrians is recommended. An arterial with buses and trucks may have an effective curb radius of 25 to 30 ft. Curb radius reductions are important for skewed intersections, where it is necessary to create the smallest possible radius on the obtuse-angle corner to avoid high-speed turns.

Important issues for curb radius reduction are as follows:

- Parking or bicycle lanes at an intersection can increase the effective radius.
- If curb radius is small in an area with high traffic volumes, vehicles may drive over the curb.
- Consider emergency vehicle access (Zegeer et al. 2013, PEDSAFE, Curb Radius Reduction).

Summary of Effects

No research studies were identified that have evaluated the safety or behavioral effects for pedestrians of reducing corner radii, which as mentioned, are intended to slow motorist turning speeds and increase chances for motorists to perceive and yield to crossing pedestrians. Slower speeds are also expected to reduce the severity of collisions that do occur. There is an equation to estimate a CMF for all crashes based on the skew angle, which can also lead to wide radii at some corners. The equation can be used to estimate effects compared with an intersection without any skew (all right angles) (see Thomas et al. 2015b or the CMF Clearinghouse).

Use of Reduced Corner Radius

A lower percentage of states, 64%, and local jurisdictions, 78%, use the approach of reducing the corner radius at intersections in comparison with the proportions using curb extensions. Of those, at least five jurisdictions—including Ann Arbor, Michigan; Santa Barbara, California; and Portland, Oregon—seem to try to keep or modify turning radii to the minimum allowable based on the design vehicle or road type, or in the case of Cambridge, Massachusetts, as standard design for city streets. Seattle, Washington, also reduces curb radius at intersections to slow motorist speeds (see a case example from BikeSafe, Curb Radii/Curb Revisions, Sundstrom et al. 2014).

Corridorwide Speed Calming

Description and Purpose of Treatment

Areawide traffic calming is a comprehensive strategy comprising a variety of countermeasures with the objectives of reducing traffic speed or volume or both; reducing conflict between local traffic and through traffic; making it easier for pedestrians to cross roads and avoid conflicts with motor vehicles; and enhancing the overall environment by reducing noise from traffic (Mead et al. 2014). In urban areas, crashes can be scattered widely, making traditional treatments focused on specific sites less effective. Often, similar crash or risk factors (such as traffic speed, number of lanes, or transit presence) occur at different locations along a corridor. A corridorwide approach to speed calming may therefore be appropriate.

Ann Arbor, Michigan, assesses whether most roads planned for reconstruction are suitable for road diets, curb extensions, curb radius reductions, and narrower lanes. In addition, the city uses corridorwide speed calming, which may include lane narrowing, chicanes, median islands, gateway signs, and roundabouts or traffic circles at intersections. Also, see the case study from Cambridge, Massachusetts, *Traffic Calming Project Development and Evaluation,* in chapter five, on use of reconstruction projects to implement pedestrian safety improvements.

Summary of Effects

No formal studies were found that assessed the impacts of corridorwide speed calming on pedestrians as intended by this treatment. However, studies on areawide traffic-calming measures of effectiveness are the closest approximation to corridorwide speed calming available. Areawide traffic calming, using a combination of multiple types of countermeasures, has resulted in an estimated percent reduction in fatalities and

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injury collisions for all road users (Elvik and Vaa 2004). Treatments commonly applied in traffic-calming schemes, such as street closures, cul-de-sacs, diverters, traffic circles, shared street design, chicanes, flares/chokers, speed humps, speed limit signs and speed zones, enforcement programs, walkways, parking controls, and other signage, have also yielded reductions in vehicle speeds. Results of the meta-analysis indicated that these types of schemes reduced the number of total injury collisions for all road users by about 11% across all urban road types according to the CMF Clearinghouse review of this study (*CMF ID 588 Details,* n.d.). Effects were greatest on residential/local streets (18%; *CMF ID 587 Details,* n.d.) and lower on main roads (6%; *CMF ID 586 Details,* n.d).

See more discussion of traffic-calming effects in the sections on Speed Tables, Pedestrian Median Islands, and Road Diets as well as review tables in Appendix B.

Use of Corridorwide Speed Calming

Jurisdictions described a variety of considerations for corridorwide speed calming, including the following:

- Sometimes speed calming measures are implemented during corridor reconstruction projects; one jurisdiction always performs an assessment to determine whether this is possible
- As part of "greening" (planting) corridor projects
- Used for urban arterials or locations that are suburbanizing and where there are high-speed differentials.

Other jurisdictions viewed corridorwide speed calming as applying to neighborhood streets (when requested), downtown/urban center streets, or main streets.

Jurisdictions apply a wide variety of techniques and treatment combinations to calm corridors, which may include speed humps, tables, and raised intersections as well as narrower lanes and street trees. California uses road diets and St. Petersburg, Florida, mentioned using traffic signal progression. Jurisdictions also variously use roundabouts and mini circles, striping, high-visibility crosswalks with in-roadway yield signs, advance stop bars, chicanes, and curb extensions to calm streets.

Oregon indicates it uses curb extensions, raised medians, street trees, buildings close to the sidewalk (no setback), and sidewalks to calm corridors. Lowering posted speed limits was mentioned by only one jurisdiction, as was enhanced enforcement and use of radar feedback about speeds.

Pedestrian Overpass/Bridge and Underpass/Tunnel

Description and Purpose of Treatment

Pedestrian overpasses or bridges, and underpasses or tunnels, are used when it is necessary to completely separate pedestrians from vehicular traffic. This is most often required with freeways, railways and natural barriers, or busy roads that may hinder the use of traditional pedestrian crossing facilities. Overpasses and underpasses allow for uninterrupted flow of pedestrian movement by providing crossings where no other pedestrian facility is available or possible (Figure 12). They often connect off-road trails and paths across major barriers (Zegeer et al. 2013, PEDSAFE, Pedestrian Overpasses/Underpasses).



FIGURE 12 Pedestrian overpass connects pedestrian areas across a natural barrier—Liberty Bridge over Reedy River and falls in downtown Greenville, South Carolina. *Source*: Libby Thomas/author.

Summary of Effects

Clearly, overpasses and underpasses of highways and other roadways can enhance pedestrian safety, if they are used by a majority of pedestrians.

In some instances, there may be no feasible alternative to providing separated-grade facilities to provide pedestrian movement across major highways and other types of barriers such as rivers. In other situations, it will be important to assess the feasibility, convenience to pedestrians, and other issues of providing accessible and user-friendly overpasses and underpasses versus providing comprehensive at-grade facilities, and these issues should be factored into the cost equations.

Pedestrian overpasses and underpasses can be effective in reducing pedestrian crashes in certain locations. However, grade-separated crossings are expensive structures and may not be used by pedestrians if not perceived to be safer and more convenient than crossing at street level. An important measure of effectiveness for overpasses and underpasses is how much they are used by pedestrians. Overpasses and underpasses can also present problems for disabled users, so it is important that proper attention to accessibility be taken into account.

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Use of Pedestrian Overpass/Bridge

Although a majority of agencies sometimes use or have used overpasses (83% of states and 61% of local jurisdictions) per the respondents to this survey, some are no longer using them or trying to remove them owing to a lack of ADA compliance, or use them rarely. Typical responses to when overpasses might be used is for regional trails, "when possible," over major highways or other barriers, and depending on the volume of pedestrians and conflicts. Another situation is when a developer wants to include an overpass in a project and there is political pressure for the state to maintain it.

Lighting and positive guidance or fencing to discourage at-grade crossings were commonly mentioned as associated treatments.

Use of Pedestrian Underpass/Tunnel

Fewer jurisdictions use underpasses or tunnels than overpasses/bridges. When they do, the reasons are usually similar, and lighting is typically considered, as well as signing, and positive guidance or even fencing to discourage at-grade crossings. They may also be implemented along with flood control improvements, although one jurisdiction mentioned environmental impacts as also discouraging use.

Enhanced Illumination at Crossings

Description and Purpose of Treatment

Road lighting sometimes has been centered on the needs of motorists and not of pedestrians. Illumination at pedestrian crosswalks must be considered to enhance visibility of pedestrians who are crossing during nighttime and other low-visibility conditions. In commercial areas with heavy nighttime pedestrian activity, streetlights and building lights can enhance the visibility in the area. Streetlights along both sides of arterials at consistent intervals enhances overall ambience. Pedestrian crossing areas should be augmented with additional brighter lighting both on the approaches to and at the crosswalks (Zegeer et al. 2013, PEDSAFE, Lighting and Illumination) (Figure 13).

Summary of Effects

Studies have shown that pedestrian safety and motorist and driver behaviors such as pedestrians' use of crosswalks and driver yielding are improved by the use of enhanced illumination at crossing locations. Lighting is estimated to reduce injury crashes at intersections by 27% (CMF 0.73), and reduce all severity of crashes at intersections by 21% (CMF of 0.79). For segments, lighting improvements are estimated to reduce injury crashes by 23% (CMF 0.77) and all crashes by 20% (CMF 0.80) (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Harkey et al. 2008).

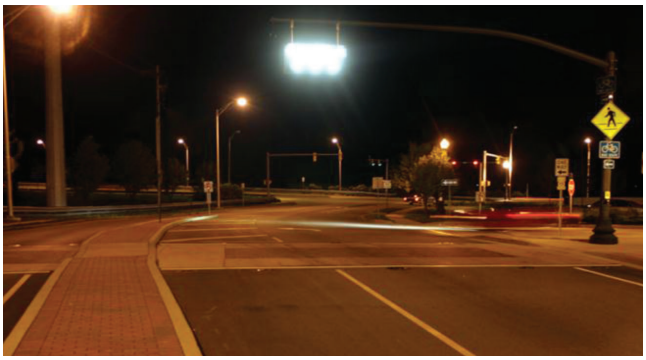


FIGURE 13 Enhanced lighting at raised crosswalk in West Lafayette, Indiana. *Source*: http://www.pedbikeimages.org, Dan Burden.

Use of Enhanced Illumination at Crossings

Seventy-two percent of states and 78% of the local agencies also use enhanced illumination at crossings on some occasions. A number of jurisdictions replied that staff always checks to make sure adequate lighting exists at locations under review for traffic changes. Several mentioned using lights in combination with RRFBs or PHBs, intersections with major trail crossings, or locations with high nighttime crashes. One jurisdiction mentioned that lighting may be underused, and potentially needs more research. However, one state indicated that lighting is most often provided by the municipal partner agency for nonfreeway roads because of maintenance, energy costs, and dark skies initiatives at the local level.

Other Types of Design Features Used

As far as other or innovative types of design features being used to improve safety for pedestrians, most of those mentioned were also included in the lists of designs or traffic-calming devices. However, roundabouts; dedicated, separate multiuse paths; and removal of free right turns were uniquely mentioned. There was no other frequently mentioned design that appears to be receiving widespread implementation. Roundabouts were not a focus of this synthesis.

Summary of Effectiveness of Pedestrian Design Features

Table 7 provides an overview of the state of knowledge of key safety effects, including estimates of expected crash effects when available, and behavioral measures of pedestrian design features.

Summary of Applications of Roadway Design Features

Table 8 summarizes the responses for which design treatments are used by state and local jurisdictions. Note that the question was phrased as yes or no to *sometimes used*, and

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TABLE 7
OVERVIEW OF STUDIES AND FINDINGS FOR EFFECTS OF DESIGN TREATMENTS ON PEDESTRIAN SAFETY

Design or Treatment	Area Types Studied	Key Measured Effects
Raised median/ pedestrian crossing	Mostly urban, suburban multilane arterials; controlled and uncontrolled crossings	• CMF estimate of 0.54 pedestrian crashes at uncontrolled locations with marked crosswalk • CMF estimate of 0.61 pedestrian crashes at uncontrolled locations (unmarked crosswalk) • Raised medians may sometimes contribute to increased speeds. • Other treatments may also be needed on multilane, higher-volume, higher-speed roads.
Pedestrian median crossing island	Major and minor arterials; residential streets; urban/suburban; midblock and intersection; controlled and uncontrolled	• See CMFs for medians. • Motorist yielding may increase, especially if used with other treatments such as curb extensions and advance stop lines and signs, or stop or warning beacon devices. • May help reduce speeding when implemented with multiple measures • Mixed results for pedestrian delay • Potential for motor vehicles to strike the islands
Raised crosswalk or speed table	Mostly two-lane streets and residential collectors Raised intersections have been used in residential, central business district, and other commercial zones. CMF study for the *HSM*—estimates not incorporated	• Lower speeds • Improved motorist yielding at some locations • CMF estimate of 0.70 for all crashes • CMF estimate of 0.64 for all fatal injury crashes
Curb extension/bulb-out	New York City (urban) study of crash effects Various in behavioral assessments including urban residential and arterial streets	• Trend in reduced crash severity • Potential motorist yielding improvements combined with advance stop bars and median island • Unclear effects on motorist yielding, motorist speed, pedestrian delay when used alone • See reduce corner radius—expected effects are similar.
Reduce corner radius	No peer-reviewed studies identified measuring safety effects for pedestrians	• Expert-based guides suggest that narrower radii can improve pedestrian safety by – Requiring motorists to reduce vehicle speed to make sharper turns; – Shortening pedestrian crossing distances, which reduces pedestrian exposure, which may also shorten time needed for the pedestrian crossing; – Providing larger pedestrian waiting areas at corners; and – Improving sight lines. • Pedestrian service may also be improved by allowing for greater flexibility of curb ramp placement in line with walkways.
Road diet	Urban streets (New York City) Urban/suburban in large metro areas, and rural arterials passing through smaller towns/cities—effects on all crash types and severities	• Downward trend in midblock pedestrian crashes (one study) • Estimated reductions in total crashes: – CMF of 0.81 for arterials in larger urban areas; and – CMF of 0.53 for main highways passing through smaller towns. • Gains space for other uses, including pedestrians, but often bike lanes or parking • Calms streets/reduces speeds, but effects may vary • Good practice guides caution for the need for site-specific assessment and describe many of the relevant considerations.
Narrow lane width	• Various—but none examining impacts on pedestrian crashes	• There seem to be no negative safety or operational impacts for lanes as narrow as 10 ft in urban areas, but cautions are urged with regard to large vehicle volumes (Petritsch n.d.). • No peer-reviewed studies identified assessing effects on pedestrian crashes • Study results are mixed with respect to effects on all crashes and may depend on how lanes are narrowed, why they are narrowed (e.g., if to add more motor vehicle lanes, speeds may increase), and adjacent lane and shoulder presence and width. • Speed effects may depend on road configuration, including adjacent lanes, shoulders, and other design and environmental characteristics (as well as enforcement).

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Table continued from p. 45

Design or Treatment	Area Types Studied	Key Measured Effects
Pedestrian overpass/bridge	One crash-based study from Japan Assessment of use by convenience measure study	• Reductions in crashes (if used) – CMF estimate of 0.10 pedestrian fatal/injury crashes – CMF estimate of 0.14 pedestrian total crashes – CMF 0.87, pedestrian total crashes when replaces unsignalized intersection • Best-practice guides (and research) suggest that convenience or time it takes to cross using bridge/tunnel versus at grade will affect how much pedestrians use an overpass and underpass. • Accessibility is also a key concern.
Pedestrian underpass/tunnel	See pedestrian overpass/bridge	See pedestrian overpass/bridge
Corridorwide speed calming	No studies identified assessing corridorwide safety effects on pedestrians Meta-analysis of multiple studies of areawide effects on all crashes	• Total crash reductions from 10% (main roads) to 25% (residential/local streets)—from meta-analysis of *areawide* traffic calming • The *HSM* provides estimates of effects of lowering speeds for all injury and fatal crashes (not just pedestrians) that could be used to generate estimates of effectiveness for speed calming measures.
Enhanced illumination at crossing	Urban, midblock; high nighttime collisions and motorists failing to yield	• CMF estimate of 0.58 for pedestrian nighttime crashes • CMF estimate of 0.73 intersection injury crashes • Improved yielding by drivers • Increase in pedestrians using crosswalk • In addition to safety and security considerations, light pollution and energy costs must be considered.

Note: See text for each countermeasure description and FHWA's *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes (*2013) for most CMFs and references; see Appendix B tables for study details including behavioral effects.

does not indicate the frequency or intensity of use of different treatments.

TABLE 8

SUMMARY OF STATES AND OF LOCAL JURISDICTIONS USING EACH OF THE DESIGN TREATMENTS TO IMPROVE THE SAFETY OF PEDESTRIAN CROSSINGS

Design Features	States Using Treatment	Local Jurisdictions Using Treatment
Raised median	88.9%	66.7%
Pedestrian refuge/median crossing island	97.2%	94.4%
Raised crosswalk or speed table	16.7%	72.2%
Curb extension/bulb-out	94.4%	94.4%
Reduce corner radius	63.9%	77.8%
Road diet	77.8%	72.2%
Narrow lane width	66.7%	77.8%
Corridorwide speed calming	33.3%	66.7%
Pedestrian overpass/bridge	83.3%	61.1%
Pedestrian underpass/tunnel	61.1%	44.4%
Enhanced illumination at pedestrian crossings	72.2%	77.8%
Total responding	36	18

The design treatments most often used (at least sometimes) by states and the local jurisdictions responding were the following:

- Pedestrian refuges/median crossing islands are used by 97% of states and 94% of select local jurisdictions.
- Curb extensions/bulb-outs are used by 94% of states and 94% of select local jurisdictions.
- Raised medians are used by 89% of states and 67% of local jurisdictions. However, a few agencies qualified that their primary reason for using medians was for motor vehicle reasons, or that this was the typical design for all arterial streets.
- Pedestrian overpasses/bridges are used by 83% of states and 61% of local jurisdictions.
- Road diets are used by 78% of states and 72% of local jurisdictions in the survey.

Other treatments were also fairly widely used, including the following:

- Enhanced illumination at pedestrian crossings are used by 72% of states and 78% of local jurisdictions.
- Reducing the corner radius is used by 64% of states and 78% of local jurisdictions.
- Pedestrian underpasses/tunnels are used by 61% of states and 44% of local jurisdictions.

The two types of speed- or traffic-calming measures asked about were used much less often by states than by the local jurisdictions, which may pertain to some extent to the types of roads managed:

- Corridorwide speed calming is used by 33% of states and 67% of local jurisdictions.
- Raised crosswalks or speed tables are used by 17% of states and 72% of local jurisdictions.

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TRAFFIC CONTROL DEVICES

If road designs are such that traffic speeds and conflict potential between motor vehicles and pedestrians are high, it becomes more important to select traffic control devices to safely manage the interactions of pedestrians and motorists. Treatment descriptions, safety effects, and use of various traffic control devices (TCDs) are described in the following sections, after some information regarding device activation and yielding laws that may affect use and success of different treatments. However, as previously discussed, there are many other factors, including enforcement and driving culture, that can affect success of treatments in different locales and area types.

Active Versus Passive Activation

Pushbuttons are generally more appropriate at locations or time periods with low or intermittent pedestrian activity (PBIC, *SRTS Guide, Traffic Signals,* n.d.). If used, they should be in clear view and meet accessibility requirements (Figure 14). With devices that are pedestrian activated, whether the pedestrian does in fact activate the device may have a great bearing on whether the motorists yield. Fitzpatrick et al. (2015) found that drivers were more than three times as likely to yield when an RRFB was activated than when it was not.



FIGURE 14 Pushbutton activation with direction and use information—West Grand, Michigan. *Source*: http://www.pedbikeimages.org, Dan Burden.

As pedestrian detection technologies improve, automated detection has the potential to remove much of the uncertainty around whether the pedestrian will activate a pedestrian signal (Figure 14). In addition, automated detection technologies can be used to extend the walk phase for slower pedestrians, further helping prevent conflicts. Concerns with reliability and maintenance issues may have limited U.S. jurisdictions' use of these technologies in the past. However, some international jurisdictions, including Britain, and more recently, Sydney, Australia, have extensive experience with using these technologies in Pedestrian User-Friendly Intelligent (PUFFIN) signals (Fischer et al. 2009; Thomas et al. 2015a). In the United States, Tucson has used PUFFIN technology in conjunction with PHBs. See PEDSAFE 2013, Automated Pedestrian Detection (Zegeer et al. 2013) for more information.

Pedestrians may also be more willing to pushbuttons at signal locations with PCSs in place. When a treatment gives more information to pedestrians, such as through the pedestrian countdown timers, there may be more incentive to push the buttons. Also, when a pushbutton activation lets pedestrians know that the signal call has been activated through a sound or a light, activation may be increased (Redmon 2005).

Stop Versus Yield Laws

State laws vary with regard to requirements for motorists to stop versus yield for pedestrians at or *in* uncontrolled crosswalks. Nine states and the District of Columbia have laws requiring motorists to stop when approaching a pedestrian in an uncontrolled crosswalk per a report by the National Conference of State Legislatures (2015). Most states require motorists to yield to pedestrians only *in* uncontrolled crosswalks, and states vary in the strictness of yielding laws as well (such as whether motorists are required to yield at unmarked crosswalks, or whether the pedestrian must be in the same half of the roadway, in the next lane, etc.). Research into the potential safety impacts of these different laws was not found. However, the differences in laws sometimes affect application of treatments. There is also reason to think that these laws may affect motorist and pedestrian understanding and interactions, including motorists giving way to pedestrians at crosswalks and consequently the amount of pedestrian delay at uncontrolled crosswalks (McGrane and Mitman 2013).

High-Visibility Crosswalks

Description and Purpose of Treatment

The 2009 *MUTCD* states that "marked crosswalks provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops" (FHWA 2009) (Figure 15). High visibility describes the crosswalk marking type that is usually ladder, continental, bar pairs, and triple four markings (Mead et al. 2014).

Summary of Effects

Studies have estimated high visibility crosswalks reduce pedestrian crashes by 48 percent in general (CMF of 0.52),

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and by 37 percent (CMF of 0.63) when applied in school crossing zones (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013 citing Chen et al. 2012, and Feldman, Manzi and Mitman 2010, respectively) but local effects may vary. High-visibility markings have also proved to be more readily detected by drivers and increase yielding, which may be especially important at uncontrolled locations (McGrane and Mitman 2013).



FIGURE 15 Bar-pair-style high-visibility crosswalk markings in Bainbridge Island, Washington, can help reduce wear from tire tracks. *Source*: http://www.pedbikeimages.org, Carl Sundstrom.

Use of High-Visibility Crosswalks

Nearly all jurisdictions use high-visibility crosswalks in some circumstances. One-fifth of jurisdictions responding to the question about where they have been applied indicated that they now use high-visibility crosswalks at all marked crosswalk locations. Others mentioned using these at some locations, such as areas with high pedestrian activity or downtown development districts, midblock or uncontrolled locations, high-speed or wide roads, high-priority intersections, or school zones/areas. One jurisdiction mentioned that it is currently updating its guidance but continues to prefer using them at select locations because of long-term maintenance costs.

Advanced stop/yield bars and signs were mentioned several times by agencies concentrating high-visibility crosswalks at midblock or uncontrolled locations. Other types of signs, signals, and warnings were mentioned, including RRFBs, overhead flashers and oversized signs, and R1-6a (in-street, stop for pedestrian) signs. One state also requires reflective pavement markers at midblock crosswalks.

Advance Stop/Yield Bars and Signs

Description and Purpose of Treatment

Advance stop or yield markings, used in conjunction with signs, are a type of pavement marking placed before a crosswalk on multilane roads to increase the distance at which drivers stop or yield to allow pedestrians to cross (Figure 16). The advance stop or yield line would be supplemented with "Stop Here for Pedestrians" or Yield Here to Pedestrians" signs (R1-5 or R1-5a) to alert drivers where to stop to let a pedestrian cross.



FIGURE 16 Advance yield bars used with "Yield Here to Pedestrians" (R1-5) sign in Milwaukee, Wisconsin. Note additional pedestrian warning sign and arrow at crosswalk. *Source*: PBIC (n.d.).

An advance stop or yield line placed 20 to 50 ft ahead of the crosswalk can reduce the likelihood of a multiple-threat crash at unsignalized midblock crossings. The line or markings encourage drivers to stop far enough in advance of the crosswalk that a pedestrian can see if a second motor vehicle is not stopping and be able to take evasive action, and can also increase the second driver's chances of detecting the pedestrian in time to stop. A setback of 30 ft for the line has been found to be a good distance for most purposes. Parking is also to be restricted between the stop or yield line and the crosswalk to allow for better visibility. See PEDSAFE, Advance Yield/Stop Lines (Zegeer et al. 2013) for more information.

Summary of Effects

A number of studies by Van Houten and colleagues have found reductions in conflicts with advance stop bars or yield markings and signs of various configurations and intensities of applications. Although the increases in percentages of motorists who yield or stop tends to be small, *the distance* at which motorists stop or yield has increased, which improves sight lines between motorists in other lanes and pedestrians and helps reduce the multiple-threat crash type (Malenfant

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and Van Houten 1990; Van Houten 1998; Van Houten and Malenfant 1992; Van Houten, Malenfant, and McCusker 2001; Van Houten et al. 2002). The addition of enforcement and educational measures may also improve the percentages of motorists who yield, as found in a study from three Canadian cities (Malenfant and Van Houten 1990). Other measures could also be tried to increase yielding. Crash-based evidence is not yet available, but NCHRP Project 17-56 aims to develop CMFs for advance stop/yield lines and three other treatments, including median islands, PHBs, and RRFBs.

Use of Advance Stop/Yield Bars and Signs

Nearly 90% of both state and local agencies responding indicated that they use advance stop/yield bars and signs.

This low-cost treatment combination can be viewed as a supportive device in that it has substantially increased stop/yield distances from uncontrolled crosswalks and reduced motor vehicle–pedestrian conflicts. The device on its own is not expected to gain much additional yielding on the part of motorists. Two agencies mentioned they use RRFBs and other treatments such as median islands, curb extensions, and lighting along with advance stop/yield bars and signs to improve conditions for pedestrians. One jurisdiction mentioned using advance stop/yield lines along with PHBs. Most of the remaining 19 jurisdictions that provided information mentioned using marked or high-visibility crosswalks, or signs and other kinds of flashers or warning signs, in conjunction with advance stop lines.

In-Roadway "Yield to Pedestrians" Signs

Description and Purpose of Treatment

In the roadway, "Yield to Pedestrian" signs are placed in the middle of an uncontrolled crosswalk, often but not always on crossing islands, and direct drivers to yield to crossing pedestrians (Figure 17).

Summary of Effects

The use of in-roadway "Yield to Pedestrians" signs has been found to increase motorist yielding at crosswalks substantially, whether signs are placed directly at the crosswalk or farther away. However, trends suggest that motorist yielding may be increased with signs placed directly at the crosswalk, by using multiple signs at the crosswalk, or at the crosswalk plus locations farther away. There is little information on effects on conflicts, but one study found no consistent effect on motorist and pedestrian conflicts. There is also limited evidence about whether more pedestrians use the crosswalks treated with these signs, or whether delay is reduced. A couple of studies have found evidence of significant traffic speed reductions, although one of these studies evaluated signs used in conjunction with removable islands. The use of signs along with PHBs also resulted in a higher yielding rate compared with PHBs alone or signs alone. Crash-based evidence of safety effects of these devices is also lacking. A further consideration noted by some studies is that the devices are damaged or removed in some cases.



FIGURE 17 In-roadway "Yield to Pedestrian" signs (R1-6 signs) used with high-visibility crosswalk, median island, and detectable ramps. *Source*: http://www.pedbikeimages.org, Lyubov Zuyeva.

Use of In-Roadway "Yield to Pedestrians" Signs

About 70% of states and local jurisdictions use in-roadway "Yield to Pedestrians" signs.

Pedestrian Warning Signs

Description and Purpose of Treatment

Advance pedestrian warning signs are typically used where pedestrian crossing are not expected. According to PEDSAFE, fluorescent yellow/green color is approved for pedestrian, bicycle, and school warning signs (FHWA 2009, Section 2A.11; Zegeer et al. 2013, PEDSAFE Signing) (Figure 18).

Summary of Effects

Signs in conjunction with other treatments or improved conspicuity through enhanced lighting treatments or both may improve driver yielding. Some treatments and studies have found improvements in pedestrian–vehicle conflicts, but results vary according to treatments and studies. In addition, signs alone may not bring yielding rates to very high levels. Crash-based evidence is lacking. Definite conclusions about use and optimal types and placement of signs are difficult to reach.

Use of Pedestrian Warning Signs

All 40 states surveyed and 88% of local jurisdictions apply pedestrian warning signs on occasion. Several mentioned

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that they use these at midblock or uncontrolled crossings; several indicated at all such crossings. Other locations mentioned were near bus stops; where there are high pedestrian volumes; near schools; or where sight distance issues, documented crashes, or conflicts exist. One jurisdiction indicated that it used custom-made Yield to Pedestrians signs before other treatments were available. Finally, several jurisdictions mentioned they use pedestrian warning signs in all settings, or at all marked crosswalks, and sometimes other locations (all-way stops and traffic signals).



FIGURE 18 Pedestrian crossing warning (W11-2 in foreground) with crossing sign and arrow pointing at crosswalk in background, Chapel Hill, North Carolina. *Source*: http://www.pedbikeimages.org, Dan Burden.

In-Pavement Flashing Lights (Associated with Crosswalks)

Description and Purpose of Treatment

In-pavement lights or flashing crosswalk warning systems are sometimes used to alert motorists to the presence of pedestrians crossing at uncontrolled locations. Both sides of the crosswalk are lined with encased raised pavement markers, which sometimes contain LED strobe lighting. The lights display outward in the directions of oncoming traffic and may be activated by passive detection of pedestrians waiting in the crossing area, or activated by pushbutton (Figure 19).

Summary of Effects

Effects on motorist speeds and yielding have varied widely across studies. Short-term improvements in motorist yielding have been reported, and were generally greater at nighttime for most locations. Yielding improvements tended to reduce over time. Although in some cases the treatment has been shown to also reduce vehicle approach speeds, a major drawback to this device is maintenance and the tendency for the installations to become damaged or malfunction (Thomas 2006).



FIGURE 19 In-pavement flashing lights at crosswalk. *Source*: U.S. Air Force photo, Jason Minto; Dover Air Force Base website (http://www.dover.af.mil/News/Article-Display/Article/230536/dover-installs-lighted-crosswalks).

Use of In-Pavement Flashing Lights

Several state and local jurisdictions mentioned having used these in the past, but that they are removing them as a result of unreliability, maintenance issues, and ineffectiveness compared with other TCDs. Concerns include the inability of following drivers to see the devices compared with overhead or side-mounted devices, and lack of visibility in daytime. One state mentioned it now preferentially uses PHBs or RRFBs.

Overhead or Roadside-Mounted Flashing Beacons

Description and Purpose of Treatment

Overhead and roadside-mounted pedestrian-activated yellow beacons are used to alert motorists that pedestrians are crossing the roadway (Figure 20).



FIGURE 20 Overhead flashing beacons used with crosswalk warning signs (W11-2A) and median island in Fargo, North Dakota. *Source*: http://www.pedbikeimages.org, Dan Burden.

Summary of Effects

Research has shown that overhead pedestrian signs with flashing beacons may encourage motorists to yield for pedestrians more often than when there are no signs (Mead et al. 2014, citing Nitzburg and Knoblauch 2001, Huang et

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al. 2000, and Van Houten et al. 1999). These positive effects, may, however, vary or be modest because (1) yellow warning beacons are not exclusive to pedestrian crossings, so drivers may not necessarily expect a pedestrian when they see a flashing beacon; and (2) motorists learn that many pedestrians are able to cross the road more quickly than the timing on the beacon allows and therefore may think the person has already finished crossing the road if a yielding or stopped car blocks the pedestrian from sight.

In field studies for *TCRP Report 112/NCHRP Report 562,* Fitzpatrick et al. (2006a) measured motorist yielding rates to "natural" population pedestrians from 36% to 62% at three pushbutton-activated sites, and ranging from 61% to 73% for passive/automatically activated overhead flashing beacons.

Overhead flashing beacons have sometimes, but not always, achieved increases in motorist yielding or other behavioral improvements. The varied types of devices studied and application with other warning signs and treatments and location types provides a limited basis for conclusions about safety and mobility effects for pedestrians.

Use of Overhead or Roadside-Mounted Flashing Beacons

About 80% of states, but only 41% of local jurisdictions, indicated that they currently sometimes use these types of beacons. Some jurisdictions use overhead or roadside-mounted flashing beacons to call attention to crossings on busy streets or high-speed or wide/arterial roadways with pedestrians crossing, school crossings, where a median island cannot be installed, or other areas with safety issues such as poor sight distance or conflicts. However, it appears these may be more of a "legacy" device. A number of jurisdictions indicated that they are no longer using overhead or roadside-mounted flashing beacons, but are now using RRFBs or PHBs in locations where they might have used the beacons in the past. One jurisdiction has, however, used them in advance of RRFBs. When asked about use of these devices, San Francisco practitioners responded, "Costs the same as installing a traffic signal but without the same safety benefits." Massachusetts indicated that these are no longer installed at new locations, and that eligible locations now tend to get RRFBs.

Rectangular Rapid Flash Beacon

Description and Purpose of Treatment

The rectangular rapid flash beacon device includes amber LED flashing lights installed to enhance pedestrian crossing warning signs at uncontrolled crosswalks (Zegeer et al. 2013, PEDSAFE, Rectangular Rapid Flash Beacon). The crosswalks should not be controlled by signals, stop signs, or yield control signs. RRFBs are placed on both sides of an uncontrolled crosswalk, below a pedestrian crossing sign, and above an arrow pointing at the crosswalk (Figure 21). The beacons differ from standard flashing beacons by using a rapid flash frequency (approximately 190 times per minute), brighter light intensity, and ability to aim the LED lighting. RRFBs can be automated or pedestrian actuated, and feature an irregular, eye-catching flash pattern to call attention to the presence of pedestrians. The RRFB was given interim approval as a crossing sign enhancement by the FHWA in 2008 (FHWA 2009). PEDSAFE indicates that RRFBs are good for two-lane streets but may be less suited for use on multilane roads because of the multiple-threat crash potential (Zegeer et al. 2013).

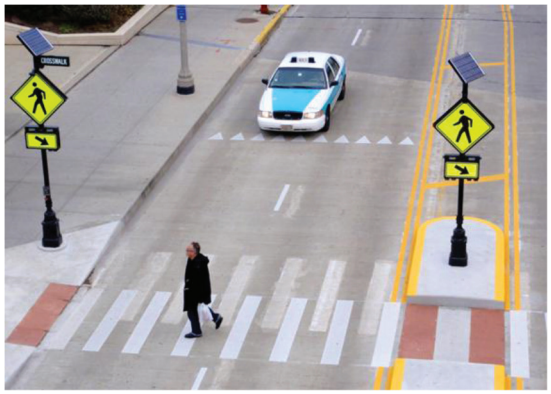


FIGURE 21 RRFB installation with median islands, advance yield bars, and high-visibility crosswalk in Chicago, Illinois. *Source*: Flickr.com, Steven Vance—Chicago.

Summary of Effects

Research has frequently demonstrated that installing RRFBs on roadside pedestrian crossing signs can significantly increase motorist yielding behavior at uncontrolled crossings from very low levels before installation. In general, yielding has risen to anywhere from 35% of drivers up to nearly 100% nighttime yielding when two beacons per approach direction were installed. Whether pedestrians activate the device, if pushbutton activation is required, also appears to influence outcomes (Fitzpatrick et al. 2014). A 2010 study for FHWA evaluated yielding when the devices were implemented on 22 multilane roads in St. Petersburg, Florida; Washington, D.C.; and Mudelein, Illinois, and documented both rapid and sustained increases in yielding from an average of 4% of drivers before treatment to an average of 84% across all sites at 2 years postinstallation (Shurbutt and Van Houten 2010). However, questions remain about the potential for multiple-threat collisions, which can occur when one driver yields and an approaching driver in another lane does not notice the pedestrian, who may be obscured by the yielding vehicle. Advance stop/yield bars can help reduce the potential by encouraging yielding farther back from the crosswalk.

Low levels of activation have also been reported (Hua et al. 2009). Foster et al. (2014) reported, however, that 94%

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and 83% of pedestrians at two sites in Portland, Oregon, activated the devices. Yielding may also increase over time as drivers become more familiar with the devices. Pedestrians may also be learning to use the devices more often, or there may be variation in results across geographic locations. Differences in enforcement and driving culture are also likely influences, although unequivocal evidence to support these conjectures is lacking.

There remains some uncertainty about the other factors that may affect success of this treatment. Other studies (not of RRFBs) have shown driver yielding is strongly affected by actual driving speed on approaches to uncontrolled crosswalks (Gårder 2004; Bertulis and Dulaski 2014). A 2014 Texas study indicated that yielding rates varied by city, and that wider roads may be associated with lower yielding rates at RRFB sites. However, this study also found that yielding appeared to be higher at locations with higher speed limits, within the range of those studied (30 to 45 mph) (Fitzpatrick et al. 2014). However, speed limits were overlapped somewhat with cities in the study, and actual driving speeds were not documented in Fitzpatrick et al. (2014). In addition, all of the Texas sites were also marked as school crossings, which may have contributed to higher yielding rates.

It is not known at present if there is some threshold level of use of RRFBs or of PHBs (see the section on PHBs) that may result in an increasing or diminishing effect for one of both of these types of devices. Fitzpatrick et al. (2014) suggests that cities with more of either type of device have better outcomes. However, it is important that the use of warning-type beacons be carefully considered in the context of both the particular location and the network as a whole, given that experts caution that overuse of signs and beacons may result in drivers learning to disregard such devices.

An active (at the time of this synthesis) NCHRP Project 17-56, "Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments," aims to validate safety benefits and develop crash modification factors for RRFBs and other pedestrian crossing treatments, including PHBs, advance stop/yield lines, and median islands.

St. Petersburg, Florida, reports the following experience: "Three PHBs were installed along a regional trail and we are only achieving 78% motorist yielding compliance to a solid red beacon. In contrast, RRFBs at 54 locations are achieving 90% + compliance."

Use of Rectangular Rapid Flash Beacon

Three-fourths of the states and 82% of the local jurisdictions have tried RRFBs, and some have quite a lot of experience with them. There were diverse practices in terms of the criteria or location types where RRFBs are being applied. It is clear that a number of jurisdictions are applying RRFBs on multilane roads. Some jurisdictions indicated they use the treatment at high-volume or high-speed intersections or at special situations (school crossings), whereas others specified crossings that require enhanced safety but do not have high speeds (which these jurisdictions indicated as 40 mph and up) and have adequate sight distance. Other jurisdictions, such as, for example, Ann Arbor, Michigan, appear to have a more standard policy, and may use RRFBs at all multilane unsignalized crosswalks, depending on available resources. St. Petersburg has installed 55 of the devices thus far, with 55 more scheduled, and is pleased with their success (see sidebar).

Other jurisdictions mentioned pedestrian volumes as a criterion, whereas Santa Barbara mentioned that it uses the 2005 Zegeer et al. report, *Safety Effects of Marked Versus Unmarked Crosswalks*, to identify locations that may require enhancements such as RRFBs. A couple of jurisdictions mentioned use of these devices in association with roundabouts. Studies from Texas indicate that RRFBs are being used sometimes on two-lane, two-way streets; one-way streets with four and five lanes; and two-way streets with up to six lanes. All of the studied locations are also in school zones, which the authors thought could have contributed to the high yielding rates in this study (Fitzpatrick et al. 2014). Advance yield bars and "Yield Here" signs were not described by the authors, but were present in images of the study locations in the article.

Treatments mentioned as being used with RRFBs include crosswalks or high-visibility and ADA-compliant crosswalks. Signs and advance warning signs were also mentioned by a few agencies. California uses advanced yield lines and signs (recommended at uncontrolled crossings to reduce multiple-threat crash risk), pedestrian crossing warning signs, and high-visibility markings in conjunction with RRFBs. Arizona; Kentucky; and Portland and Eugene, Oregon, also mentioned advance stop/yield lines. The state of Oregon sometimes uses median islands, curb extensions, and lighting; lighting was also mentioned by other jurisdictions. Michigan typically uses RRFBs and crossing guards at school crossing locations that would benefit from greater conspicuity. Virginia mentioned crosswalks and advance signing, as well as public awareness and stakeholder (e.g., law enforcement) awareness.

Pedestrian Hybrid Beacon (Formerly Called HAWK Signal)

Description and Purpose of Treatment

Pedestrian hybrid beacons, also known as HAWK beacons (short for High-Intensity Activated Cross Walk Beacon), are traffic control devices developed by Tucson, Arizona, traffic engineer Richard Nassi in the late 1990s as a means of providing safe pedestrian crossings where minor streets intersected with major arterials (Mead et al. 2014; Fitzpatrick and Park 2010a, citing Nassi and Barton 2008) (Figure 22). The devices

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have also been used at midblock crosswalks, and although there are pedestrian volume warrants outlined by the *MUTCD*, they are significantly lower than for traffic signals [Zegeer et al. 2013, PEDSAFE, Pedestrian Hybrid Beacon (PHB).



FIGURE 22 Pedestrian hybrid beacon signal, Tucson, Arizona. *Source*: http://www.pedbikeimages.org, Mike Cynecki.

A research effort carried out to assess alternative traffic control devices for Oregon resulted in a decision matrix between PHBs and RRFBs, or neither (Hunter-Zaworski and Mueller 2012, p. 78, report available at http://www.oregon.gov/odot/td/tp_res/docs/reports/2012/spr721pedreport.pdf).

At speeds greater than 40 mph, the decision guidance defaults to PHBs. Other criteria that are considered when speeds are at or below 40 include the existence or possibility of a median, visibility, whether there are more than three lanes or high traffic volume or both, and if the crossing is located in a high-risk surrounding environment (e.g., environments that include visual clutter and factors such as transit stops, retail and housing, schools, recreation and senior centers, or other vulnerable pedestrians).

The PHB signal beacons are located both on the roadside and on mast arms over the major approaches to a crossing location. The head contains two red lenses above a single yellow lens. The lights are normally dark, but when activated, the beacon first displays a few seconds of flashing yellow, followed by a steady yellow interval, and then "displays a steady red indication to drivers and a WALK indication to pedestrians, thereby allowing them to cross the major road while traffic is stopped" (FHWA 2014).

During the flashing pedestrian clearance interval, the red indications of the PHB changes to an alternating flash pattern to allow drivers to proceed after they have stopped, if the pedestrian has cleared the roadway, thereby contributing less to vehicle delay than traditional stop-and-go signals. The first PHB was installed in Tucson in 2000. The PHB was considered an experimental treatment until 2009, when it was included for the first time in the *MUTCD* (FHWA 2009). Pedestrian volume warrants are, however, considerably lower for implementing a PHB than for a traffic signal (Zegeer et al. 2013). See Tucson's 2014 ranking criteria for prioritizing crosswalks for treatment with PHBs in chapter five.

Summary of Effects

Motorist compliance or yielding at crosswalks is improved with PHBs compared with no control and compared with warning-type devices. Yielding has generally been consistently high, 90% and greater, at study locations with PHBs installed. A pedestrian crash CMF estimate of 0.31 (69% reduction), and a total crash CMF of 0.71 (29% reduction) were also derived from a 2010 FHWA study at 21 sites in Tucson (Fitzpatrick and Park 2010a, 2010b; Fitzpatrick et al. 2011). Fewer pedestrian conflicts have also been observed after PHB installation. In a study conducted by the Texas Transportation Institute, *wider* crossings were associated with *higher* yielding rates at sites in Texas, and posted speed did not have an effect on yielding, suggesting that this countermeasure is effective for wider and higher-speed locations. However, results from one study suggest that drivers might use the signal indications—especially when the beacon is in dark mode—to perceive that pedestrians are not present and increase speed. There is also presumably some risk of multiple-threat collision when the flashing red phase is active or if, as some states indicated in survey responses, drivers do not, in fact, stop. See results from more studies in Appendix B.

Use of Pedestrian Hybrid Beacons

Three-fourths of states and a smaller percentage of local jurisdictions (65%) indicate that they sometimes use PHBs. PHBs are being applied, according to responses, at midblock locations; at other (uncontrolled) approaches with known safety concerns or high crashes; or on roadways with multiple lanes, high speeds, and high user demand. Because these devices combine elements of stop and go with "warning" devices (with warrants outlined in the *MUTCD*), many jurisdictions' respondents mentioned the importance of high volumes of traffic or high demand by pedestrians, bicyclists, equestrians, or warrants as being a decision factor.

One PHB has been installed in San Francisco, a Vision Zero city, on a street managed by CALTRANS (state agency). However, "SFMTA [San Francisco Municipal Transportation Agency] feels that for the investment of funds, a full traffic signal is a better alternative at urban locations. Our engineers feel that Hawk signals [PHBs] prioritize auto service levels over pedestrian safety. It may be appropriate in a suburban context, but not in an urban context where there are higher volumes of people crossing, and reducing vehicle delay is not a priority."

At this point, SFMTA has no plans to implement PHBs on streets managed by the city.

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Also, as mentioned by a few agencies, PHBs are considered when warrants for regular traffic signals are not met. Two jurisdictions, Washington State and Oakland County, Michigan, have used PHBs at pedestrian crossings at roundabouts. Washington also mentioned using PHBs at limited-visibility locations.

Several jurisdictions are just beginning to look at using PHBs, or have a few in planning stages, and one state indicated that the device is counter to state law and is not used on the state system. When used, treatments sometimes used with PHBs include the following:

- California mentioned advanced stop bars, pedestrian countdown signal with accessible pedestrian signals (APS), and crosswalk stop on red (R10-23) sign.
- Virginia mentioned crosswalks and advanced signing, as well as public awareness and stakeholder (e.g., law enforcement) awareness.
- North Carolina mentioned public outreach and education.
- Oregon may use median islands, curb extensions, and lighting.
- Wisconsin has a draft policy in progress for PHBs and RRFBs.

Use of RRFBs and HAWK installations at multilane roundabouts were studied for the effects on safety and accessibility for blind persons at two multilane roundabouts in Oakland County, Michigan. The complete study is available on the Road Commission for Oakland County website at http://www.rcocweb.org/Lists/Publications/Attachments/126/HAWK%20Final%20Report%202011.pdf.

One agency mentions a point that public education and outreach may be important for newer (even if *MUTCD*-approved) types of devices, especially if they have not been used in an area. A Texas study cited earlier (in the RRFB section) also suggests that effects tend to be more positive in cities or areas with multiple installations of PHB devices compared with locations with one to few, suggesting a learning curve that education and outreach may help accelerate.

Other jurisdictions that have used the devices report favorable results: Scottsdale, Arizona, reports, "Our HAWKs are operating successfully and our RRFBs have been well accepted." Soon after meeting the minimum warrant of 20 pedestrians per hour and installing a PHB, the volume of pedestrians at the crossing increased to 360 per hour.

Scottsdale, Arizona, indicates: "The HAWK crossing Scottsdale Road for the new Scottsdale Quarter on the border of Phoenix and Scottsdale just met the pedestrian warrant of 20 pedestrians per hour. Only a month later there were 360 pedestrians in an hour and it went as high as 660 pedestrians per hour. This two-stage crossing treatment connects two major commercial centers in both cities," and the city deems the installation very successful.

Install Traffic Signal Without Pedestrian Countdown Signals

Description and Purpose of Treatment

Traffic signals are intended to create a gap for pedestrians to cross the road where they would otherwise experience safety issues, significant delay or other difficulties in crossing. Traditional signals with WALK/DON'T WALK pedestrian indications may remain for their useful lives, but pedestrian countdown signals should be installed for all new treatments. The MUTCD provides warrants for the installation of traffic signals based on pedestrian and motor vehicle volumes, but also describes special considerations. These include the lack of a signal possibly inhibiting "young, elderly, and/or persons with physical or visual disabilities" from crossing and/or "nearby facilities and activity centers" intended to serve these populations possibly generating demand so that counts may not accurately reflect pedestrian demand. Thus, engineering judgment is expected to consider pedestrian needs comprehensively (Zegeer et al. 2013, PEDSAFE, Traffic Signals). PEDSAFE also indicates that where pedestrians are regular and frequent, a pedestrian phase should be actuated automatically.

Summary of Effects

It is not clear how the use of a traditional walk/don't walk signal affects pedestrian crash risk for intersections without pedestrian signals, because the need for pedestrian signals may be much greater at some sites than others. More research is needed to better understand the effects of pedestrian signals, but it is clear that pedestrians may be confused at intersections with wide street crossings where no pedestrian signals (or inadequate crossing time or conflicts with turning vehicles) exist.

Certain types of traffic signal phasing, such as an exclusive phase for pedestrians or restricted left-turn phasing, have been found to reduce pedestrian–motor vehicle collisions, as compared with traditional concurrent signal phasing (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Harkey et al. 2008 and Chen et al. 2012). More information on other phasing or signal control strategies are described under the leading pedestrian interval countermeasure and right-turn-on-red restrictions.

Use of Installation of Traffic Signal Without PCS

Although several jurisdictions continue to have locations with signals that have not been updated yet, most jurisdictions are routinely replacing these, or have mostly done so with signals with pedestrian countdown signals (PCSs) in keeping with MUTCD guidelines. Only one jurisdiction mentioned that it sometimes installs signals without pedestrian countdown timers in locations with no pedestrian accommodation or connectivity and no indication of pedestrian demand, mostly in rural areas.

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Install Traffic Signal with Pedestrian Countdown Signal

Description and Purpose of Treatment

Countdown signals are indications designed to begin counting down at the beginning of the clearance interval (flashing "WALK"/"DON'T WALK") and can be on fixed-time or push-button operation (Figure 23). They indicate to the pedestrian how much time is left in the crossing phase. According to the *MUTCD*, countdown pedestrian indications are required for all newly installed traffic signals where pedestrian signals are installed. See PEDSAFE Traffic Signals, Pedestrian Signals, Pedestrian Signal Timing, and other signal-related countermeasures in PEDSAFE for more information (Zegeer et al. 2013).



FIGURE 23 PCS with countdown indicators. (Top) Countdown timer below walk/don't walk indicators, Washington, D.C. (Bottom) Side-by-side walk and countdown indicators, New York City. *Source*: Flickr.com, Eric Fischer (lower image modified by cropping).

Summary of Effects

A CMF of 0.75 for pedestrian crashes was developed from one study of the effects of replacing traditional walk/don't walk pedestrian signals with pedestrian countdown signal heads (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Markowitz et al. 2006). However, other studies have found more mixed results from widespread installation.

Another positive finding: motorist behaviors have not been shown, thus far, to be significantly negatively affected by information from the countdown timers. Pedestrians may or may not comply more often with the walk phase of the signal, and results are somewhat mixed as to whether they tend to be stranded less often in the crosswalk at a signal change.

Regarding crashes, as with traditional signals, safety benefits may be affected by the particular phasing and timing strategies used, such as allowing more pedestrian walk time (CMF = 0.49), or providing exclusive phases (0.65) (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Chen et al. 2012. These studies are also summarized in Appendix B of this study, under Install Traffic Signal with Pedestrian Countdown Signal. Also see the CMF Clearinghouse for more CMFs on signal phasing strategies. Other signal timing and traffic control strategies are covered under the leading pedestrian interval and no-turn-on-red restrictions countermeasures sections.

Use of Installation of Traffic Signal with PCS

Again, almost all the jurisdictions responding are using PCSs for replacements or at new signalized intersections with pedestrian indications or anywhere pedestrians are present. A couple of jurisdictions qualified that they use PCSs at locations near schools and other pedestrian generators, or at locations with crash histories or bike crossing improvement projects.

Leading Pedestrian Interval

Description and Purpose of Treatment

A leading pedestrian interval at a signalized intersection gives pedestrians anywhere from a 3- to 7-s head start before traffic is released by the parallel-path corresponding green signal. This treatment is basically intended to help enforce the pedestrian right of way and encourages turning motorists to yield to parallel-path crossing pedestrians by delaying the release of the motorists until pedestrians have established presence in the crosswalk (Zegeer et al. 2013, PEDSAFE Leading Pedestrian Interval).

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Summary of Effects

LPIs, which have been studied predominantly at high-pedestrian sites, are another countermeasure that has some crash-based evidence of effectiveness. A CMF of 0.95 (5% reduction) for pedestrian crashes was estimated for LPIs (FHWA, citing ITE Briefing Sheet 8, 2004), but a more recent study estimates reductions of 59% in pedestrian–vehicle crashes at 10 treated intersections (significant at the 95% confidence level) (Fayish and Gross 2010). Behavioral studies provide additional support for crash reductions, showing a reduction in conflicts with turning vehicles, particularly left-turning vehicles. RTOR restrictions may also be needed to further reduce conflicts and crashes with right-turning vehicles and improve ability of pedestrians to access the crosswalk when waiting on the curb in some situations such as intersections with high volume of right-turning vehicles (Hubbard et al. 2008).

Use of Leading Pedestrian Intervals

About 61% of states and 77% of local jurisdictions surveyed reported using LPIs. These are often used on a case-by-case basis, either where complaints come in or collision history or conflicts suggest their use. Maryland indicates, "Generally used where motorists are more aggressive and pedestrian volumes are not high enough to command that motorists yield. More specific guidance is currently being developed." Other situations mentioned were for crosswalks along approaches with heavy turning traffic; locations with dual turning movements, high pedestrian volumes, and high elderly population; or school crosswalks or other identified safety improvement locations. A couple of jurisdictions appear to be routinely employing LPIs or using them at locations with concurrent signal phasing and significant pedestrians or turning conflicts. Maryland indicates it is currently developing more specific guidance for implementation of LPIs.

Use of Pedestrian-Only Walk Phases

Pedestrian-only walk phases (0.65 CMF; *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Chen et al. 2012) typically have more limited use, and were primarily based on volumes of pedestrians. One state mentioned that these had been traditionally used at all signals, but that state is moving away from them to improve efficiency for all users.

Right Turn on Red Restrictions

Description and Purpose of Treatment

During the mid-1970s, a number of states in the eastern portion of the United States adopted the "permissive" type of RTOR that was already common in some western states. This approach allowed RTOR at all locations that were not otherwise marked by a prohibitory sign. Before making a RTOR, motorists are required to stop and yield to pedestrians, bicyclists, and oncoming vehicles.

No-turn-on-red restrictions are meant to keep motorists from turning right during red lights across the path of conflicting pedestrians, and are usually indicated through signs (Figure 24). Some communities are using active signs that can be adjusted for peak/nonpeak periods. Although laws require motorists to come to a full stop and yield to cross-street traffic and pedestrians before turning right on red, many motorists do not fully comply with the regulations, especially at intersections with wide turning radii. Motorists are often intent on looking for traffic approaching from their left and may not look for pedestrians approaching on their right. In addition, motorists often pull across the crosswalk to wait for a gap in traffic, blocking pedestrian crossing movements. In some instances, motorists simply do not come to a full stop (Zegeer et al. 2013, PEDSAFE Right-Turn-on-Red Restrictions). PEDSAFE also indicates that restrictions are to be considered where exclusive pedestrian phases or high pedestrian volumes are present.



FIGURE 24 No-turn-on-red time-based restriction in the District of Columbia. *Source*: Flickr.com, M.V. Jantzen.

Summary of Effects

Although collisions and injuries to pedestrians resulting from right turns on red usually make up a small percentage of pedestrian and bicycle crashes, both pedestrian and bicycle crash rates were observed to increase in several states following implementation of RTOR allowance. Pedestrian conflicts with right-turning vehicles that violate right-turn-on-red laws can be significant, given the high percentage of motorists that do not fully stop and the observed behavior of motorists to look only left before pulling out. Active signs may be more effective than static ones at inducing motorists to stop before turning right on red. In addition, time-related

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restrictions may be more effective than ones that call on the motorist to notice pedestrian presence (no RTOR when pedestrians present), but more evidence is needed regarding safety and mobility outcomes for pedestrians. NTOR has been estimated to reduce all crashes by about 3% (CMF = 0.97), but estimates of effects for pedestrians are not yet available (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Harkey et al. 2008).

Several agencies, including Ithaca, New York, and Charlotte, North Carolina, reported using dynamic no-turn-on-red signs. Charlotte has tried these in conjunction with a red arrow for right-turning lanes at busy intersections. They are activated by pedestrian pushbutton and hold the right-turning traffic while pedestrians cross. During peak hours when right-turning traffic cannot be held through the entire walk phase, they switch to a "Yield to Pedestrians" message. Oregon uses curb extensions, lighting, and LPIs along with NTOR.

Use of No-Turn-on-Red Restrictions

A high percentage of states (86%) and local jurisdictions (94%) use no turn on red (NTOR) on occasion. New York City has a citywide regulation restricting right turns on red. Most agencies that provided answers mentioned sight distance or vehicular sight distance as a main consideration for implementing NTOR restrictions. Others indicated they use or only use NTOR where there are high numbers of pedestrians or pedestrians/bicyclists (including where there are bike boxes or documented conflicts. A few agencies mentioned using NTOR at school crossings or other areas of special concern such as crossings that are also near a light rail light, at skewed intersections, or near freeway off ramps.

See a PEDSAFE case study on an inexpensive treatment used in Hoboken, New Jersey, for "daylighting" intersections—that is, reducing cars illegally parked too close to the intersection—available at http://pedbikesafe.org/PEDSAFE/casestudies_detail.cfm?CM_NUM=9&CS_NUM=74.

Parking Restrictions

Description and Purpose of Treatment

Vehicles that are parked too close to pedestrian crossings obscure the visibility of both drivers and pedestrians. This increases the risk of dart-dash-type pedestrian collisions at both intersections and midblock crosswalks. Eliminating parking from the roadway near a crossing can improve pedestrian and driver sight lines and make it easier for pedestrians to cross (Figure 25). It is important to install physical barriers to negate the possibility of illegal parking. The removal of parking spaces can also free up the roadway for other uses, such as curb bulb-outs/extensions, landscaping, or bicycle parking (Zegeer et al. 2013, PEDSAFE, Parking Restrictions). Typically, jurisdictions should restrict vehicles from parking within at least 20 ft of an intersection. In its *Urban Street Design Guide,* NACTO (n.d.) suggests 20–25 ft restricted areas.

Summary of Effects

One study estimated restricting parking near intersections to off street to yield a CMF of 0.7 in pedestrian crashes (*Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* 2013, citing Gan et al. 2005). About 75% of states and 88% of the local jurisdictions use parking restrictions in some instances. Oregon may use curb extensions, lighting, LPIs, medians, and RRFBs in conjunction with parking restrictions. Some jurisdictions mentioned using restrictions near both midblock and intersection crossings. One jurisdiction indicated that it would like additional guidance on using parking restrictions.



FIGURE 25 Parking restrictions improve sight lines between motorists and pedestrians near crosswalks. *Source*: PEDSAFE, Peter Lagerwey.

Summary of Effectiveness of Traffic Control Devices and Treatments

Table 9 provides an overview of pedestrian safety effects from evaluations of traffic control devices. When available, estimates of effects on pedestrian crashes are provided; sometimes estimates of total crash effects are included, especially when these are high-quality estimates. Often the known safety effects are only from observed behaviors measures

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TABLE 9
OVERVIEW OF STUDIES AND FINDINGS FOR TRAFFIC CONTROL DEVICE TREATMENTS

Design or Treatment	Area Types Studied	Key Measured Effects
High-visibility crosswalks	General urban crossings, urban school zone crossings; behavioral effects also studied at university campus midblock locations	• CMF 0.52 pedestrian crashes • CMF 0.73 pedestrian crashes in school zones • High-visibility markings have also proved to be more readily detected by drivers and to increase yielding.
Advance stop/yield bars plus signs	Mostly multilane uncontrolled crossings in urban areas. One study included rural pedestrian areas where pedestrian crashes had occurred.	• Motorist yielding/stopping distance increases at uncontrolled locations. • Pedestrian–motor vehicle conflicts decrease substantially at uncontrolled locations. • Generally only small increases in motorist yielding, unless combined with enforcement and educational measures. Other engineering measures may also increase yielding in association with the treatment, but the evidence base is thin. • Driver yielding, vehicle stop position, or pedestrian–vehicle conflicts may not be affected at signalized locations. • Crash-based evidence is unavailable at present.
In-roadway "Yield to Pedestrians" sign	Uncontrolled midblock and intersections; multilane; unknown number of lanes; state highways; one-way and two-way streets	• Substantial increase in motorist yielding at all types of crosswalk locations studied compared with no signs • Trends suggest motorist yielding may be highest with signs placed directly at the crosswalk, compared with farther away, or by using multiple signs at the crosswalk with or without signs at locations farther away. • There is little information on effects on conflicts. • There is also limited evidence about pedestrian mobility/delay effects or changes in pedestrian behaviors. • Traffic speed reductions have been observed in two studies, although one of these combined signs with removable refuge islands. • The use of signs along with PHBs also resulted in a higher yielding rate compared with PHBs alone or signs alone. • Crash-based evidence is unavailable at present. • Prevalence of damage or device removal may affect the benefits.
Pedestrian warning signs	Varies	• Signs, especially in conjunction with other treatments or improved conspicuity through enhanced lighting treatments may improve driver yielding. • Some treatments and studies have found improvements in pedestrian–vehicle conflicts, but results vary according to treatments and studies. • Signs alone may not bring yielding rates to very high levels. • Definite conclusions about signs and types and placement of signs for maximal effectiveness for different types of locations are difficult to reach. • Crash-based evidence is unavailable at present.
In-pavement flashing lights (associated with crosswalks)	Mix of urban and suburban locations, including midblock, T-intersections; road types from local/campus to undivided and divided arterials	• Motorist yielding generally improved, but often to much less than 50%. • Speed results varied. • Yielding rates have tended to degrade over time. • Nighttime yielding may have improved by a larger percentage than daytime, but initial nighttime rates were usually very low. • Treatment not sufficient to channelize pedestrians to the crossing in some situations • Varied study locations and conditions, but no studies have compared effects in different environments • Crash-based evidence is unavailable.
Overhead or roadside-mounted flashing beacon	Urban and suburban uncontrolled crosswalks	• Some improvements in motorist yielding may be observed; possibly higher in conjunction with other treatments. • Crash-based evidence is unavailable.
Rectangular Rapid Flashing Beacon	Urban and suburban uncontrolled crossings, including one trail crossing	• Significant increases in motorist yielding behavior at uncontrolled crosswalks up to high rates (90% and above) in many locations, including at multilane sites, but yielding rates as low as 34% in some cities • Variations in outcomes may relate to time since installation, city of implementation, number of treatments in a city, width of crossing (and possibly number of lanes), traffic speed, and whether the beacon is activated • Higher speed limits (within the range of those studied, 30–45 mph from Texas sites) were associated with slightly higher rates of yielding at 22 sites in three cities; however all sites also had "School Zone" signs. • Crash-based evidence is unavailable at present. • Concerns about multilane use, potential multiple-threat crash situation

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Design or Treatment	Area Types Studied	Key Measured Effects
Pedestrian hybrid beacon (formerly called HAWK signal)	Urban/suburban midblock crossings and uncontrolled intersections	• 0.31 CMF pedestrian crashes • 0.71 CMF all crashes • Increase to high rate of motorist yielding/compliance at crosswalks—generally 90% and higher • Wider crossing distance was positively associated with driver yielding in a Texas study of 32 sites in four cities.
Install traffic signal without pedestrian countdown signal	Varied intersections in urban areas	• Exclusive phasing or restricted turn phases provide safety benefits to pedestrians.
Install traffic signal with pedestrian countdown signal (PCS)	Varied intersections in urban areas	• CMF of 0.75 for pedestrian crashes • Other crash effects also reported mixed results on crash effects of widespread implementation of PCS (replacing traffic signals without PCS) – Nonsignificant, slight increase in pedestrian collisions when PCS signals installed at formerly nonsignalized locations • CMF of 0.65 for pedestrian crashes, with exclusive pedestrian phase • Giving pedestrians more time in pedestrian walk phase associated with safety (and mobility) benefits • Drivers do not appear to increase their speed on a late green (per information on pedestrian countdown). • Pedestrian compliance starting on "WALK" indication—mixed results • Pedestrians remaining in crosswalk at signal change to green for opposing traffic—mixed results
Leading pedestrian interval	Varied signalized intersections of urban, suburban, and small town thoroughfares	• 59% statistically significant reduction in pedestrian–vehicle crashes at 10 treated intersections (CMF of 0.41) • Reduced conflicts, especially with left-turning motorists • RTOR restrictions may also be needed to reduce conflicts and crashes with right-turning vehicles.
"No turn on red" restrictions	Varied signalized intersections in urban and suburban locations	• 0.97 CMF all crashes; no crash evidence for pedestrian crashes exclusively • Active signs may be more effective than static ones at inducing motorists to stop before turning right on red. • Time-related restrictions may be more effective than ones that call on the motorist to notice pedestrian presence (no RTOR when pedestrians present).
Parking restrictions	One study	• One study estimated restricting parking near intersections to off street to yield a CMF of 0.7 in pedestrian crashes.

Note: See text for description of each countermeasure and *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* (FHWA 2013) for most CMFs and references; see Appendix B tables for study details including behavioral effects.

TABLE 10

SUMMARY OF STATE AND LOCAL JURISDICTION USE OF TRAFFIC CONTROL DEVICES TO IMPROVE PEDESTRIAN SAFETY AT CROSSINGS

Traffic Control Devices	States Using Treatment	Local Jurisdictions Using Treatment
Pedestrian warning signs	100%	88.2%
Traffic signal with pedestrian countdown signal	97.3%	100%
High-visibility crosswalks (e.g., continental, zebra, bar pairs)	97.3%	100%
Advance stop/yield bars and signs	89.2%	88.2%
"No turn on red" restrictions	86.5%	94.1%
Overhead or roadside-mounted flashing beacon	78.4%	41.2%
Rectangular rapid flashing beacon	75.7%	82.4%
(Pedestrian) hybrid beacon (formerly called HAWK signal)	75.7%	64.7%
Parking restrictions	75%	88.2%
In-roadway "Yield to Pedestrians" signs	73.0%	70.6%
Leading pedestrian interval	62.2%	76.5%
Pedestrian-only walk phase or pedestrian scramble	43.2%	52.9%
Install traffic signal without pedestrian countdown signal	18.9%	11.8%
In-pavement flashing lights (associated with crosswalks)	16.2%	0
Total responding	37	17

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such as motorist yielding, speed, or pedestrian delay or compliance with crosswalks, because as mentioned previously, crash-based estimates of pedestrian safety effectiveness require many study locations and robust analysis methods.

See Appendix B for tables with summaries of each study reviewed for each treatment, including crash-based and behavioral effects of the treatments studied. Also see the Toolbox of Countermeasures and *Their Potential Effectiveness for Pedestrian Crashes* (2013), which summarizes most CMFs included, and provides links to the original studies.

SUMMARY OF APPLICATION OF TRAFFIC CONTROL DEVICES

Table 10 summarizes the responses for which traffic control devices are used by jurisdictions, by type of jurisdiction. Recall that the local jurisdictions surveyed were a select sample of cities thought to have good practices in place. Washington, D.C., responses are included with the states. Most traffic control devices were used, at least sometimes, to enhance pedestrian crossings. The treatments most often used were the following:

- Pedestrian warning signs are used by all the states responding and 88% of the local jurisdictions.
- Traffic signals with pedestrian countdown timers (as currently recommended in the *MUTCD*) are used by nearly all states (97%) and local jurisdictions (100%).
- High-visibility crosswalk markings are used by 97% of the states and 100% of the local jurisdictions.
- High-visibility crosswalks are also used by nearly all states that responded (97%), and by all of the local jurisdictions that responded.

The local jurisdictions responding tended to make less use of overhead beacons (41% of those responding) than states (78%), with some cities indicating that they cost nearly the same as a traffic signal, but are much less effective, or that RRFBs are now being used where overhead beacons might formerly have been used.

Among the treatments least often used were traffic signals without pedestrian countdown signals (19% of states and 12% of local jurisdictions responding). Another treatment seldom being used at present, according to these jurisdictions, is in-roadway flashing crosswalk lights (16% of states and none of the set of local jurisdictions).

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CHAPTER FIVE

EXAMPLES OF GUIDANCE TOOLS AND ORIGINAL CASE EXAMPLES ON PROVISION OF SAFER PEDESTRIAN CROSSINGS

EXAMPLES OF STATE AND LOCAL JURISDICTIONS CROSSING TREATMENT GUIDES

A number of local jurisdictions as well as a few states have developed guidance to help practitioners standardize their approaches and considerations for determining appropriate actions in regard to pedestrian crossings.

Boulder, Colorado, crossing treatment guidance was updated in 2011 to reflect current research including evaluations and experiences with treatments in that city (City of Boulder Transportation Division 2011). A number of jurisdictions besides Boulder have found value in the guide, as mentioned by survey respondents, and it is summarized here using information directly from the guide.

A flowchart and guidance for North Carolina DOT was rolled out in 2015, following pilot trainings and feedback from across the state. A summary of that guide is also provided following the description of the Boulder guide. Again, the information presented comes directly from the report and flowchart.

Finally, because many jurisdictions are interested in how to assess locations for PHBs, Tucson, Arizona, which first implemented PHBs as an experimental device in the 1990s, provided the comprehensive criteria and ranking weights it uses to assess locations for PHBs.

Boulder, Colorado—*Pedestrian Crossing Treatment Installation Guidelines* (2011)

See https:/www-static.bouldercolorado.gov/docs/pedestrian-crossing-treamtment-installation-guidelines-1-201307011719.pdf.

In November 2011, the city of Boulder updated its criteria, procedures, and policies for the installation of pedestrian crossing treatments. The guide is intended to help assist the city with long-established goals to provide safe and efficient pedestrian facilities that will help its goal to reduce auto-dependency. The decision to travel as a pedestrian is in part subject to the pedestrian's ability and perceived ability to safely and efficiently cross roadways along the travel route. The new guidelines combine data collected for the previous *1996 City of Boulder Pedestrian Crossing Treatment Warrants* document and new data collected for the 2011 updated document. The new guide proposes updated pedestrian crossing treatment criteria and procedures, which are selected using a flowchart and decision matrix approach, and identifies specific treatments that are applicable for the range of pedestrian and vehicle volumes, types, speeds, and roadway geometry.

Since 1996 new studies and research have become available, which has allowed the city to update its approach toward pedestrian crossing treatments and safety. The city has used results from Zegeer et al. (2005) *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines,* as well as 14 years of data collected at 40 locations with a variety of treatments to outline a new process for selecting and evaluating treatments. Data collection has taken place on certain commonly applied treatments that include enhanced signage, pedestrian-actuated flashing signs, and raised crossings on right-turn bypass islands. These have been installed at two-lane and multilane intersection and midblock crossings. Results have revealed that while the devices have typically increased driver yielding, some treatments have also led to higher vehicle-to-vehicle and vehicle-to-pedestrian crashes at multilane high-volume locations. The combination of these results and recent national and international research was used to create a "consistent procedure for considering the installation of crossing treatments where needed on a case-by-case basis in the City of Boulder. Implementation of crossing treatments will require funds that could potentially have been spent on other transportation system improvements, and, therefore must be considered carefully in the funding allocation process" (City of Boulder Transportation Division 2011, iv).

The new evaluation procedure involves a four-step process:

Step 1—Identification and Description of Crossing Location: The pedestrian crossing location site characteristics should be identified. These include the major and minor street of the crossing, if the crossing connects both ends of a multiuse path, the posted speed along the major street, and any existing traffic controls or crossing treatments, markings, lighting, or relevant physical features. If the crossing connects both ends of a multiuse path, then minimum pedestrian volume requirements are not required to be met to apply prescribed treatments.

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Step 2—Physical Data Collection: This involves determining the existing roadway configuration, number of lanes, presence of a median, and presence of and distance to the nearest marked or protected crossing, and measuring the stopping sight distance on all vehicular approaches to the crossing. If the sight distance is less than eight times the posted speed limit, then removal of obstructions or lowering the speed limit or both would be considered.

Step 3—Traffic Data Collection and Operational Observations: This involves the collection of pedestrian volumes during peak hours, differentiated by important locational features like proximity to schools, and separate counts for pedestrians and bicyclists, elderly and young, and disabled pedestrians. Hourly and average daily traffic counts of vehicles also should be accomplished. Finally, specific traffic flow and operational observations are to be recorded, which include significant queuing, vehicle types, and directionally specific queues.

Step 4—Apply Data to Flowchart and Decision Matrix: Formal fill-in-the-blank worksheets are provided that allow the recording of the data in Steps 1–3. Once these data are gathered, they can be used to apply a flowchart process and decision matrix to determine the proper type and implementation of specific crossing treatments.

The flowchart first asks if the crossing is at a controlled or uncontrolled location. Then, through a series of yes-or-no answers to specific questions regarding site data collected in Steps 1–3, multiple treatments or actions are determined (Figure 26).

Possible treatments or actions at uncontrolled crossing sites include the following:

1. No action recommended
2. Consider unmarked pedestrian crossing facilitation
3. Direct pedestrians to nearest marked or protected crossing
4. Consider HAWK, traffic signal, or grade-separated crossing
5. Remove sight distance obstructions or lower speed limit, or both
6. Go to criteria for crossing treatments and uncontrolled locations decision matrix.

Possible treatments or actions at controlled crossing sites include the following:

1. No action recommended
2. Install marked crosswalk
3. Install marked crosswalk with school crossing sign on mast arm
4. Install marked crosswalk with advanced pedestrian signs

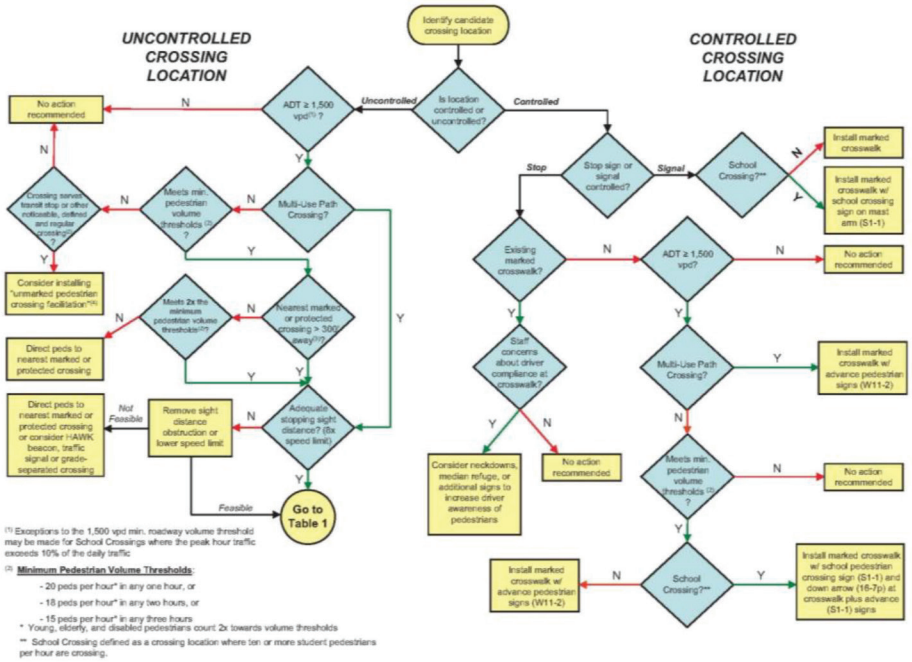


FIGURE 26 Flowchart for pedestrian crossing treatments—uncontrolled or controlled crossing location. *Source: Pedestrian Crossing Treatment Installation Guidelines,* City of Boulder Transportation Division (2011).

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5. Consider neck downs, median refuge, or additional signage to increase driver awareness

6. Install marked crosswalk with school pedestrian crossing sign and down arrow at crosswalk, plus advance signs.

A decision matrix is to be used for identifying treatments at uncontrolled locations. It uses roadway configurations, presence of refuge islands, number of lanes, vehicle volume per day, and posted speed to identify treatments types. See Table 1 in Boulder's guide, available at https:/www-static.bouldercolorado.gov/docs/pedestrian-crossing-treamtment-installation-guidelines-1-201307011719.pdf.

Several overall issues are to be analyzed in addition to the flowchart and decision matrix process. These include the stipulation that treatments would not be included at locations with less than 1,500 vehicles per day with the exception of school crossing locations where peak hour traffic exceeds 10% of ADT. There is also a minimum threshold of roughly 20 pedestrians per hour, where pedestrian crossing treatment should be applied. This has exceptions for the young and elderly and school crossings at 18, 15, and 10 per hour.

Each possible pedestrian treatment is defined in terms of what it must include each time it is installed. Pedestrian signals, HAWKs, and RRFBs also have further selection criteria detailed by linear graphs with detailed thresholds based on total pedestrians per hour, speed limits above 35 mph and at or below 35mph, and total vehicles per hour (see Figure 27).

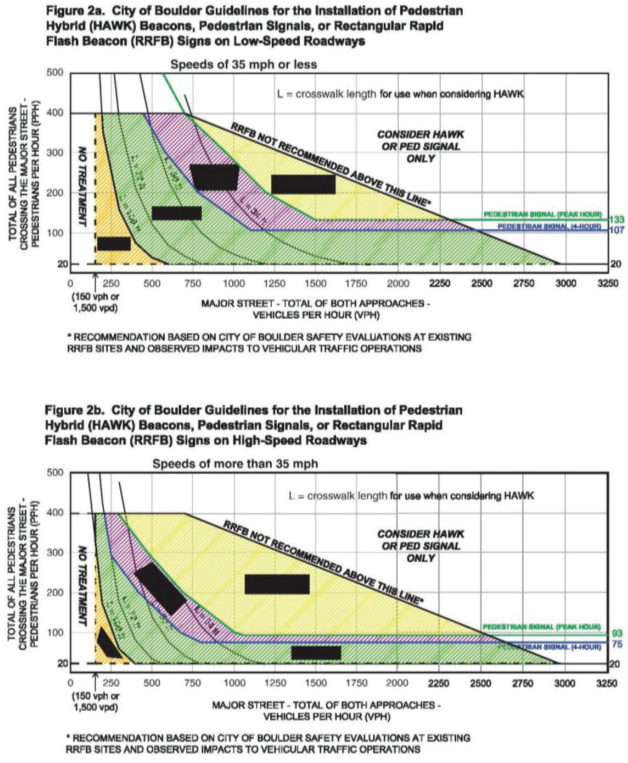


FIGURE 27 Pedestrian signal, RRFB, PHB-HAWK selection line graphs for speeds of 35 mph and less (top), and speeds of more than 35 mph (bottom). *Source: Pedestrian Crossing Treatment Installation Guidelines,* City of Boulder Transportation Division (2011).

Finally, supplemental policies provide overall guidance. These include details on adequate crosswalk lighting, avoiding overuse of crossing treatments, multiuse path crossing signage and crosswalk marking requirements, textured and colored pavement treatment details, accessible crosswalk requirements, use of raised crosswalks at right-turn bypass islands, and the removal of treatments.

This process has been developed toward the city's overall goals of providing safe and effective pedestrian crossing treatments and continuing to evaluate and improve its existing network, and doing so within the bounds of the financial and physical constraints for implementation. The data collection, flowchart, decision matrix, and supplemental policies are based on recent state-of-the-practice research as well as local data collection results over the past 14 years at 40 sites. The guidance helps simplify the process for choosing the most effective treatments depending on the relevant site-specific characteristics of individual locations.

North Carolina Department of Transportation (NCDOT)—Pedestrian Crossing Guidance and Flow Chart, Schroeder et al. (2015)

See https:/connect.ncdot.gov/resources/safety/Teppl/Pages/Teppl-Topic.aspx?Topic_List=P37.

In April 2015, NCDOT released a Pedestrian Crossing Guidance Flow Chart designed to provide a systematic process for engineers and planners to use in the evaluation of which crossing locations warrant facilities, and what kinds of enhancements would be provided in a Complete Streets context. In particular, this research focused on guidelines for NCDOT to evaluate the feasibility of including crosswalks or pedestrian signalization or both at signalized intersections and marked crosswalks on the approaches of uncontrolled intersections (Schroeder et al. 2015).

The proposed flowchart process is to be used in conjunction with field visits to verify site characteristics and gather data. Engineering judgment is to be applied with flowchart use. Crossing locations within school zones are beyond the scope. A 95-page guide supplements the flowchart with supporting information, warrants, images, and references.

The flowchart is to be used when citizen or municipal requests are made, during development of pedestrian or greenway plans, upon identification of a pedestrian crash hot spot, as part of systematic reviews of existing crossing locations, and as a component within an established operations and maintenance assessment process.

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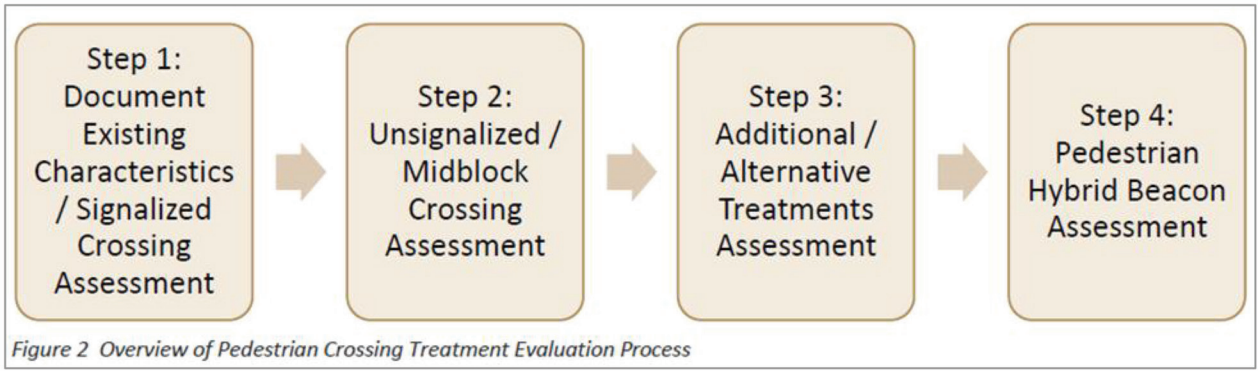


FIGURE 28 Overview of NCDOT four-step assessment process. *Source*: Schroeder et al. (2015).

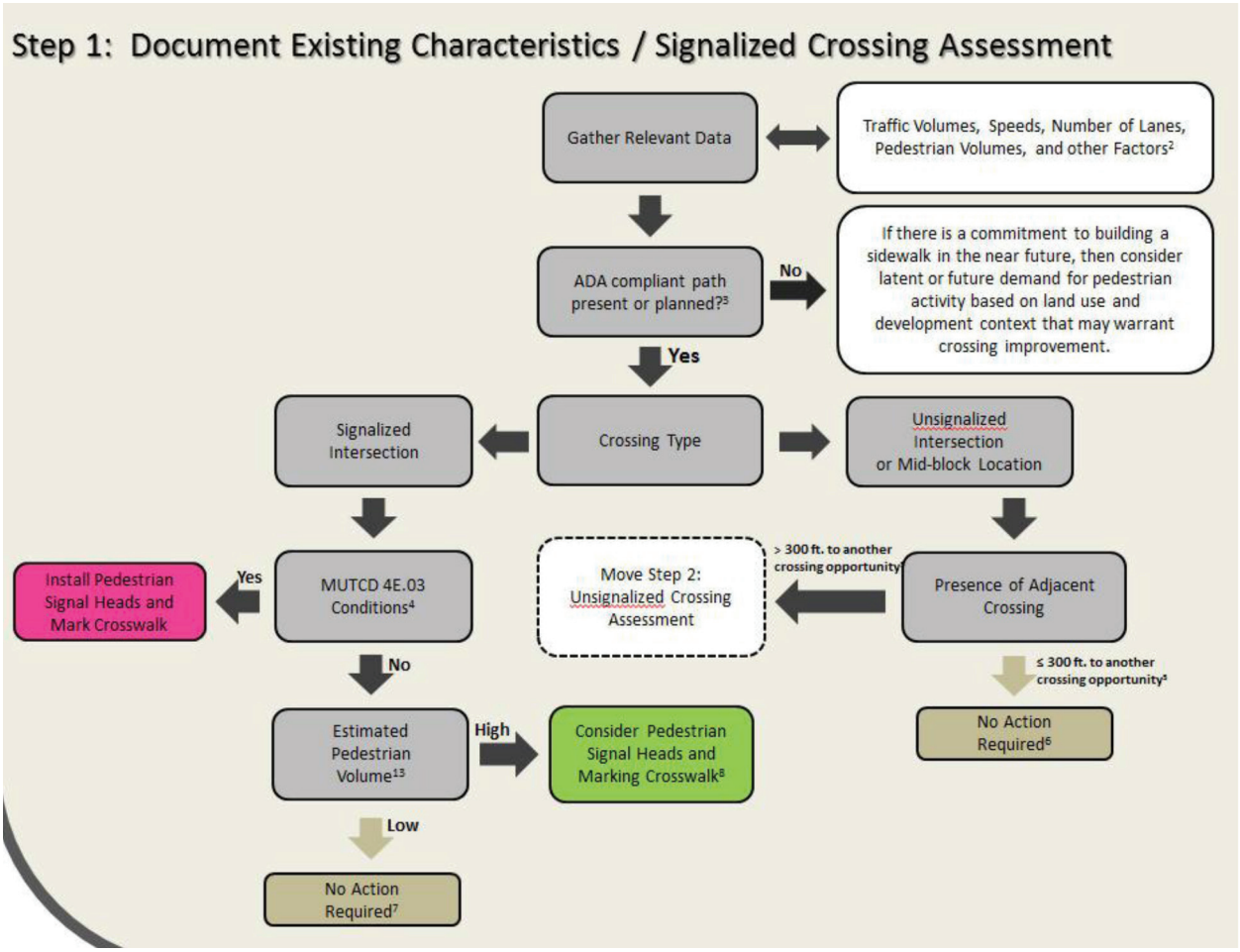


FIGURE 29 NCDOT Flow Chart Step 1. *Source*: Schroeder et al. (2015).

Important data variables to be gathered at crossing locations are traffic volume, speed limit, operating speed, quantity and type of pedestrian activity, pedestrian crash history, roadside features and conditions, area factors, and signing or other traffic control device options. The flowchart is broken up into four steps (Figure 28).

Step 1—Document Existing Characteristics/Signalized Crossing Assessment: This step focuses on whether to provide pedestrian signals at signalized crossings. The first action in Step 1 is to gather relevant data, which includes the previously listed important variables. In addition, other data variables to be included are sight distance restrictions, driver yielding rates, pedestrian compliance, crash history, heavy truck traffic, lighting, proximity to transit stops, special pedestrian populations (e.g., children and elderly), future projected traffic or pedestrian volumes or both, and future projected land use changes, growth, or development patterns (Figure 29).

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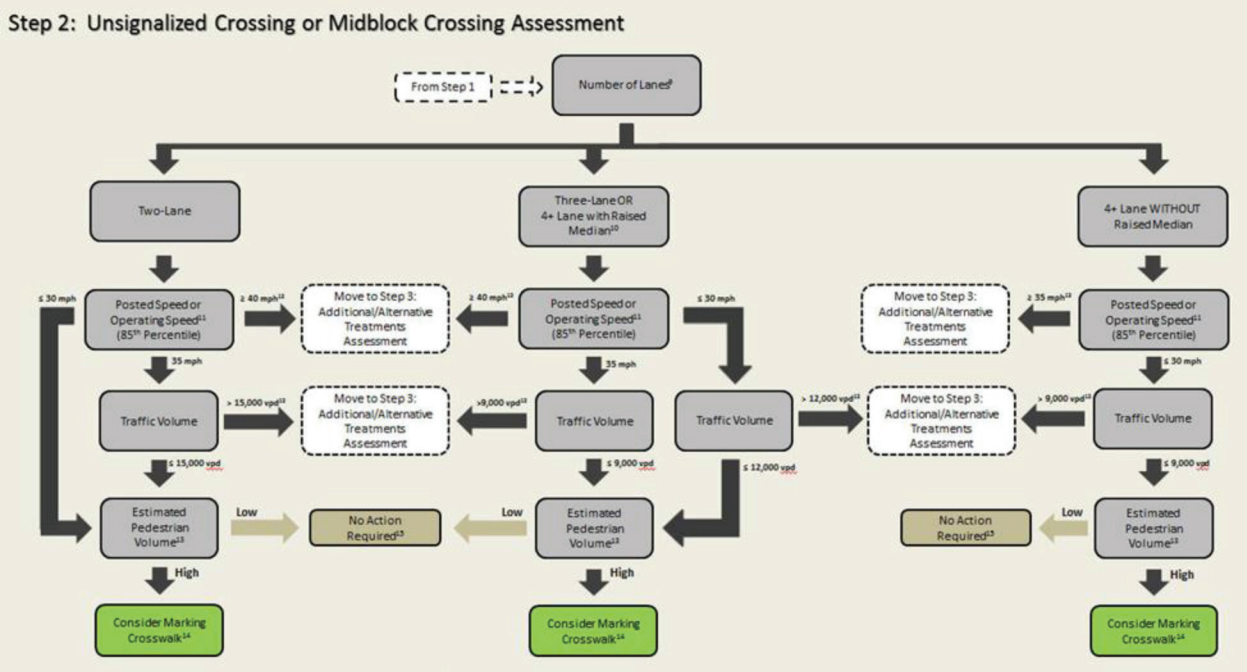


FIGURE 30 NCDOT Flow Chart Step 2. *Source*: Schroeder et al. (2015).

In the process of moving through the flowchart in Step 1, possible outcomes could be no action required, to install pedestrian signal heads, to consider installing signal heads, or to move to Step 2 of the flowchart. When estimating pedestrian volume, choosing an appropriate low-volume threshold is required based on site characteristics. Issues include if the crossing location is not near high pedestrian trip generators, does not connect complementary land uses, or has less than 25 pedestrians per hour during peak hours or less than 100 pedestrians per day, or if there are significant populations of children and elderly pedestrians.

Step 2—Unsignalized/Midblock Crossing Assessment: If the location is an unsignalized intersection or midblock location, Step 2 begins with determining the number of lanes, the posted or operating speed, vehicle traffic volumes, and pedestrian volumes. Possible outcomes include no action required, consider marking the crosswalk, and moving to Step 3, which addresses treatments in addition to or as an alternative to marked crosswalks (Figure 30). Number of lanes does not take into account lane width or on-street parking and bike lanes that increase crossing distance. Two-way center turn lanes are to be counted as one lane when determining lane count. Most sites can use the posted speed limits; however, when there is concern that 85th percentile operating speeds may be near or exceed speed thresholds for treatment selection, a speed study is to be conducted to determine the actual 85th percentile operating speed. Presence of raised medians is also to be considered. Multilane undivided roads or painted medians are considered the same as no median. It is important that engineering judgment be used to determine which marking pattern is most appropriate, but midblock crosswalks are always to be marked with high-visibility patterns. School crossings as well as locations where pedestrians may not be expected by drivers can also use high-visibility markings.

Step 3—Additional/Alternative Treatments Assessment: If it is determined in Step 2 that the location requires treatments in addition to or in lieu of marked crosswalks, then Step 3 begins with determining if the posted or 85th percentile operating speed is less than or equal to 35 mph or greater than 35 mph (Figure 31). Pedestrian volumes, *MUTCD* signal warrants, estimated pedestrian delay, and motorist compliance are also important variables. Potential outcomes include considering geometric improvements, signal installations, marked crosswalks, supplemental treatments, or moving to Step 4, which assesses the possibility for PHBs.

Possible geometric improvements require further engineering studies to determine which crossing geometries are to be implemented. These may include installation of median refuge islands, curb extensions, traffic-calming devices, treatments to minimize crossing distance and make the crossing perpendicular to traffic, and treatments that enhance visibility of and by the pedestrian by removing obstacles to pedestrian and driver lines of sight. Depending on if *MUTCD* Warrants 4 or 5 are met, traffic signal installation may be appropriate but not required. Engineering studies should be used to determine the appropriate traffic signal pedestrian enhancement. Total pedestrian delay for the approach is determined using Equation 18-21 of the *2000 Highway Capacity Manual* and multiplying that by the peak-hour pedestrian volume. Motorist compliance is considered high if driver yielding to pedestrians rates in the area are high. Speed limit, motorist compliance, and total pedestrian

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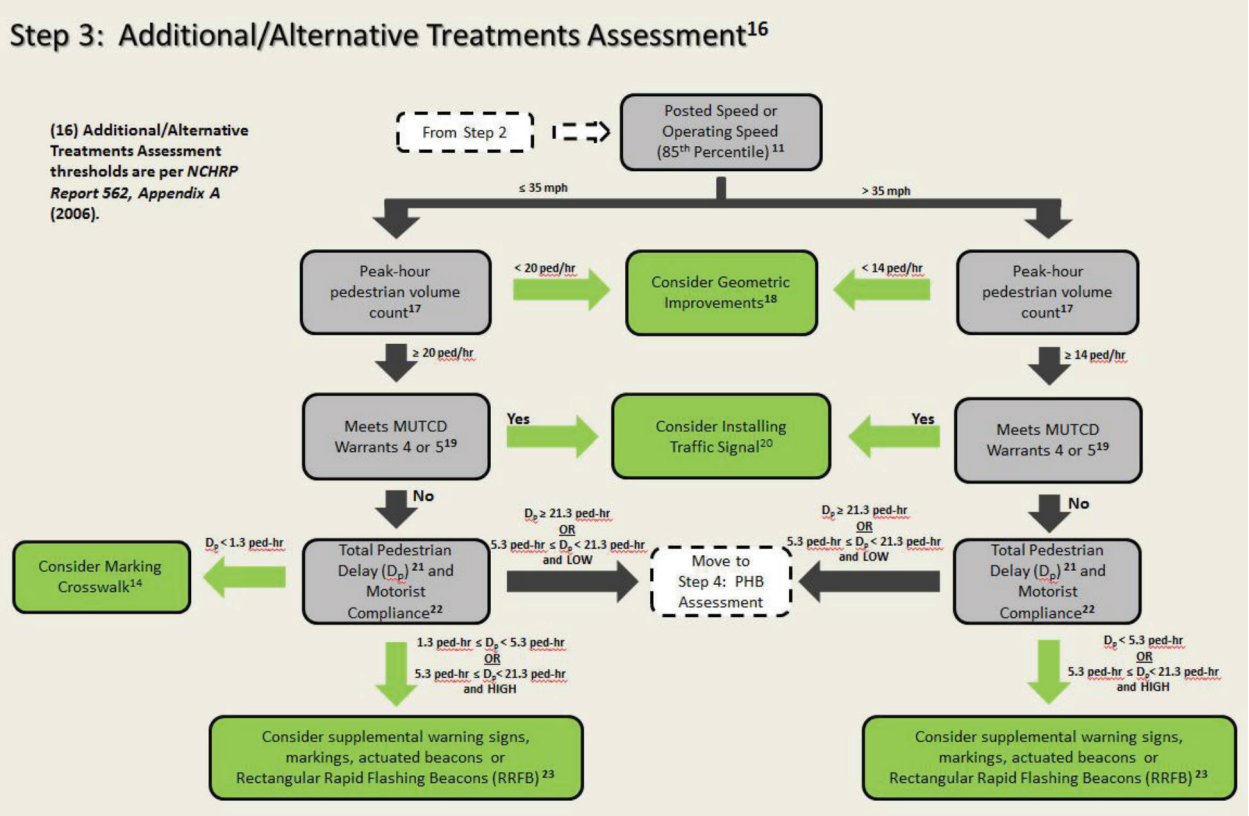


FIGURE 31 NCDOT Flow Chart Step 3. *Source*: Schroeder et al. (2015).

delay is used in a decision matrix to decide whether only marking the crosswalk would be considered; if supplemental warning signs, actuated beacons, or RRFBs are to be considered in addition to markings; or moving to Step 4 of the flowchart should be initiated.

Step 4—Pedestrian Hybrid Beacon Assessment: The final step is used to determine if a PHB should be considered. It begins with checking whether the posted or 85th percentile operating speed is less than or equal to 35 mph, or greater than 35 mph (Figure 32). The crosswalk length, vehicle volume, and pedestrian volume are then used to determine whether to consider a PHB or another signal installation, or if no action is required. Line graphs based on pedestrians per hour and vehicles per hour, with crossing length as the curve, are used to plot the specific location. If the plotted point falls above the appropriate curve for crosswalk length, then installing a PHB is to be considered. This assumes that a traffic signal does not meet *MUTCD* Warrants 4 or 5, or a traffic signal was rejected using an engineering study. If the plotted point falls below the curve for crosswalk length, then supplemental warning signs, markings, or RRFBs would be considered.

Tucson, Arizona—Criteria and Ranking for PHBs

Many jurisdictions are interested in how to assess locations for pedestrian hybrid beacons. Tucson, which first implemented PHBs as an experimental device in the 1990s, provided the updated comprehensive criteria and weights it uses to assess and rank locations. Tucson receives many requests to install these devices as the public has become familiar with them. The city developed a comprehensive list of criteria and points for potential PHB installation, which is reproduced as Figure 33.

Using the criteria listed, the city had a 2014 ranked list of 92 sites for potential PHBs, with points from a high of 85 (ranked first) to 20 points.

ORIGINAL CASE EXAMPLES

With the assistance of the jurisdictions, six original case examples were developed for this synthesis. In addition, a few case examples are included that were originally developed for other guidance resources, including the *Safe Routes to School Guide* and PEDSAFE.

The case example from Seattle describes the use of the FHWA crosswalk study guidance to assess all uncontrolled, marked crosswalks in the city to identify if and what treatments were needed to improve their safety. Short- and long-range plans for addressing the crosswalk deficiencies were developed.

The District of Columbia Department of Transportation (DDOT) pedestrian program adapted the FHWA crosswalk

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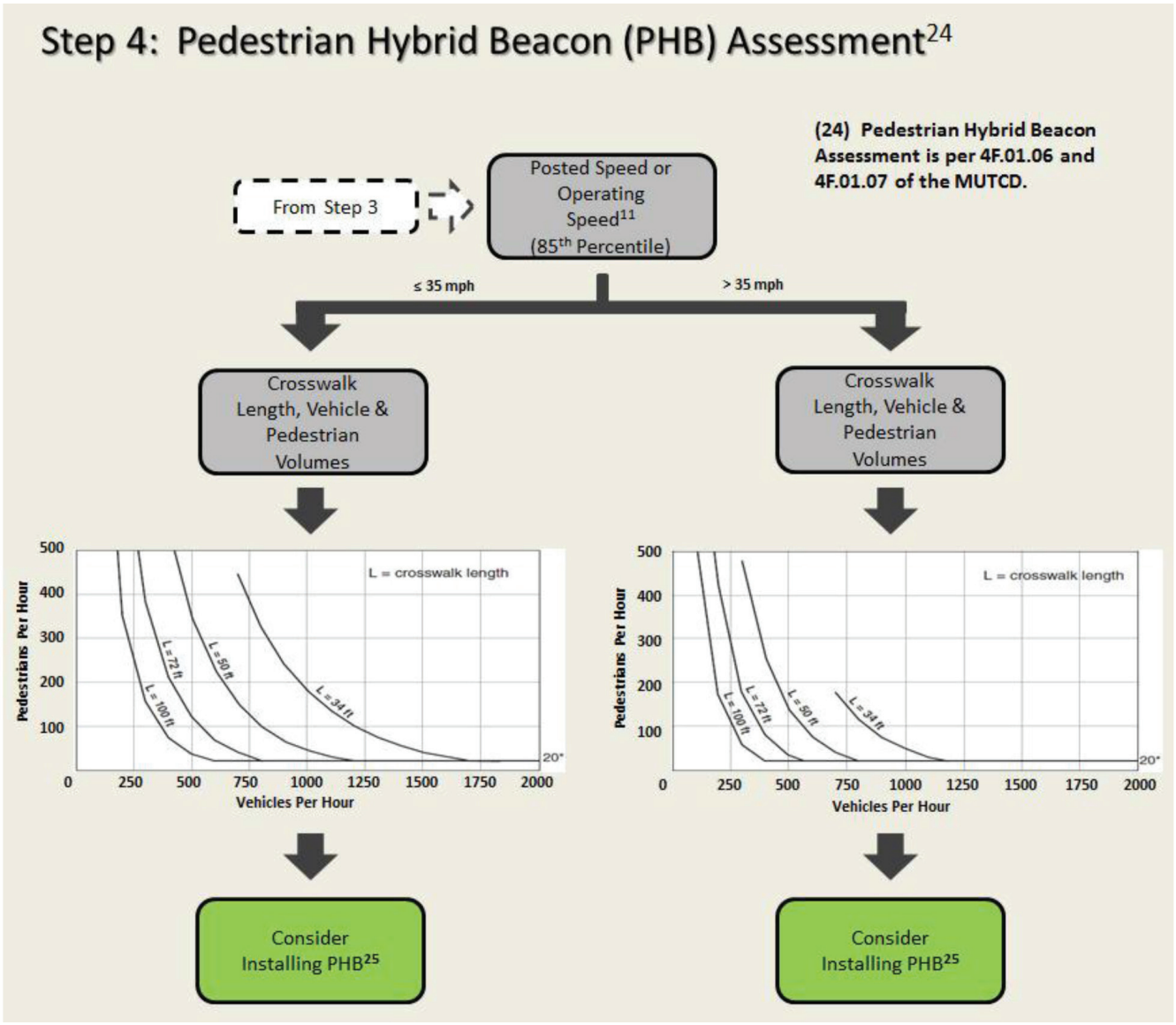


FIGURE 32 NCDOT Flow Chart Step 4. *Source*: Schroeder et al. (2015).

study guidance by Zegeer et al. (2005) to the lower speed limits of Washington, D.C., and developed a tailored decision matrix with four treatment categories for different types of roads. In addition, DDOT adapted warrant information from Tucson, Arizona, for PHBs.

Eugene, Oregon, has used multiple forms of outreach to identify problems and solutions that help meet the community's goals of environmental sustainability and an equitable street network that fits with its goal to make it easier for people to walk.

Cambridge, Massachusetts, uses a design approach to calm streets and encourage safe sharing by all modes. The city evaluates traffic-calming projects through speed studies and neighborhood feedback. To implement such projects, the city incorporates traffic-calming projects into planned reconstruction projects and other project types in a Complete Streets approach.

San Francisco and New York City are both Vision Zero cities and have taken data-driven and community-based planning approaches to identify problems and the most cost-effective treatments to drive down pedestrian fatalities and injuries.

Doubtless there are many other good examples of effective practices in outreach and identification of problem locations, and application of best available knowledge to identify effective solutions to provide safer pedestrian crossings. Following the original case examples, a few other case examples describing innovative treatments and approaches are replicated from their original sources. These provide a few examples of how a thoughtful approach to assessing the

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2014 FINAL HAWK Request Ranking
NOTES

COLUMN	LABEL	Notes
A	Ward	Indicates the ward that the intersection is located in
B	Major Street	Indicates major street that needs to be crossed
C	Intersecting Street	Indicates minor street near the major street that needs to be crossed
D	Crash Points	Crash in 2013 = 10 points each Crash in 2010, 2011, 2012 = 5 points each Fatal crash in any year = 5 additional points per fatal crash Notes: Ped/Bike crashes within 300 ft are counted Ped/Bike crashes involving a crossing maneuver are counted
E	Actual ADT	ADT from PAG Volumes map (in 1,000s)
F	ADT Points	ADT < 25 K = 5 points ADT > 25 K > 35 K = 10 points ADT > 35 K = 15 points
G	Assigned Stress Index	These data come from PAG as Shape Files
H	Stress Points	LOW STRESS = 0 points MEDIUM LOW STRESS = 0 points MEDIUM STRESS = 5 points MEDIUM HIGH STRESS = 7 points HIGH STRESS = 9 points
I	In Libraries/Parks/Groceries Buffer?	Yes/No from PAG shape files. 1/4 mile buffer.
J	Library/Park/Grocery Assigned Points	Yes = 5 points No = 0 points
K	Actual Speed Limit	Posted speed limit
L	No. of Lanes	From Aerial photos
M	SL / # Lanes Points	< or = 35 mph | > 35 mph 2 or 3 lanes 0 pts | 5 pts 4 lanes 10 pts | 20 pts 5 lanes 10 pts | 20 pts 6+ lanes 10 pts | 20 pts
N	Calc'd Distance	Measured from center of intersection to center of intersection
O	Distance Points	> 1320 ft = 10 points
P	Distance Notes	
Q	Regional Priority	BB = identified future bike boulevard Bike Route = identified bike route N = no regional priority
R	Priority Points	BB = 10 points Bike Route = 5 points N = 0 points
S	ILLUM AT XING	Illumination = continuous street lighting
T	Midpoint Safe Haven?	Y= median island TWLTL = painted center turn lane N = No midpoint safe haven
U	Midpoint Points	Y = 0 points TWLTL = 0 points N = 5 points
V	PAG Activity Demand Score	Based on PAG data provided as shape file
W	PAG Activity Points	-30 to 255 = 0 points > 255 to 350 = 5 points > 350 = 10 points
X	1/4 mi from school?	Yes/No determined using shape file
Y	School Points	No = 0 points Yes = 5 points, School crosswalk = 10 points
Z	Percent Elderly	From US Census Data provided as shape file
AA	Elderly Points	Greater than the average = 5 points

FIGURE 33 Tucson, Arizona, criteria and points scale for ranking sites for potential PHB application. *Source*: Diahn Swartz, Tucson Transportation Department.

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problem can lead to new designs and applications of operational measures that can create safer and context-appropriate solutions.

Seattle, Washington—Pedestrian Crosswalk Inventory and Improvement Program

Adapted from "The City of Seattle, WA, USA, Crosswalk Inventory and Improvement Plan" by Hefferan and Lagerwey (2004), with supplemental information provided by Toole Design Group and Seattle Department of Transportation

In 2001, the city of Seattle used the results of the study, *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations* by Zegeer et al. (2005) to inventory and systematically evaluate approximately 850 uncontrolled marked crosswalks in its jurisdiction. Seattle used the inventory and evaluation process to identify crosswalks that did not need any changes, crosswalks that could be made safer by adding treatments, and a small number of crosswalks that were removed.

The results of the Zegeer et al. study provided guidance on effects of marking crosswalks at uncontrolled locations. This report found conditions for which marked crosswalks appear to have no effect on the number of pedestrian crashes, but it also found that higher pedestrian volumes and ADT, and a greater number of lanes, were all associated with higher rates of pedestrian crashes, as described earlier.

Using this information, Seattle city officials first developed a crosswalk inventory form to be used on each uncontrolled, marked crosswalk. The form was designed to be completed in the field by trained evaluators in 15 to 20 minutes, and enabled them to determine whether each crosswalk complied with the Zegeer study guidelines. A matrix was developed based on

- Number of travel lanes and median type,
- Vehicle ADT, and
- Posted speed limits.

The matrix categorized the location as either a candidate for a marked crosswalk, not a good candidate unless mitigating treatments were included, or may or may not be a good candidate for a marked crosswalk and may require mitigating treatments based on the findings in Zegeer et al (2005). The form also provided a place to sketch the crosswalk and its site characteristics, included fill-in-the-blank or multiple choice answers to questions about important road variables, and was accompanied by digital photographs.

This information allowed city records about each crosswalk's current site conditions and important features for planning improvements to be updated. For example, if a location had no curb ramp, it was noted as a location for a future ADA ramp; if there was a drain, it was noted it may not be the best place for a curb extension. Information on pedestrian and vehicle flows and patterns could also be noted. Finally, the form included a place for a suggested action plan to be identified and certain engineering measures to be suggested. These included sign and paint upgrades, curb ramps, bus stop relocation, additional overhead signs, illumination upgrades, curb bulb-outs, reduced curb radii, pedestrian refuge crossing islands, road diet, parking removal, raised intersections, suggested pedestrian half or full signal additions, and crosswalk removal. Associated land use features like nearby schools, bus routes, and potential pedestrian generators or attractors were also described for each crosswalk.

Approximately 850 uncontrolled marked crosswalks were inventoried on both arterial and nonarterial streets, constituting all of the uncontrolled marked crosswalks in the city. More than 700 were found to be candidates for marked crosswalks, 40 were found to be possible candidates, and about 80 did not rank as candidates for marked crosswalks alone. Almost every crosswalk was determined to be a candidate for at least one of the suggested improvements. When spatially analyzed, some crosswalks that were candidates for improvements were found to cluster in corridors. This aided in subsequent project prioritization, as crosswalks in corridors could often be addressed by one corridor treatment, rather than many different changes to individual crosswalks. For example, road diets could be used to reduce four-lane roads to two-lane roads, making it easier to add median islands, wider sidewalks, and other pedestrian safety improvements that would reap greater safety results.

Given the previously cited inventory results, an effective Crosswalk Improvement Plan was developed by the Seattle Department of Transportation (Hefferan et al. 2002). The three primary goals of the Crosswalk Improvement Plan were to improve facilities at uncontrolled marked crosswalks to facilitate increased driver yielding, to make changes that would help pedestrians cross the street more safely, and to minimize the number of crosswalks that would be removed. The long-term goal was to eliminate crosswalks in the "N" (usually not a good candidate for a crosswalk unless mitigating measures are taken) and "P" (may or may not be a good candidate for a marked crosswalk; might need mitigating measures) categories, "through the provision of engineering solutions to improve the safety of such crosswalks" or through "provision of other satisfactory ways for pedestrians to get across the street" (Hefferan and Lagerwey 2004, p.45).

The plan divided inventoried crosswalks into three types of interventions based on cost, time of implementation, and complexity:

- Those with simple measures such as curb ramps,
- Those with moderately complex measures such as curb bulb-outs, and
- Those with complex measures such as road diets.

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Existing policies and guidelines, leveraging improvements as part of other larger road projects (termed "piggy-backing"), and connecting improvements to existing neighborhood plans also helped determine project prioritization. Projects with an overall cost of generally more than $70,000 fell under the umbrella of the Capital Improvement Plan (Figure 34). Projects with the least amount of time and resources required were likely to be completed first; those with long timelines and high amounts of resource required were more likely to require a longer timeline and more coordination. Some improvements occurred even before the entire inventory was completed. Crosswalk removals were not completed without provision of other engineering treatments nearby, such as addition of traffic signals, crossing islands, curb revisions, corridor traffic calming, and other measures. The plan produced a matrix that outlined projects for the next 5 years. In 2002 alone, 58 new curb ramps were installed, 800 school signs were replaced, eight locations received curb extensions, two roads diets were completed, four new traffic signals were added, and 12 new crosswalks were marked.

Seattle's Crosswalk Inventory and Improvement Program has the advantage of being systematic and based on solid data on safety effects. Before the inventory, crosswalk improvement locations came to light primarily through community complaints or crash data analysis projects, which may miss crosswalks that do not meet current guidelines but also do not have a history of collisions. The inventory approach is a systemic (proactive) method other jurisdictions can emulate to identify and address safety improvement opportunities at uncontrolled marked crosswalks.

Washington, D.C.—Uncontrolled Crosswalk Engineering Treatments Selection

Information compiled from the survey responses with supplemental information provided by George Branyan, DDOT

The Washington, D.C., District Department of Transportation utilizes numerous federal and local guides and studies in consideration of decisions on pedestrian safety needs at crossing locations. Among federal comprehensive sources, the *MUTCD* and *Safety Effects of Marked Versus Unmarked Crosswalks* (Zegeer et al. 2005) are important influences for identifying locations for pedestrian crossing improvements. However, the MUTCD applies the Zegeer study results only on roadways with posted speed limits of 40 mph or higher. Because many D.C. streets have posted speeds of 30 mph or lower, the guidance needed to be adapted for this context. The *District of Columbia Pedestrian Master Plan* of 2009 provides a Pedestrian Design Guidelines Manual, which includes a decision matrix called the Uncontrolled Crosswalk Engineering Treatments Table. This selection matrix was developed to apply recommendations of the Zegeer study to uncontrolled crossing locations with posted speed of 30 mph or less in Washington, D.C. (Figure 35).

The matrix uses the roadway configuration (number of lanes and presence of median) and the vehicle volumes per day (vpd), to categorize which engineering treatment is recommended. All traffic volumes below 1,500 vpd, regardless of roadway configuration, receive a parallel crosswalk and W11-2 pedestrian warning sign assembly. The remaining four columns allow engineering treatment selection based on roadway configuration at traffic volume ranges of 1,500 to 9,000 vpd, 9,000 to 12,000 vpd, 12,000 to 15,000 vpd, and greater than 15,000 vpd. Four possible treatments can be selected:

- *Treatment A* is a high-visibility crosswalk and Side of Street Pedestrian Law Sign.
- *Treatment B* is and in-street pedestrian stop sign with advanced stop line/bars, which are suggested to be used for all multilane crossings.
- *Treatment C* includes an activated pedestrian device, such as an RRFB, flashing beacon, or in-roadway lights.
- *Treatment D* involves adding a signal (PHB or full traffic signal) or grade separation. The matrix is used by

Table: From Director's Rule # 01-02 on marked crosswalks *(circle one)*

Number of Travel Lanes (including Center Turn Lane) and Median Type	Vehicle ADT ≤9,000			Vehicle ADT >9,000 to 12,000			Vehicle ADT >12,000 to 15,000			Vehicle ADT >15,000		
	≤30 mph	35 mph	40 mph	≤30 mph	35 mph	40 mph	≤30 mph	35 mph	40 mph	≤30 mph	35 mph	40 mph
2 Lanes	C	C	P	C	C	P	C	C	N	C	P	N
3 Lanes	C	C	P	C	P	P	P	P	N	P	N	N
≤ 4 Lanes with Raised Median	C	C	P	C	P	N	P	P	N	N	N	N
≥ 4 Lanes with No Median	C	P	N	P	P	N	N	N	N	N	N	N

Circle one. **(These are general recommendations; good engineering judgement should be used in individual cases for deciding where to install marked crosswalks):**

C) Candidate for a marked crosswalk.

P) May or may not be a good candidate for a marked crosswalk. Might require mitigation, need more info.

N) Usually not a good candidate for a marked crosswalk unless mitigating measures are taken, need more info.

FIGURE 34 Seattle crosswalk assessment matrix adapted from FHWA study. *Source*: Hefferan and Lagerwey (2004).

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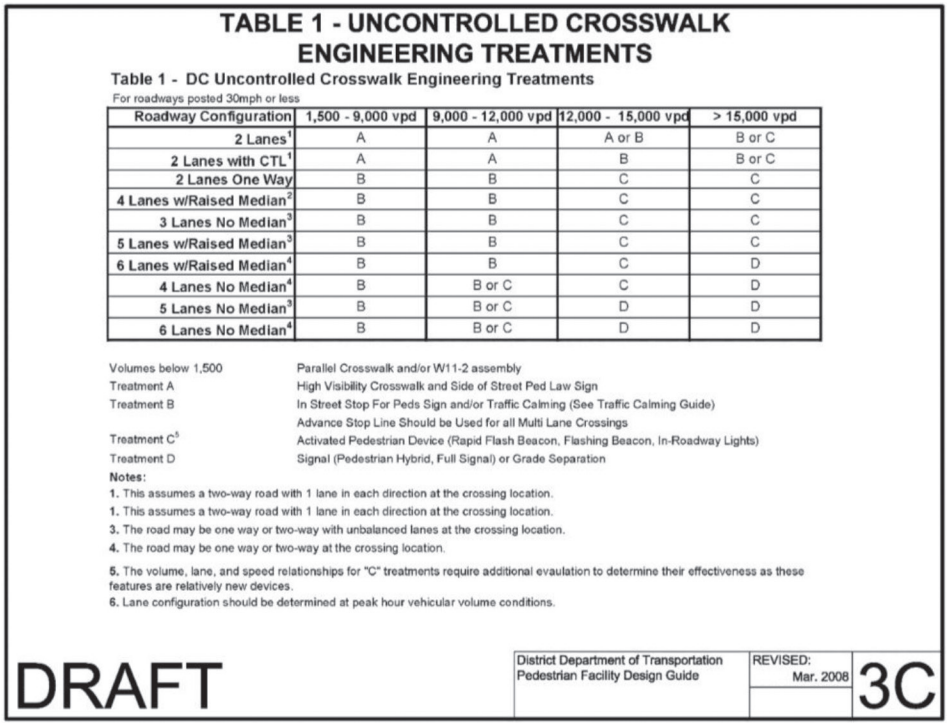


TABLE 1 - UNCONTROLLED CROSSWALK ENGINEERING TREATMENTS

Table 1 - DC Uncontrolled Crosswalk Engineering Treatments

For roadways posted 30mph or less

Roadway Configuration	1,500 - 9,000 vpd	9,000 - 12,000 vpd	12,000 - 15,000 vpd	> 15,000 vpd
2 Lanes[1]	A	A	A or B	B or C
2 Lanes with CTL[1]	A	A	B	B or C
2 Lanes One Way	B	B	C	C
4 Lanes w/Raised Median[2]	B	B	C	C
3 Lanes No Median[3]	B	B	C	C
5 Lanes w/Raised Median[3]	B	B	C	C
6 Lanes w/Raised Median[4]	B	B	C	D
4 Lanes No Median[4]	B	B or C	C	D
5 Lanes No Median[3]	B	B or C	D	D
6 Lanes No Median[4]	B	B or C	D	D

Volumes below 1,500	Parallel Crosswalk and/or W11-2 assembly
Treatment A	High Visibility Crosswalk and Side of Street Ped Law Sign
Treatment B	In Street Stop For Peds Sign and/or Traffic Calming (See Traffic Calming Guide)
	Advance Stop Line Should be Used for all Multi Lane Crossings
Treatment C[5]	Activated Pedestrian Device (Rapid Flash Beacon, Flashing Beacon, In-Roadway Lights)
Treatment D	Signal (Pedestrian Hybrid, Full Signal) or Grade Separation

Notes:

1. This assumes a two-way road with 1 lane in each direction at the crossing location.
1. This assumes a two-way road with 1 lane in each direction at the crossing location.
3. The road may be one way or two-way with unbalanced lanes at the crossing location.
4. The road may be one way or two-way at the crossing location.
5. The volume, lane, and speed relationships for "C" treatments require additional evaulation to determine their effectiveness as these features are relatively new devices.
6. Lane configuration should be determined at peak hour vehicular volume conditions.

DRAFT

District Department of Transportation Pedestrian Facility Design Guide	REVISED: Mar. 2008	3C

FIGURE 35 Uncontrolled Crosswalk Engineering Treatments. *Source*: DDOT *Pedestrian Master Plan* of 2009.

some traffic engineers and technicians as guidance and not necessarily as a strict decision matrix.

Locations in need of pedestrian crossing treatments were identified in the *District of Columbia Pedestrian Master Plan,* including eight problematic corridors, one in each ward of the city. Several of these have been the focus of extensive traffic safety studies utilizing traffic, crash, and safety data.

Many uncontrolled crosswalk locations causing concern are also brought to light by resident complaints, sometimes through city council members. One challenge in this process is that different departments may handle complaints differently. Some engineers and technicians rely on more traditional and conventional guidance to evaluate uncontrolled crosswalk safety problems, whereas others use the crosswalk matrix in their assessment. Ideally, the engineer or technician will collaborate with the pedestrian coordinator to develop a plan to improve safety at a crosswalk.

DDOT's process for determining the suitability of PHBs was developed in 2014. Requests for PHBs are sent to the signals team in the Traffic Operations Administration and a preliminary evaluation screening is conducted. The screening tool is similar to those developed in Tucson and Phoenix, Arizona, and Portland, Oregon. The screening tool considers multiple factors, including the number of lanes; ADT; distance to nearest signalized crossing; presence of bus stops and ridership; vehicle, pedestrian, and bicyclist crashes; proximity to schools and recreations centers; and senior population. The tool has a 200-point scale, and if the locational evaluation yields a score of around 150, it triggers a full warrant study under *MUTCD* Pedestrian Volume Signal Warrant 4 standards.

As the uncontrolled crosswalk engineering treatment matrix indicates, in Washington, D.C., PHBs are considered for use on uncontrolled crossings only:

- Five- and six-lane roads with no median and 12,000 to 15,000 vpd;
- Six-lane roads with a median and volumes of 12,000 to 15,000 vpd; or
- Four- to six-lane roads with no median and volumes higher than 15,000 vpd.

The *District of Columbia Pedestrian Master Plan* of 2009 further states, "The HAWK signal is best suited for uncontrolled crossings of multi-lane, higher speed or volume roadways where there is a need to provide occasional pedestrian crossings without inordinate delay to motor vehicles (i.e., school crossings, low volume neighborhood street crossings of high volume, multi-lane arterials)" (Toole Design Group 2009). DDOT also follows *MUTCD* pedestrian volume signal warrant guidelines when initially considering a traffic control signal of any kind (Treatment D in the matrix).

DDOT's Uncontrolled Crosswalk Engineering Treatments Table is tailored for the lower-speed environment of Washington, D.C., and is meant as guidance to augment other standards such as those in the *MUTCD* and other documents.

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In general, identifying locations in need of pedestrian crossing safety treatments is an ongoing and evolving process for DDOT, but the matrix is a good example of one proactive tool DDOT uses to guide uncontrolled crossing treatment decisions criteria.

Eugene, Oregon—Community-Based Identification of Needs and Solutions

Information compiled from Eugene, Oregon, survey responses with supplemental information provided by Reed Dunbar, Bicycle & Pedestrian Planner, Eugene

Eugene, Oregon (population about 160,000) has adopted use of a *Bicycle and Pedestrian Master Plan,* a series of Transportation Improvement Policies, NACTO design guidelines, and 8 80 Cities vision for a more environmentally sustainable and equitable street network that fit with the city's goal to make it easier for people to walk. The city uses a variety of means to identify crossing locations in need of safety improvements and to develop treatments that meet pedestrian needs throughout the city. Staff frequently uses crash analysis to identify problems, as well as consistently reviewing pedestrian needs within the processes for all types of transportation projects developed.

Leveraging all types of projects includes using the city's American's with Disabilities Act (ADA) transition plan and special funding to identify and make other improvements during repaving and ramp upgrades. The city is currently in the second 5-year cycle of a voter referendum–approved pavement repair funding plan and program and updates ramps automatically when road repaving/repairs occur. The city has a methodology that prioritizes Safe Routes to School locations first, followed by residential and commercial uses. The city prioritizes meeting not just the letter, but the spirit of ADA requirements for providing an accessible network for all pedestrians when improvements are made.

In coordinating with the road maintenance plans, staff looks not just at the ramps required to be updated/installed through these projects, but also at nearby locations to ensure that other ramps needed to ensure connectivity in the area are present and up to standards. The city also has a database of sidewalk facilities, and staff knows where the gaps are. At the same time, the city leverages opportunities associated with these repaving/ramp upgrades as well as other types of projects to examine where people are crossing and whether they have sufficient time at signal-controlled locations or sufficient gaps in traffic at uncontrolled locations to safely complete crossings.

The city is also engaged with the community and provides a complaint hotline phone number for the public to make requests, and sometimes uses online Wikimaps or web-based systems to gather input on problem locations and types. Between phone calls and Internet-based inputs, last year the city processed more than 30,000 requests for service from community members describing where they have problems and the nature of the problems. Personnel receiving the calls are trained to help gather complete and consistent types of information. The information from callers is logged into a complaint database, assigned to a project manager, and disseminated to all public works staff in various departments, and resolutions are tracked.

The city estimates that about half of pedestrian-related calls relate to uncontrolled locations where assistance is needed to get safely across the street, with the other half relating to intersection issues such as signal timing or conflicts. The staff works hard to investigate and follow up on all complaints, although there is not always time to investigate them all. The data can also be compared with needs identified through other processes.

Staff also identifies locations in a more proactive fashion based on land uses, traffic volumes, and vulnerable populations. Planning staff has been working with poor and non-English-speaking neighborhoods to help build bridges to those who typically do not call in complaints or needs. Improving communications and trust with underserved neighborhoods remains a challenge; in the meantime, the city's management prioritizes staff spending more time to identify needs in those communities where residents do not speak out. City councilors from those districts are also typically active in ensuring a "fair share" to address the safety needs in those communities. In addition, staff performs numerous traffic speed studies, and systemwide are looking at how fast traffic is moving, because speed has a strong bearing on injury potential. Many arterials in the city are posted at 45 mph (and designed for those speeds), so the city is also exploring how to push down speeds to reduce fatalities and injuries in a new Vision Zero way of thinking.

To home in on the most appropriate treatments, planning staff generally performs a pedestrian count to determine how many users there are. However, if there is not an existing crossing at a severe problem location (and thus low numbers of pedestrians), staff may use pedestrian generators and land use to supplement counts with estimates of demand or unmet pedestrian need. However, there is sometimes disagreement about using such data between planning and engineering departments. The city holds a public meeting, and based on the problem types, other studies—which often include traffic gaps analysis—and public input, traffic engineers will select countermeasures. Staff also considers pedestrian characteristics to help determine appropriate treatments. For example, if the location is near an area with many seniors, the solution for a multilane roadway is more likely to include a stop-control, pedestrian hybrid beacon compared with a rectangular rapid flash beacon warning device.

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Although the city has had success using RRFBs in conjunction with pedestrian refuge islands at multilane locations, selected in part because of lower cost, it is now considering PHBs more often on multilane streets because of the recent move toward a Vision Zero framework. For the first PHB implemented on a multilane roadway that separated a school from a residential neighborhood, it was installed without a pedestrian refuge at a three-lane cross section, and is reportedly working quite well (Figure 36). The location also has an active transit stop that local commuters use to get to a community college farther on the outskirts of town. Interestingly, this location also has an aging, grade-separated crossing that is non-ADA compliant, having only stairs for access. Families with young children and strollers, wheelchair users, and others could not use the overpass. Speed limits in the area also are transitioning from a 55 mph limit (just out of town) to a 35 mph limit, but many drivers do not lower their speeds to 35 mph, even though the four lanes of arterial highway narrows to three lanes near the school. With all of these good reasons to use a PHB, the organization and groundswell of community support in the neighborhood helped push the PHB for this location to the top of alternatives.

According to the city, "all other locations generally feature some attempt to narrow the crossing distance (curb extensions or islands) and the use of pedestrian warning signs or crosswalks. Budget is also a consideration." To some extent, improvement priorities also consider geographic or socioeconomic areas equity.



FIGURE 36 Crossing enhanced with pedestrian hybrid beacon in Eugene, Oregon. *Source*: Reed Dunbar, City of Eugene.

The processes used by Eugene illustrate the complexity and dynamism of developing safer pedestrian crossings that will meet the community's needs. Dedicated and knowledgeable staff, responsiveness to local complaints, and other public input help provide budget-sensitive solutions appropriate to the context and community. Although the community has not adopted a definite Vision Zero approach to guide decision making, it is moving in that direction with recent decisions about PHBs versus RRFBs and a focus on lowering speeds.

Cambridge, Massachussets—Traffic-Calming Project Development and Evaluation

Information compiled from survey responses with supplemental information provided by Juan Avendano, Bill Deignan, and Cara Seiderman, the City of Cambridge Community Development Department

The city of Cambridge runs an extensive traffic-calming project evaluation program that involves formal postproject speed studies and resident surveys. The main goal of the city's traffic-calming efforts is to design streets in such a way as to "improve the quality of life in neighborhoods and allow cars to peacefully coexist with other modes of transportation" (City of Cambridge, Community Development Department, Traffic Calming Program 2011). This is accomplished by using various physical engineering countermeasures that encourage people to drive more slowly and increase the comfort and safety of walking and bicycling, and without relying on compliance with traffic control devices such as signs and signals, or on speed enforcement. The implementation of traffic-calming projects is largely done in conjunction with streets that are being reconstructed as part of the city's Five Year Sidewalk and Street Reconstruction Plan. This plan identifies specific streets and sidewalks that are to be reconstructed each year for the next 5 years. In addition, the city considers locations to implement traffic-calming measures at the request of community residents and in conjunction with other reconstruction projects such as street repaving or sewer maintenance. (Figure 38 shows the locations of projects implemented over the past 20 years.)



FIGURE 37 Brattle Street before and after traffic-calming project. *Source*: Brattle Street Traffic Calming Project Evaluation 2012, City of Cambridge website (https://www.cambridgema.gov/~/media/Files/CDD/Transportation/TrafficCalmingProjects/Brattle%20Street%20Traffic%20Calming%20Project%20Evaluation20120815.pdf?la=en).

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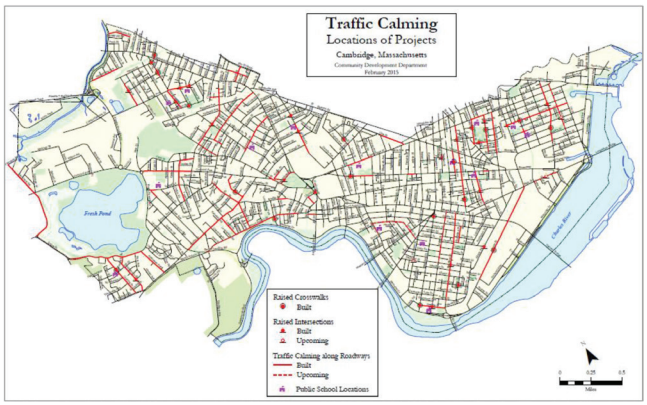


FIGURE 38 Traffic calming over past 20 years. *Source*: City of Cambridge, Community Development Department.

The Five Year Sidewalk and Street Reconstruction Plan is a living document that is updated regularly as conditions change, and is based around a Complete Streets concept. This concept emphasizes that streets are for users of all ages and modes, including pedestrians, bicyclists, motorists and public transportation users. The plan states that "complete streets make it easy to cross the street, walk to shops, and bicycle to work . . . make buses run on time and make it safe for people to walk to and from train stations" (Cambridge Department of Public Works 2015). The plan's stated goals not only emphasize Complete Streets, but outline the need to maintain safe and accessible streets, to prioritize these projects based on need, and to effectively communicate design and construction projects with neighborhoods while facilitating an integrated design process with minimum disruption to community life.

As part of the 5-year plan's project prioritization, issues identified by staff and the community are also taken into account to help identify potential projects. Issues identified by the community are received through a formal traffic-calming request form that residents submit to the city's traffic-calming project manager. The form asks for the street names and locations of concern; the time of day that the problems occur; if other residents on the street have the same concerns; and a list of problems experienced that includes speeding, street crossing difficulty, lack of courtesy to bicyclists, cars parked too close to the corner, difficulty biking, and drivers not yielding to pedestrians (Traffic Calming Request Form n.d.). City departments then work together to prioritize the list of potential sites based on factors such as the severity of the speeding problem; the ability to coordinate improvements with other construction projects; and the proximity to schools, playgrounds, and other land uses important for pedestrian safety (City of Cambridge, Community Development Department 2000).

Once a street location is up for reconstruction as part of the Five Year Plan, officials work closely with the neighborhood residents through a series of public meetings to determine the most effective way to slow traffic and address specific pedestrian and bicyclist safety concerns. Street width, traffic volume, and traffic speeds are studied to help determine the most effective methods of calming. The most common treatment types include horizontal and vertical measures, such as curb extensions, raised crosswalks, raised intersections, chicanes, and pedestrian refuge crossing islands. After a project proposal is finalized, it is implemented in conjunction with other street reconstruction projects and coordination with other important city departments.

The city has had a successful traffic-calming program for nearly 20 years. The program has constructed approximately 50 raised crosswalks and intersections in that time. The program has resulted in strong community support, reduced vehicular speeds, and increased yielding to pedestrians in crosswalks. The city works closely with the fire department to ensure that the traffic-calming elements increase overall safety while maintaining the ability of emergency vehicles to respond in a timely manner. To that end, the city reviews each design with the fire department, closely evaluates the locations of the raised devices to ensure a minimal number are located on primary response routes, locates the devices so as to maximize their benefits to pedestrians, and design the slopes to be accessible for the vehicles anticipated on the given street. The slopes of the devices generally range between 5% and 7%. The steeper slopes are used on lower-volume residential streets, and the more gradual slopes are used on busier response routes.

Before–after speed studies and resident surveys are the primary methods used to evaluate the effectiveness of traffic calming, and are generally conducted within a year of construction. Brattle Street is a two-lane road in a residential area with a posted speed limit of 30 mph. Before–after speed studies involved observing the percentage of vehicles exceeding the speed limit and comparison of 85th percentile speeds ("Brattle Street Traffic Calming Project Evaluation" 2012). The 2010 Brattle Street project used a series of curb extensions, chicanes, and pedestrian crossing islands (Figure 37). As a result of the traffic-calming treatments applied, there was a reduction of the number of vehicles traveling from 25 mph to 30 mph and an increase in the number of vehicles traveling from 21 mph to 25 mph. Observed 85th percentile speeds decreased from 31 mph to 30 mph.

Postcards with a link to an online resident survey were mailed to 417 residents postproject, and received at a 13% response rate ("Brattle Street Traffic Calming Project Evaluation" 2012).

A postproject resident survey was also sent to 140 residents after the Windsor Street traffic-calming project, along with a stamped self-addressed return envelope, and received an 11% response rate. The survey asked about resident perceptions of improved safety for pedestrians. It also asked for

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opinions on the overall look of the street, if enough community outreach was performed, and for opinions of the raised intersections. Overall, 69% of those surveyed believed the overall look of the street improved, traffic speeds were reduced, and pedestrian safety was improved. Only 13% had a negative view of the project. Of those surveyed, 56% did not know if the city did a good job reaching out to residents, 38% believe it did, and only 6% believed it did not. Two-thirds of respondents reported they would like to see more similar projects in the future ("Windsor Street Traffic Calming Project Evaluation" n.d.).

Resident survey results provide an excellent tool for learning of community concerns about project implementation and the community's perceptions of safety treatments installed. Because speed reductions are a primary goal of the city's traffic-calming projects, and have been shown to significantly reduce crash rates and severity, the before-and-after speed studies provide an excellent metric to evaluate how effective the traffic-calming efforts have been. The city has completed numerous successful traffic-calming projects throughout its street network over the past 20 years and has analyzed overall crash data during those decades (Figure 38). It has found that there has been about a 33% reduction in crashes, and that the severity of crashes has generally been reduced.

In short, the speed study and resident survey results together allow city officials to gauge effectiveness in treatment selection and project execution, and if improvements can be made for future projects. In addition, the program takes advantage of planned programs to implement improvements in a cost-effective way.

San Francisco, California—Data-Driven Investment Approach for Achieving Vision Zero

Adapted from Achieving Vision Zero: A Data-Driven Investment Strategy for Eliminating Pedestrian Fatalities on a Citywide Level, *by Kronenberg et al. (2015) with supplemental information provided by SFMTA*

In 2014, San Francisco Municipal Transportation Agency (SFMTA) completed a unique data-driven process for identifying problematic pedestrian safety locations and matching them with highly effective, yet low-cost countermeasures. The primary goal was to create a systematic, data-driven approach to meet the Vision Zero goal of eliminating fatalities in the most cost-effective manner. The process output generated a prioritized pedestrian safety project list of 195 intersections over 5 years that targeted the specific safety needs at each location. This strategy exemplifies a process to help meet the challenge many cities and jurisdictions face when trying to prioritize safety improvement projects with limited funding and resources. City planners, engineers, and analysts created a "new, streamlined approach for capital-constrained project development and prioritization that is applicable to all types of safety improvements across any jurisdiction" (Kronenberg et al. 2015, p.2).

Development of the strategy was based on the hypothesis that pedestrian injuries and fatalities are not merely the result of random unpreventable accidents, but are caused instead by specific user behaviors and built environment circumstances that can be changed. Engineering tools and countermeasures proven to elicit safer behaviors and reduce the likelihood and severity of user mistakes were identified for locations in the city where interventions were needed most. First, a thorough analysis of 5 years of network crash data was conducted to identify high-injury and -fatality locations and create pedestrian collision profiles for each location. The project team then examined and assigned costs to potentially effective countermeasures, matched to each collision profile. Finally, a scenario-planning exercise was used to evaluate and select a final pedestrian safety implementation strategy for each location (Kronenberg et al. 2015).

Data analysis was entirely dependent on the San Francisco Department of Public Health's (SFDPH's) *TransBASE* data set, which provided an inventory of all pedestrian injuries and fatalities caused by motor vehicle collisions between 2007 and 2011. Extensive data on each collision were included in pedestrian injury records along with more than 200 spatially referenced variables collected from multiple other agencies. Each pedestrian injury record and spatially referenced variable was linked to an intersection or street segment to allow spatial analysis. Location-specific network information included the presence of destinations featuring businesses, educational institutions, and community amenities, as well as collision characteristics, infrastructure, traffic volumes, zoning, population demographics, and health exposures. Additional land use and transportation data augmented the primary data set and were attained from the U.S. Census, San Francisco Planning Department, San Francisco Unified School District, SFDPH, SFMTA, and San Francisco Department of Public Works (Kronenberg et al. 2015).

Because the San Francisco jurisdiction is composed of more than 1,100 miles of roadway, a prioritization approach was needed. Therefore, a *high-injury network* was developed that focused on the most problematic locations. The focus was on identifying *high-injury corridors*, which were summarized according to *corridor length, fatalities and severe injuries per mile, total injuries per mile*, *and total weighted injuries per mile*. Eighty-seven corridors were identified that comprised 6% of the city's street miles, yet 60% of total pedestrian injuries during the period of study. Though intersection-level data were initially aggregated into the high-injury corridors to facilitate effective corridor countermeasures such as road diets and speed control treatments, pedestrian injury accidents that were intersection related were also analyzed to focus attention on particular *high-injury intersections* (Kronenberg et al. 2015).

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Each intersection and corridor in the high-injury network needed to be matched with site-specific safety countermeasure recommendations. To this end, 14 separate *collision profiles* were created by analyzing common crash-related factors obtained from extensive review of local, national, and international crash studies, and confined to variables available in the combined data set. These factors included person characteristics (i.e., age and gender), collision circumstances (i.e., driver turning left at intersection or pedestrian outside of crosswalk), and environmental conditions (i.e., high traffic volumes, time of day, or proximity to land use types). Collision profiles included the related crash factors and a description of the collision type. For example,

- The collision profile "Complex Intersection" included the crash factor "five-leg or freeway ramp" and the description, "Collisions that occurred in intersection with complex travel patterns"; and
- The collision profile "Mid-Block Collision" included the crash factors "driver failure to yield or pedestrian failure to cross in crosswalk" and "high vehicle volume," and the description, "Collisions that occurred at midblock locations with or without a crosswalk" (Kronenberg et al. 2015).

Of all injuries and fatalities, 90% were captured in the assembled list of 14 crash profiles, which was used to inform the subsequent investment cost analysis and project prioritization (Kronenberg et al. 2015). Possible safety countermeasures were identified for each collision profile based on known quantifiable measures of effectiveness (MOEs). MOEs included collision reduction, crash modification factors, driver yielding, speed reductions, injury-severity reductions, and increase in compliance. Site-specific needs could then be addressed according to level of expected effectiveness of targeted pedestrian safety countermeasures.

The list of possible countermeasures included four categories:

1. Signalization: LPIs, PCSs, flashing beacons, RRFBs, PHBs, improved signal timing, scramble phasing, protected left-turn phasing, APS, and adding new traffic signals

2. Geometric: roundabouts, raised crosswalks/speed tables, refuge islands, painted medians, corner bulbouts, temporary measures, lane narrowing, road diets, new crosswalks, crosswalk removal, chicanes, chokers, and curb ramps

3. Signs, Markings, and Operational: lighting, automated speed enforcement, no turn on red, no left turn, advanced stop lines, daylighting, high-visibility crosswalks, overhead crossing signs, and pedestrian warning signs

4. Speed Control Measures and Miscellaneous: speed humps, portable speed trailer or speed display signs, shared space, channelization, landscaping, lower speed limits, vehicle restriction, and closures (Kronenberg et al. 2015).

Countermeasure costs were developed to "facilitate cost–benefit analysis of different investment scenarios and to estimate a total cost for the citywide program." Possible treatments were categorized according to the relative cost of implementing the measure or measures at any given location, according to the following: low = less than $10,000; medium = between $10,000 and $100,000; and high = greater than $100,000. Each countermeasure listed earlier was assigned to a cost category (Kronenberg et al. 2015).

The project team then could compare the relative effectiveness of each countermeasure against its relative cost, and categorize each into high, medium, and low cost-effectiveness. An example of some pairings is shown in Figure 39.

Selected Collision Profile and Countermeasure Pairings

Facility	CMF	Appropriate Profiles	Cost	Effectiveness
Corner Bulbs	Unknown	Right turns at signalized intersection High pedestrian volumes Complex intersection Uncontrolled marked crosswalk on arterial	High	Medium
Leading Pedestrian Interval	0.95	Left turns at signalized intersection (one-way) Right turns at signalized intersection High pedestrian volumes	Low	Medium
Left turn prohibitions	0.9	Left turns at signalized intersection Left turns at signalized intersection (one-way)	Medium	High
No Right on Red	0.97	Right turns at signalized intersection	Low	Low
Pedestrian Refuge Islands	0.54 (marked crosswalk)	Left turns at signalized intersection Left turns at signalized intersection (one-way) Mid-block collision Complex Intersection Uncontrolled marked crosswalk on arterial	Medium	High

FIGURE 39 San Francisco collision profiles and countermeasure pairings. *Source*: Kronenburg et al. (2015).

The process of creating collision profiles based off the high-injury network crash data and assigning cost-effective countermeasures for each profile generated a large list of potential pedestrian safety improvement projects. An investment scenario and evaluation criteria were developed that allowed the city to evaluate these projects within long-term capital constraints and to understand the tradeoffs involved with each possible approach. Three investment strategy scenarios were developed that established criteria to evaluate and compare projects and identify the preferred investment scenario. They helped guide the city in project selection and prioritization as part of its pedestrian safety Capital Improvement Program. They are as follows:

1. Location Based: Focuses investments on high injury corridors with the highest concentration of collisions per mile.

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2. Collision Profile Based: Focuses investments to the locations across the city with the most severe injury collision profiles.

3. Countermeasure Based: Favors countermeasures with the shortest implementation time frame and lowest capital cost (Kronenberg et al. 2015).

Crash modification factors (CMFs) were applied to project the reduction of fatalities and severe injuries under each scenario. CMFs at intersections with multiple countermeasures were multiplied. Projected reductions in fatalities and injuries under each scenario were also evaluated according to capital cost, time of implementation, and impacts to other modes of travel. Combinations with other nonengineering treatments such as education and enforcement were also considered.

Decision makers evaluated all three scenarios and arrived at a hybrid, two-phased selection approach. The first phase prioritized projects with quick and inexpensive treatments with large short-term benefits at locations with five collision profiles. Phase 1 treatments included LPIs, temporary medians, parking and turn prohibitions, traffic circles, and reduced lane width. The second phase addressed medium- to long-term projects with more expensive needs and the remaining collision profiles. It was decided that the highest-priority locations were along the high-injury network with the highest weighted count of injuries. This created a list of 195 intersections that comprised 71% of all fatal and severe injuries along the high-injury network (Kronenberg et al. 2015).

SFMTA's data-driven investment approach for achieving Vision Zero is an innovative process for producing and prioritizing a comprehensive list of projects and countermeasures for crash hot spot areas that address multiple collision types and locations while focusing on fatal and severe injury pedestrian crash reduction. However, it does not take into account current site conditions, or final diagnosis, and therefore once project selections have taken place, they must be validated using photographs, drawings, site visits, and GIS information in order to create a list of countermeasures that can be realistically implemented (Kronenberg et al. 2015).

New York, New York—Vision Zero Pedestrian Safety Plan

Information compiled from the survey responses with supplemental information provided by NYC DOT

Pedestrian-related traffic fatalities have fallen significantly in New York City (NYC) since 1990 (NYC Vision Zero Overview: http:/www.nyc.gov/html/visionzero/pages/home/home.shtml). The city has become recognized both internationally and nationally for its safe street designs and policies. The city attributes engineering solutions and changes at dangerous locations for having contributed to a 34% decrease in fatalities since 2005. However, despite these improving statistics, since 2011 an average of 250 fatalities and 4,000 injuries related to pedestrian crashes have occurred per year. Improving pedestrian safety in all five boroughs continues to be a significant challenge. To aggressively address ongoing pedestrian safety issues, in January 2014, under Mayor Bill de Blasio, the NYC Department of Transportation (NYC DOT) adopted the Vision Zero framework.

The Vision Zero strategy was created and first adopted in Sweden in 1997. As suggested by the name, Vision Zero targets reducing fatalities and serious injuries to as close to zero as possible within a certain time frame. Such a vision alters the thinking toward deciding on road safety projects and locations from a traditional cost–benefit structure that views crashes as unavoidable accidents, to one based on ethics, responsibility, safety, and mechanisms for change.

The responsibility for road safety is no longer solely that of the user, but shared by the system designers, the overall safety culture, and the built environment, which includes the roadway, planners, engineers, vehicles, road users, emergency response, enforcement, multiple city agencies, legislation, and policy. NYC's Vision Zero (and others) views fatalities and serious injuries as system failures that not only can be minimized but can be eliminated through proper system design and shared user responsibility. Where users fail to follow the rules and safely utilize the system, it is the designer's responsibility to take steps to reduce the probability of people being killed or seriously injured, by installing the proper safety countermeasures or improving the design of the transport systems. The NYC DOT Vision Zero Action Plan (City of New York 2014) states, "The status quo is unacceptable. The City of New York must no longer regard traffic crashes as mere 'accidents,' but rather as preventable incidents that can be systematically addressed. No level of fatality on city streets is inevitable or acceptable." The plan focuses on three key tenants that guide all decisions:

1. There is no acceptable level of death and injury on streets.

2. Traffic deaths and injuries are not accidents but crashes that can be prevented.

3. The public expects safe behavior on city streets and participates in culture change.

As part of the plan, NYC DOT officials have engaged in wide-ranging studies of the problems and comprehensive community outreach in all five boroughs. During this extensive outreach, further insight was attained into problem locations, causes, and the types of safety interventions needed. Throughout the five boroughs, conflicts involving senior pedestrians are disproportionately high. Pedestrian fatalities caused by

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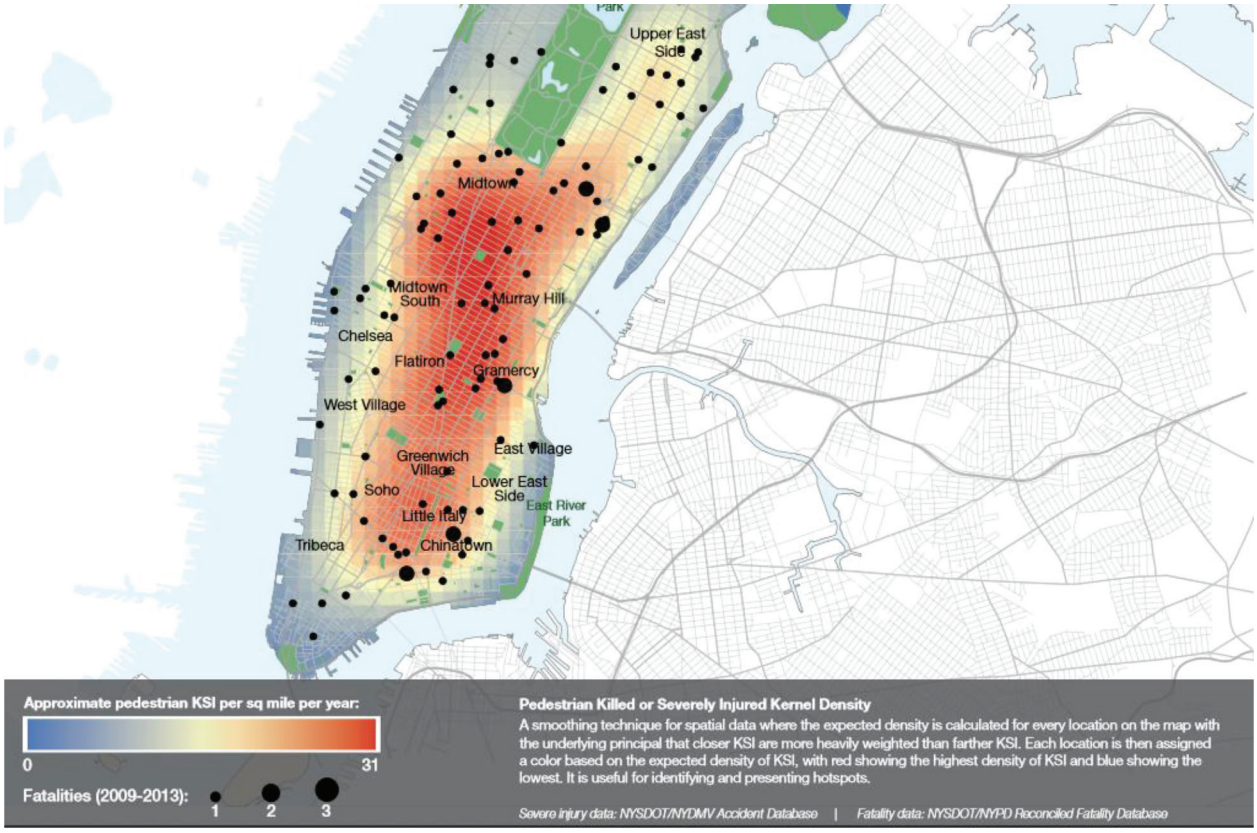


FIGURE 40 Manhattan Borough Pedestrian Safety Action Plan map. *Source*: Pedestrian Safety Action Plan: Vision Zero Manhattan (http://www.nyc.gov/html/dot/downloads/pdf/ped-safety-action-plan-manhattan.pdf).

trucks and large commercial vehicles are also a major problem in Manhattan's densely packed streets. Throughout NYC, dangerous driver choices such as failure to yield and speeding are primary and contributing causes to pedestrian fatalities and injuries. Pedestrian compliance issues and visibility problems also increase safety risks to pedestrians.

Feedback from numerous community outreach efforts combined with New York City Police Department (NYPD), New York State Department of Motor Vehicles, and New York State DOT borough-specific crash and safety data has gone toward creating Borough Pedestrian Safety Action Plans. Community outreach efforts included nine public workshops and public comments attained through a Vision Zero interactive input map. This map allows residents to post comments on trouble areas in the street network. More than 11,000 pedestrian safety issues have been identified from public comments on the interactive map. Of the complaints, 21% involved speeding and 21% involved drivers failing to yield to pedestrians. Also, 69% of workshop participants listed wide arterial streets as the first priority for pedestrian safety improvements. Pedestrians killed or severely injured (KSI) density heat maps for each borough were then created based on boroughwide rather than citywide crash data (Figure 40). Results allowed agencies to identify problem locations on a corridor, intersection, and area-wide basis.

The Borough Pedestrian Safety Action Plans "pinpoint the conditions and characteristics of pedestrian fatalities and severe injuries; they also identify corridors, intersections, and areas that disproportionately account for pedestrian fatalities and severe injuries, prioritizing them for safety interventions" (NYC Vision Zero Borough Pedestrian Safety Action Plans: http:/www.nyc.gov/html/dot/html/pedestrians/ped-safety-action-plan.shtml). Plan priorities include efforts to

1. Significantly expand exclusive pedestrian crossing time on all priority corridors by the end of 2017,
2. Modify signal timing to reduce off-peak speeding on all priority corridors by the end of 2017,
3. Install expanded speed limit signage on all priority corridors by the end of 2015,
4. Coordinate with Metropolitan Transportation Authority to ensure bus operations contribute to awareness and safety of pedestrians, and
5. Proactively design for pedestrian safety in high-growth areas including locations in the Housing New York Plan.

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In addition to these actions, NYC DOT will to commit to install 50 new safety projects per year and create other new safety initiatives. Because of the specific nature of problems within each borough, community outreach and borough-specific crash data are vital in determining and implementing new projects and deciding on treatments.

After determining project locations through a combination of crash data analysis and community outreach, NYC DOT selects which safety countermeasures to use at which pedestrian crossings based on pedestrian and vehicular volumes, level of service analysis, street width, signal phasing, constructability (drainage and utilities), street network analysis, and community review. Depending on its scope, each project design is reviewed by multiple units within NYC DOT, including signal operations, highway design, sidewalk inspection and maintenance, traffic planning, and borough engineering. Major projects are then sent to multiple outside agencies for review, including the fire department, department of sanitation, department of parks and recreation, and police department.

Common engineering treatments include raised medians, pedestrian refuge islands, curb extensions and bulb-outs, reduced corner radii, road diets, and narrow lane widths (standard is 10 ft; 11 ft is provided for bus and truck routes). Raised medians are used on short block segments where two refuge islands merge to create a continuous median. Pedestrian refuge islands are typically installed when four- to three-lane road diets are implemented (Figure 41).



FIGURE 41 Median islands on Crotona Avenue, Bronx, New York City. *Source*: NYC DOT Pedestrian Projects (http://www.nyc.gov/html/dot/html/pedestrians/pedestrian-projects.shtml).

Curb extensions are, however, used only where they do not interrupt storm drainage or storm water management processes. Road diets are generally from four to three lanes, and implemented where vehicular volumes are under 700 cars at peak hour per direction. Corridorwide speed calming, neighborhood slow zones, and enhanced illumination at crossings are also utilized in all five boroughs. Traffic-calming schemes are generally based around narrowing lanes and road diets and creating wide parking lanes (Figure 42). Leading pedestrian intervals are installed at high-crash intersections and intersections with high amounts of turning conflicts.

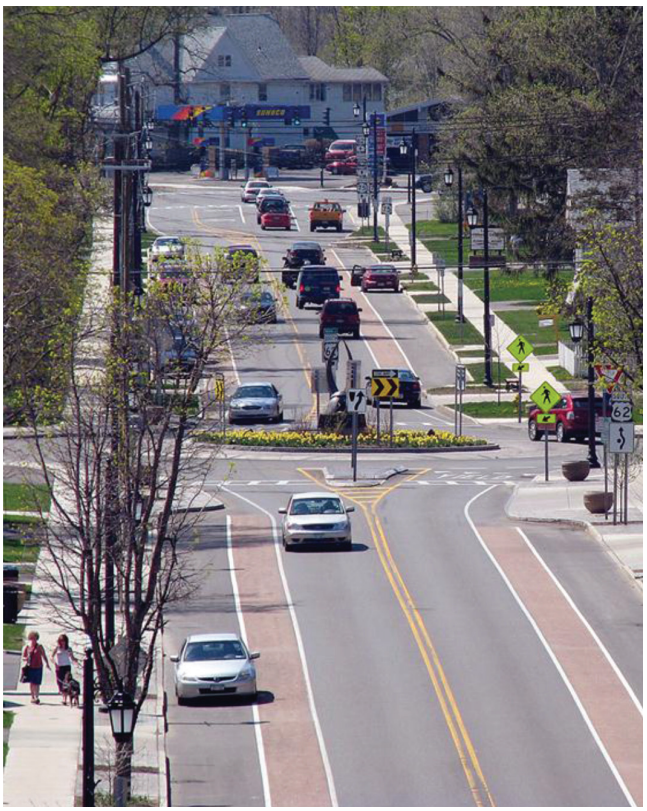


FIGURE 42 Traffic calming at NY-62 with road diet, bicycle lanes, and parking lanes with curb extensions and traffic circle. *Source*: http://www.dot.ny.gov.

NYC DOT Vision Zero also seeks to make streets in all five boroughs safer through public dialogue and education, law enforcement, innovative street design treatments, and legislation. Thus, newer treatments, including innovative traffic control devices such as raised crosswalks and intersections, parking restriction through daylighting (i.e., opening up the sight distance at intersection corners by eliminating parking near the intersection or adding curb extensions or both), and turning treatments at intersections meant to reduce truck-to-pedestrian crashes, are being considered.

Since before 2014, NYC DOT street design aspects have included more accessible pedestrian signals at high-priority locations; shortened crossing distances (through road narrowing, curb extensions, and signal timing) in identified zones with higher concentrations of senior residents; installing tactile warning strips for visually impaired pedestrians; providing new crosswalks or crosswalk enhancements at places that have been identified as desired or high-pedestrian crossing locations; clear lane markings; adding additional signalization for turns at intersections with high amounts of turning conflicts; designing spaces for buses, cyclists, drivers, and pedestrians; significant lane reductions; and providing less-complex intersection configurations.

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In 2014 (Vision Zero Year One), NYC DOT implemented numerous engineering projects, which included traffic-calming strategies such as arterial slow zones, neighborhood slow zones, and speed humps. A 25 mph citywide speed limit was passed after initial efforts seeking 20 mph limits (Figure 43), public outreach efforts created a new dialogue around street safety, and NYPD increased its crack-down on dangerous driving with a 42% increase in speeding tickets and 125% increase in failure-to-yield summons. Education efforts addressed city-employed drivers and public campaigns emphasized safer street use (NYC Vision Zero One Year Report April 2015: http:/www.nyc.gov/html/visionzero/assets/downloads/pdf/vision-zero-1-year-report.pdf).



FIGURE 43 Efforts to establish 20 mph speed limit. *Source*: http://www.nysenate.gov.

Arterials comprised only 15% of vehicle mileage, yet accounted for 60% of pedestrian fatalities. This was primarily as a result of high vehicle speeds. In response, NYC DOT initiated the Arterial Slow Zone Program, which used a combination of treatments and tools (Figure 44). These included lower speed limits, adjusting signal timing to discourage high speeds by coordinating consecutive intersection signals to be consistent with the slower speeds, and increased NYPD traffic enforcement. Signage generally indicates the slow zone, and NYPD regularly employs temporary speed boards and feedback signs throughout the zone.

Street design is understood to be most effective when both the public is educated and street safety rules are strictly enforced. To help enforce reduced vehicle speed limits, the city attained authorization from the state to continue its red light camera program and expand the speed camera program. To help educate the public and direct the street design process, the Vision Zero Action Plan also outlined 103 initiatives to be undertaken by numerous agencies, but spearheaded by NYC DOT, NYPD, the Taxi and Limousine Commission, the Department of Citywide Administration Services, and the Department of Health and Mental Hygiene. All initiatives have already begun and many are completed.

Under NYC Vision Zero, once a project plan has been proposed, community feedback is a vital part of how NYC DOT decides what safety features to include or to modify from the plan. For example, NYC DOT has recently untaken numerous projects to revamp Queens Boulevard and Bruckner Boulevard, including protected bike lanes in the overall designs. However, in July 2015 public bike advocacy groups raised their concerns about the lack of bike lanes in other projects, such as Riverside Drive, Eighth, Street and Atlantic Avenue. Such concerns from the community are taken into serious consideration as part of Vision Zero (StreetsBlog NYC. July 28, 2015. Accessed at: http:/www.streetsblog.org/2015/07/28/tish-james-calls-on-dot-to-make-bike-lanes-standard-on-vision-zero-projects/#more-348505).



FIGURE 44 Arterial slow zone on Northern Boulevard, New York City, New York. *Source*: http://www.nyc.gov.

In summary, project selection through the Vision Zero philosophy starts with the ethic that nearly all serious injury accidents can be prevented through the combination of street design, education, and enforcement efforts. Community outreach and robust data analysis based on borough-specific conditions further helps refine project selection. Redesigning high-crash problem locations is more efficient when initiatives for all involved agencies are clearly outlined, allowing greater interagency coordination. Finally, community feedback on project proposals helps refine treatments selections to best serve all road users, thus facilitating the public cultural change that is part of the Vision Zero method.

CASE EXAMPLES—INNOVATIVE TREATMENTS AND APPROACHES FROM OTHER SOURCES

Student Waiting Areas and Stand-Back Lines

Phoenix, Arizona

From Safe Routes to School Guide—*Case Examples, Engineering (National Center for Safe Routes to School, retrieved from http:/guide.saferoutesinfo.org/)*

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Unfortunately, many school crossings are at busy streets, and many of the sidewalks in Phoenix were built before the time when sidewalk buffer areas were required as a part of the design to separate pedestrians from motor vehicle traffic. It is important to provide a separation between moving vehicles and young children waiting to cross a busy street. This is not possible with a 5-ft-wide sidewalk.

One such school crossing was identified by the Washington Elementary School District in northwest Phoenix. This is a crossing for R.E. Miller Elementary School for nearly 100 children over a busy five-lane street with nearly 40,000 motor vehicles per day. Despite the presence of two crossing guards and a 15 mph school zone, the school district expressed a concern about the large groups of children waiting on a 5-ft-wide sidewalk before crossing.

The school district, city, and property owners worked together on a solution to provide a safe area for students to wait. The property owner (church) provided an easement to build a 10 ft by 20 ft waiting area behind the sidewalk (Figure 45). The school district moved the existing wood fence behind the new student waiting pad, and the city modified the landscaping behind the sidewalk, poured a concrete pad for students, and placed a "stand-back" line between the sidewalk and student waiting area. These low-cost and low-tech measures provided a considerable safety benefit at the crosswalk. Since then, Phoenix has built nearly 80 student waiting areas at major crossings where large numbers of students congregate before crossing. More of the painted stand-back lines have been installed at numerous school crossings.

This example illustrates that a jurisdiction does not have to spend a lot of money to obtain a big safety dividend. Some of the least-expensive measures can have a big impact on safety.



FIGURE 45 Images of student waiting area in Phoenix, Arizona. These images highlight the differences before and after a waiting area and stand-back line were installed at Richard E. Miller Elementary School in Phoenix. *Source*: Mike Cynecki and *Safe Routes to School Guide* case study.

Traffic Control Plan

Sabin Elementary, Portland, Oregon

From Safe Routes to School Guide—*Case Examples, Engineering (National Center for Safe Routes to School, retrieved from http:/guide.saferoutesinfo.org/)*

As a result of a technical analysis of pedestrian safety around Portland Schools, the city traffic-calming program identified Sabin Elementary as a high priority for traffic-calming measures.

The school, with 500 children enrolled, is served by a traditional grid street pattern with north–south and east–west arterials. Some of the problems affecting the area included traffic congestion during pick-up and drop-off times and unsafe pedestrian crossings.

In order to start the planning process, the city staff, along with key stakeholders, created the Sabin School Safety Committee. Among people involved in the committee were the school principal, community members, the school PTA, and Portland police. The committee identified major problems to work on, developed goals, and adopted the specific objectives of decreasing speeds on the north–south arterials, increasing visibility at key intersections, and improving crossing safety at two east–west arterial streets. Community feedback on the program was gauged through an open house, as well as a survey distributed to properties near the proposed improvement sites.

Once community concerns were addressed, the city conducted a pilot program of temporary improvements to see how they would affect driving conditions in the area. The pilot program demonstrated positive traffic-calming and pedestrian safety effects, and the city went forward with the final permanent program. The total cost for the project was $54,000.

After the traffic-calming measures were made permanent, two-way car conflicts have been reduced and pedestrian safety has increased. Discussions with nearby residents indicate that traffic congestion has decreased, as have dangerous conditions during the opening and closing of school (Zegeer et al. 2013).

15 mph School Zones

Arizona

From Safe Routes to School Guide—*Case Examples, Engineering (National Center for Safe Routes to School, retrieved from http:/guide.saferoutesinfo.org/)*

Arizona has been using 15 mph school zone crossings for elementary and middle schools since 1950 when the legislature passed State Law ARS 28-797 allowing for the uniform application of these special reduced-speed zones. School zones are operated by the schools and are established with roll-out 15 mph speed limit signs and portable "Stop When Children in Crosswalk" signs during student arrival and dismissal times (Figure 46). Their use is limited to crossings where there is not the benefit of a traffic signal or stop sign at the crossing. The law requires an engineering study before

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establishing the 15 mph school zone and the school must sign a written agreement with the local traffic authority to operate the zone. These special crosswalks are marked with yellow lines and the portable signs are typically allowed in the street 45 minutes before the start of school and 30 minutes after school dismissal. The 15 mph school zone portable signs are typically removed from the street during noncrossing times, but are allowed in the street during the entire school day if the crossing is abutting the school grounds. The law also strictly prohibits passing on the approach to the crossing, and the 15 mph speed limit extends from the advance "15 mph School in Session" portable sign through the crosswalk. The 15 mph school zones cannot be used within 600 ft of a traffic signal, stop sign, or another 15 mph school zone crossing.



FIGURE 46 15 mph slow school zone in Phoenix, Arizona. *Source*: Mike Cynecki and *Safe Routes to School Guide* case study.

Also see "Elementary School Crosswalk Enhancement Program in Bellevue, WA," a case study prepared for PEDSAFE, available at http:/pedbikesafe.org/PEDSAFE/casestudies_detail.cfm?CS_NUM=30&op=L&subop=I&state_name=Washington.

Speed-Sensitive Traffic Signals

Boulder, Colorado; Arlington, Virginia; and Washington, D.C.

From National Safe Routes to School Clearinghouse website http:/guide.saferoutesinfo.org/engineering/speed_sensitive_signals.cfm

High-speed motor vehicles pose a serious threat to the safety of children who are crossing arterial streets near schools and are one of the largest challenges in providing safe routes to school. Innovative measures have been used to reduce motor vehicle speeds such as the speed-sensitive signals used in Boulder, Colorado; Arlington, Virginia; and Washington, D.C.

The signals use pavement loops to detect the speed of a motor vehicle. If the motor vehicle exceeds the speed limit, the traffic signal ahead displays a red light. Drivers learn that speeding on such streets will require them to stop at the light and be further delayed. The sign "speed-sensitive signal" conveys that message to drivers.

Speed-sensitive signals were added as part of a traffic-calming project at Sunnyslope High School in Phoenix, Arizona. The signals monitored motorists' speed and flashed their driving speed and a bright LED strobe light if a motorist exceeded the 35 mph speed limit by 5 mph or more.

Along with other traffic improvements, including a staggered crosswalk, the speed-sensitive signals resulted in slower motorist speeds (on average cars went 6 mph under the speed limit) and a reduction in pedestrian crashes. The avenue averaged 32 pedestrian crashes per year during the previous 3 years, but only one crash in the 6 months following the project (Zegeer et al. 2013).

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CHAPTER SIX

SUMMARY AND CONCLUSIONS

This synthesis identified overarching policies, current recommended practice guides, and extensive safety research being considered by jurisdictions in application of pedestrian crossing improvements. There remains a significant degree of flexibility and nonspecificity in many federal guidance documents, such as *Manual on Uniform Traffic Control Devices* (*MUTCD*) and AASHTO design guides, as well as federal sanctioning of use of alternate design guidance and innovative treatments for provision of pedestrian facilities. In addition, the body of pedestrian safety research continues to grow, yet there remain many questions about the most appropriate treatments and treatment combinations in different environments. Thus, there continues to be a variety of practices and decision approaches for applying pedestrian crossing improvements.

In addition to policy requirements, a number of states and cities seeking to encourage more walking while improving safety are voluntarily adopting policies such as Complete Streets, and Toward Zero Deaths or Vision Zero frameworks. Cities have joined together to create an organization, the National Association of City Transportation Officials (NACTO), which has further developed Complete Streets principles and designs demonstrating their vision of how a safer, more accessible network might be provided for pedestrians in urban areas. Vision Zero cities have embraced a vision based on an ethical responsibility of the transport system designers and operators, as well as the users of the system, to minimize the possibility of people dying or becoming seriously injured when walking, cycling, or traveling by motorized vehicles. These policies are also affecting how decisions are made and the types of countermeasures being prioritized to address problems. Some examples are mentioned here.

On a more procedural level, a variety of problem identification and prioritization practices are being used by both states and local jurisdictions to identify pedestrian safety issues and select improvements. Depending on the state, problem identification practices include strategic safety planning, statewide pedestrian and bicycle plans, network screening processes employing systemic (or proactive) risk assessments from research studies (infrequent), crash-based screening approaches, design-based assessments of facility quality, and extensive reliance on local jurisdictions to identify pedestrian safety issues. These are in addition to widespread efforts to ensure compliance with the Americans with Disabilities Act (ADA). However, a few states still lack any specific policies, guidance, or procedures to identify and address pedestrian safety needs, whereas others expressed a desire to be more proactive in assessing and treating pedestrian risks but require additional information on ways to effectively do so.

Regarding resources being used to help select improvements, there is a growing body of safety evidence available to help decision makers prioritize among different treatments. Resources include limited number of crash modification factors (CMFs) for about half the treatments included in this synthesis to expert guidance and tools such as PEDSAFE that incorporate safety research shaped by expert judgment and case examples. Although crash evidence is not available for all designs, a number of design treatments also have evidence of effectiveness in reducing travel speeds. There are also some traffic control devices with evidence of crash-based effectiveness, but results are often mixed, depending on applications. A review of evidence for this synthesis finds that treatment effects, particularly yielding rates and other operational measures of effectiveness, have varied widely for certain treatments such as rectangular rapid flash beacons (RRFBs) and older warning types of devices; effects have varied by jurisdiction and by a variety of other application contexts that are not yet well understood. On the other hand, yielding effects for pedestrian hybrid beacons (PHBs), which are considered by FHWA to also be a crash-proven safety countermeasure, have appeared more consistent in the locations where applied and evaluated; as yet, however, much of the research evidence for PHBs comes from relatively few cities with extensive use of the devices. In addition, needs for data on pedestrian use or demand, including warrants for traffic control stop devices, also affect and sometimes act as barriers to selecting certain treatments.

Because treatments and applications appear to vary by jurisdiction, it is not surprising that practitioners appear to use locally produced design and other guidance, including CMF-based guidance, more often than the national expert tools. However, expert guides do offer practical information with respect to safety evidence as well as considerations and examples of applications. A number of state and local jurisdictions are incorporating other national study results and guidance into their locally tailored guides. These guides

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are often intended to be used to assess uncontrolled crossing locations or in some cases, locations with signals but no pedestrian amenities. *Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines* and associated reports by Zegeer et al. (2005) and *TCRP Report 112/NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings* (Fitzpatrick et al. 2006a) are both used or incorporated, often with warrant information and other locally derived inputs or modifications, into decision tools and guides to assess suitability for crosswalks and other improvements. These guides are intended to help streamline decision processes and reduce the variation in practices that can result from engineering judgment applied alone or on a case-by-case basis. Examples of jurisdictions that have produced or used such guidance include Boulder, Colorado; Seattle, Washington; Washington, D.C.; and North Carolina.

As mentioned previously, in addition to varying degrees of success with the same treatments, jurisdictions also report varying considerations for approaches to providing safer pedestrian crossings and selecting among treatments. As mentioned, Complete Streets and Vision Zero frameworks appear to be among the policies that are most affecting and changing how decisions are being made among states and cities that have embraced these policies. Countermeasures and designs deemed to improve pedestrian safety and mobility are being favored over those that may prioritize motorized mobility, at least in highly urban environments. Some examples, which are described in more depth in chapter five of this report, include the following:

- Cambridge, Massachusetts, traffic-calming efforts focus on redesigning streets in such a way as to encourage people to drive more slowly and increase the comfort and safety of walking and bicycling, without relying extensively on traffic control devices such as signs and signals or on speed enforcement. The implementation of traffic-calming projects, including such treatments as raised crosswalks and intersections, curb extensions, chicanes, and pedestrian refuge crossing islands, is largely done in conjunction with streets that are being reconstructed through a continually updated 5-year street and sidewalk reconstruction plan.
- San Francisco, California, conducted a thorough analysis of 5 years of network crash data to identify high-injury and -fatality locations and identified and described a limited number of pedestrian collision profiles that most characterized each location. The project team then matched countermeasures to collision profiles, assigned costs to potentially effective countermeasures, and developed a fiscally constrained prioritization plan for implementation.
- New York City analyzes crashes and gathers public input for each individual borough to identify the specific types and characteristics of predominant safety issues. The city then prioritizes corridors, intersections, and other areas that account for disproportionate numbers of pedestrian fatalities and injuries for safety interventions as part of their Vision Zero plans for each borough. Speed limit reductions and automated enforcement complement design and engineering measures. The city also uses a comprehensive multidepartment and multi-agency vetting of planned treatments.
- Eugene, Oregon, uses the *Bicycle and Pedestrian Master Plan,* a series of Transportation Improvement Policies, NACTO design guidelines, and 8 80 Cities vision, along with a variety of methods of engaging the public to identify ways to create a more environmentally sustainable and equitable street network that fits with the city's goal to make it easier for people to walk. The city frequently uses crash analysis to identify problems, as well as a complaint hotline, going out into neighborhoods, and consistently reviewing pedestrian needs within the processes for all types of transportation projects developed.

FURTHER RESEARCH NEEDS

Future studies, including an anticipated report from NCHRP Project 17-56, are expected to provide additional information regarding the crash effects of several traffic control devices and one design; these include pedestrian hybrid beacons, rectangular rapid flash beacons, advance stop/yield bars and signs, and median crossing islands. Even among those treatments with crash-based estimates of safety effects, there will be a continuing need to study the treatments locally as applications, and safety effects and other outcomes may vary among land use, enforcement, and other contexts.

Other research needs include development of more information and easy-to-apply tools for systemic risk assessment to help jurisdictions prioritize appropriate treatments to locations where they are most needed, without waiting for crashes to occur. In addition, methods other than count-based warrants, such as demand estimators and other types of threshold or application guidance, are desired to overcome limitations where safety barriers currently limit pedestrian movement (and numbers), as exemplified in several cases mentioned in this synthesis.

FINAL CONCLUSIONS

As this synthesis reports, there is a wide array of policies, application practices, and treatment outcomes across jurisdictions and studies, and there will continue to be a need to study treatments in the particular contexts where applied. Diverse state and local policies and priorities such as presence or absence of Vision Zero and Complete Streets policies, as well as local laws, enforcement practices, geographies, and other conditions likely affect deci-

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sion processes and treatment outcomes. Thus, there is no one-size-fits-all prioritization or decision matrix that can be universally applied. Engineering judgment remains an important part of the decision process, and will likely remain so for some time based on philosophical differences and policy priorities' effects on practices, as well as because of gaps in data and other needs for flexibility. This finding can have both positive and negative impacts according to practitioners. One impact mentioned is that designs that do not fully meet pedestrian needs—such as arterial streets with few controlled pedestrian crossings—continue to be implemented because guidelines are nonspecific and flexible. Thus, ongoing retrofit efforts continue to be needed to address the pedestrian crossing deficiencies. However, a number of state and local jurisdictions are incorporating existing evidence into their own decision and design guides or are making use of national guidance based on most-effective available evidence in hopes of providing more consistent and effective outcomes when locations are determined to need improvements. At the same time, a few states have yet to significantly integrate pedestrian safety analysis and crossing improvement prioritization processes into their safety practices.

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ACRONYMS AND TERMS USED IN THIS REPORT

Acronyms

ADA	Americans with Disabilities Act
HAWK	high-intensity activated cross walk
HCM	*Highway Capacity Manual*
HSIP	Highway Safety Improvement Program
HSM	*Highway Safety Manual*
LOS	level of service
LPI	leading pedestrian interval
MUTCD	*Manual on Uniform Traffic Control Devices*
NACE	National Association of County Engineers
NACTO	National Association of City Transportation Officials
NCSL	National Conference of State Legislatures
PBCAT	Pedestrian and Bicycle Crash Analysis Tool
PCS	pedestrian countdown signal
PHB	pedestrian hybrid beacon
QOS	quality of service
RRFB	rectangular rapid flash beacon
RSA	road safety audit
RTOR	right turn on red
SRTS	Safe Routes to School

Definitions of Terms

Complete Streets – Complete Streets are designed and operated to enable safe access for all users. Pedestrians, bicyclists, motorists, and transit riders of all ages and abilities may move safely along and across a "complete street." A model Complete Streets Policy is that transportation agencies routinely design and operate the entire right of way to enable safe access for all users (Smart Growth America, National Complete Streets Coalition).

Crash modification factor (CMF) – A CMF is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure. Standard errors of the estimate give an idea of the quality of the estimate and potential variation of effect. If available, calibrated or locally developed state estimates may provide a better estimate of effects for the state (Crash Modification Factors Clearinghouse).

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Data-driven approach – A data-driven approach to traffic safety broadly encompasses analysis of safety data (which may include crashes or identified risk factors associated with roadways) to assess problem types and to identify cost-effective solutions. Both reactive and systemic approaches can be used to analyze and quantify problem locations. See those definitions and FHWA's Accelerating Innovation, Data-Driven Safety Analysis web page (https://www.fhwa.dot.gov/everydaycounts/edc-3/analysis.cfm), and the *Highway Safety Manual* (2010) for more information.

Proposed Rights-of-Way Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG) – "The guidelines ensure that sidewalks, pedestrian street crossings, pedestrian signals, and other facilities for pedestrian circulation and use constructed or altered in the public right-of-way by state and local governments are readily accessible to and usable by pedestrians with disabilities. When the guidelines are adopted, with or without additions and modifications, as accessibility standards in regulations issued by other federal agencies implementing the Americans with Disabilities Act, Section 504 of the Rehabilitation Act, and the Architectural Barriers Act, compliance with the accessibility standards is mandatory" (United States Access Board, http://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way/proposed-rights-of-way-guidelines).

Self-enforcing roads – This concept has mostly been defined in terms of enforcing motorist speeds. A self-enforcing roadway design reduces the opportunities for drivers to speed, but it could also be viewed as helping to ensure that road users in general have less opportunity (or desire) to violate road safety rules and obligations. In terms of speed management, the goal of self-enforcing design is to increase consistency of design with established speed limits, and to design the road itself to induce drivers to adopt operating speeds that are within established limits and appropriate for conditions, thereby reducing the need for traffic law enforcement of speed limits (Brewer et al. 2001).

Self-explaining roads – Self-explaining road design keys on the development of a consistent design and appearance for each roadway purpose or function category (Brewer et al. 2001). Self-explaining road design complements self-enforcing road design by making the type of road and associated speed limit(s) and other appropriate behaviors more readily evident to drivers.

Toward Zero Deaths (TZD) – A TZD framework encompasses a highway safety vision that seeks to eliminate highway fatalities as a threat to public and personal health (FHWA 2015). Also see Toward Zero Deaths, National Strategy on Highway Safety website supported by federal (FHWA, FMCSA, NHTSA) and other national and international partners, including AASHTO, NACE, the Governor's Highway Safety Association, and the International Association of Chiefs of Police (http://www.towardzerodeaths.org/).

United States Road Assessment Program (USRAP) – A safety benchmarking program sponsored by the AAA Foundation for Traffic Safety, modeled on similar programs used in other countries. For more information, see http://www.usrap.us/home/

Vision Zero – Similar to TZD, Vision Zero is a traffic safety vision that no one should be killed or seriously injured within the transportation system, and that measures can be taken by system designers and operators as well as users to prevent deaths in traffic. This vision originated in Sweden in the 1990s and came to dominate the decision framework and traffic safety discussion there by the mid-1990s. A key principle is that users make mistakes, but should not die as a result; speed management is therefore a key aspect of a Vision Zero framework. Vision Zero is described in a number of English language report summaries on the Swedish National Road and Transport Research Institute website (https://www.vti.se/en/) the and Vision Zero Initiative website (http://www.visionzeroinitiative.com/en/Concept/).

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APPENDIX A

Survey Questionnaire and Summary of Survey Responses

NCHRP Project 20-05/Synthesis Topic 46-10

Purpose: The purpose of this questionnaire is to document pedestrian safety crossing treatments being used by state and local jurisdictions around the country, what practices are used to select and prioritize where and when to use which treatments, and information on local treatment experiences and evaluations that may expand the knowledge base.

About the survey: Each of you has been sent a link that is unique for your state DOT or local jurisdiction. Your answers will be automatically saved and you can return to your questionnaire as many times as needed until you complete and submit the survey.

Practices may vary throughout a state or municipal organization, such as a state DOT, and it may be necessary to seek input from others in your jurisdiction. We ask that the initial contact please ensure completion and submission. If multiple people are needed to complete the questionnaire for your jurisdiction, the unique questionnaire link may be forwarded to other individuals to complete portions. The questionnaire will not be closed until you or the final respondent indicates it is complete and submits the survey.

The questionnaire is divided into two main sections:

- Part I is about policies and guidance pertaining to identifying and prioritizing pedestrian crossing safety improvements.
- Part II is about which, and under what circumstances, specific pedestrian crossing treatments have been implemented by your jurisdiction.

We ask you to please complete all questions to the best of your ability.

Part I—Methods and Practices for Implementing Pedestrian Crossing Treatments

1. What is the name of your jurisdiction?
   - If you are a city, report city and state:
   - If you are a county, report county and state:
   - If you are a state, report only state:

2. Which comprehensive or general guiding policy(ies) does your jurisdiction have or use in consideration of pedestrian safety needs? Please indicate any federal, state, or local policies used, besides the *MUTCD* [*Manual on Uniform Traffic Control Devices*] or state-adopted versions of the *MUTCD*. [*Examples of guiding policies/plans include, but are not limited to: Complete Streets policies or guides, local transportation or pedestrian plans, public health policies, access and livability policies/goals (e.g., 8 80 Cities), climate change-related policies or goals, sustainability goals, etc.*]
   - Federal (name policies/guides):
   - State (name policies/guides):
   - Local (name policies/guides):

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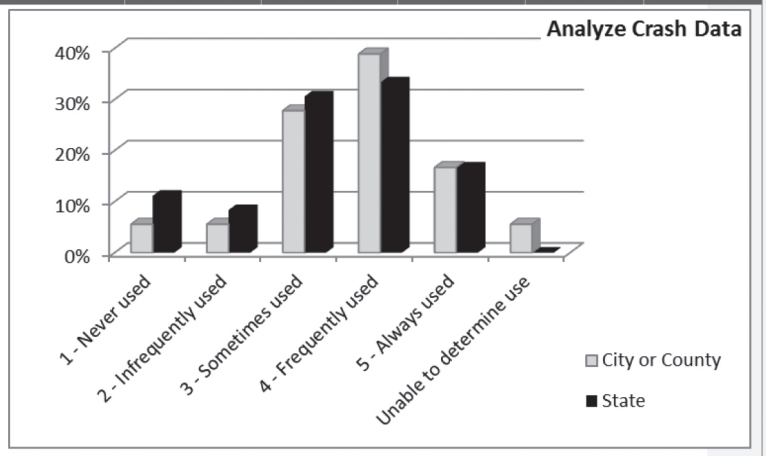
Now for questions regarding your (state or local) jurisdiction's procedures relating to prioritizing pedestrian crossing improvements.

3. First, please briefly describe how your jurisdiction identifies locations that are in need of pedestrian crossing safety improvements. [*There may be more than one process or set of criteria for different types of projects or situations. If so, please describe all.*]

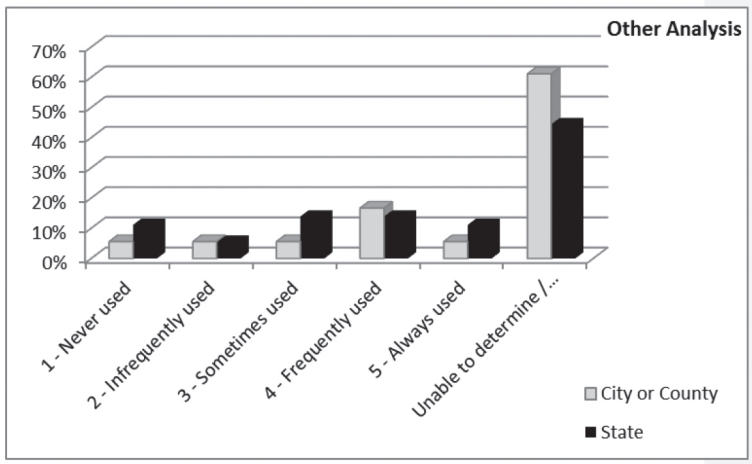
4. Please indicate the extent to which your jurisdiction uses the following specific types of procedures to identify locations in need of pedestrian crossing improvements.

Question 4

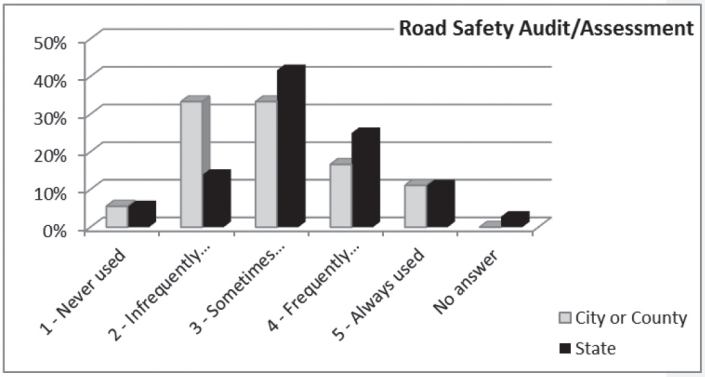
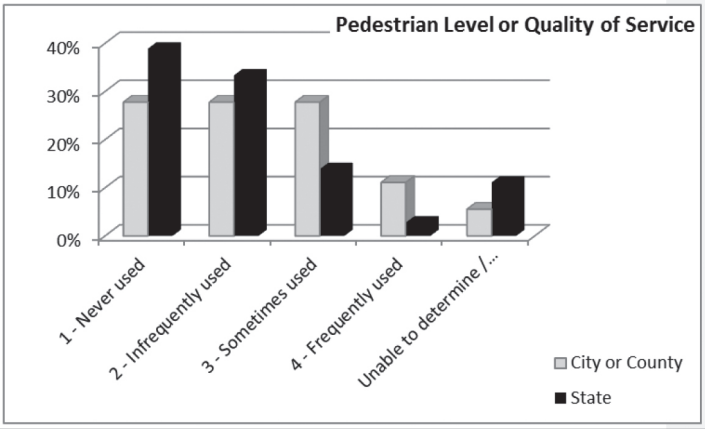
Conduct pedestrian crash analysis (e.g., network screening or GIS analysis).

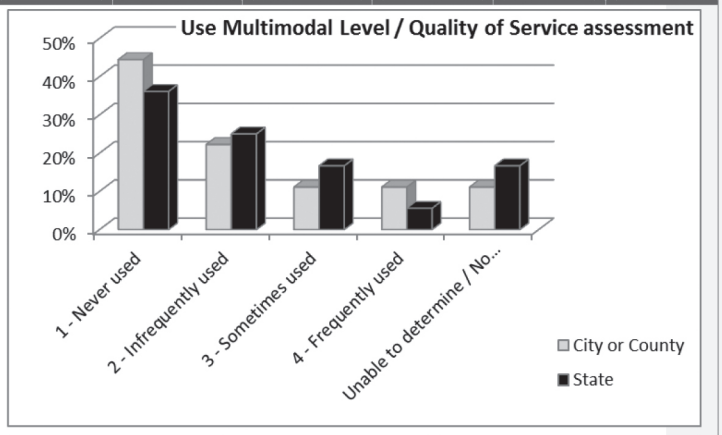
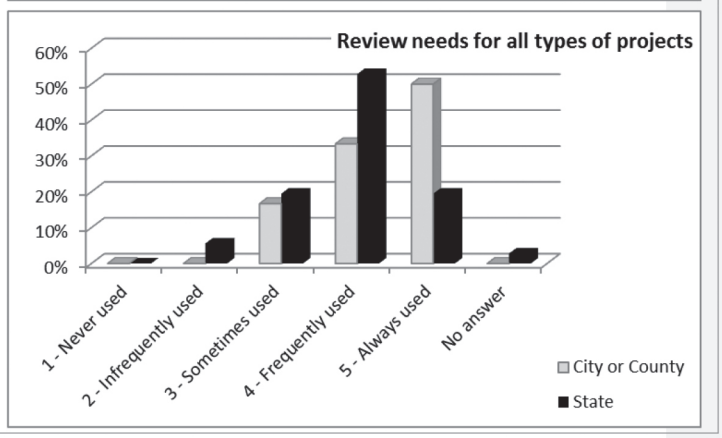


Conduct other type of analysis. [Please describe.]



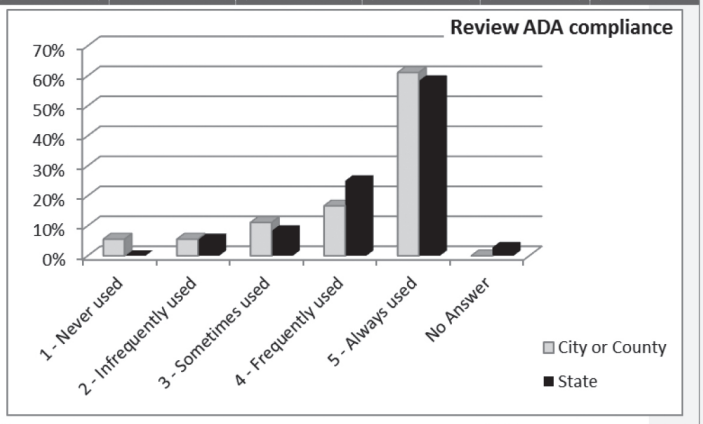
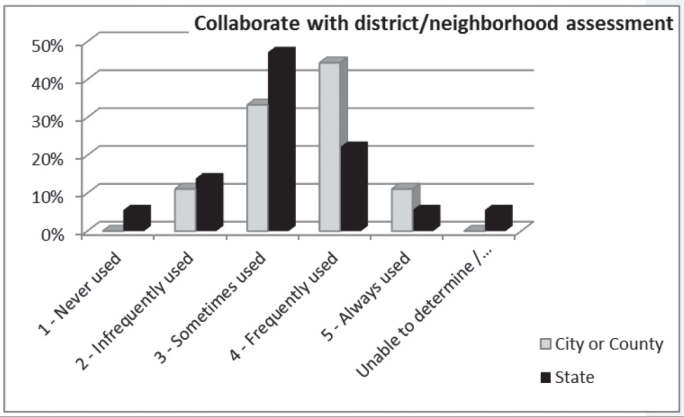
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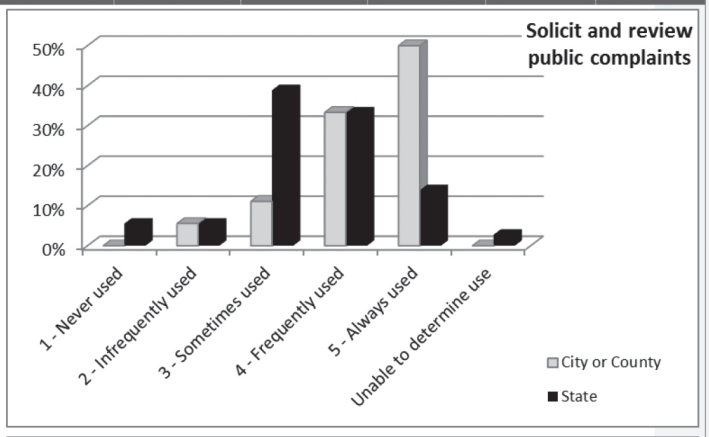
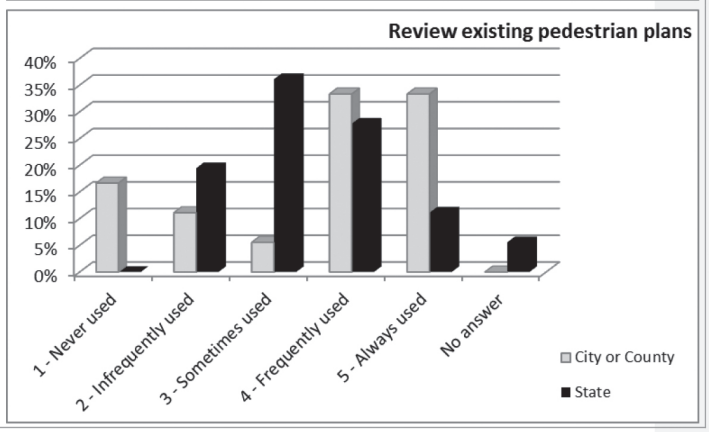
Question 4	
Conduct road safety audit/assessment.	
Conduct pedestrian level or quality of service assessment.	

Question 4	
Conduct multimodal level or quality of service assessment.	
Consistently review pedestrian crossing needs for all types of projects (reconstruction, repaving, operations, spot safety).	

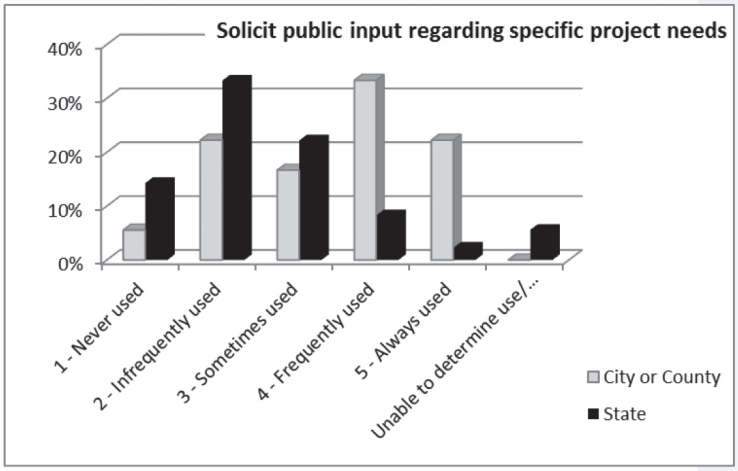
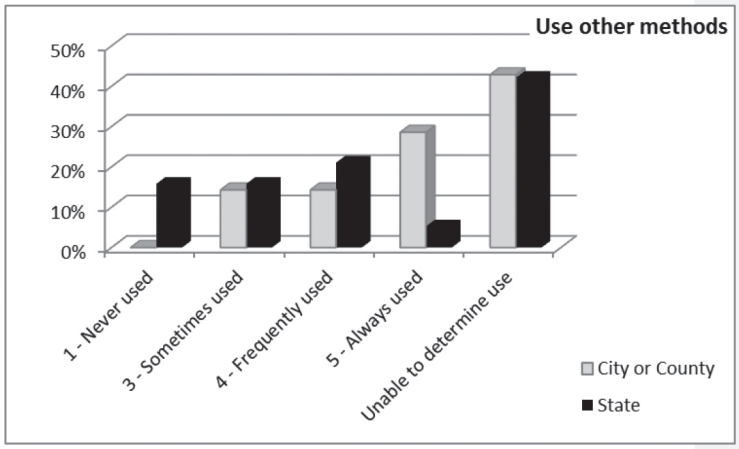
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Question 4	
Review Americans with Disabilities Act [ADA] compliance plan/needs.	
Collaborate with district/neighborhood evaluation of pedestrian safety needs (e.g., neighborhood walkability assessments, neighborhood plans).	

Question 4	
Solicit and review public complaints.	
Review existing pedestrian plans.	

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Question 4	
Solicit public input regarding specific project needs (e.g., through public surveys, Wikimaps).	
Use other methods. [Please describe.]	

5. Does your jurisdiction need additional guidance on how to identify locations for pedestrian crossing improvements?

   ☐ Yes [Please describe what type of guidance is needed.] _____

   ☐ No

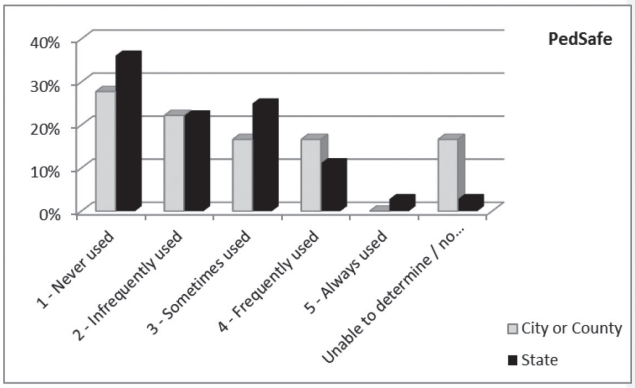
6. Now, please briefly describe how your jurisdiction selects which safety countermeasures to use at which locations to improve pedestrian crossings. [*There may be more than one process or set of criteria for different types of projects or situations. If so, please describe all.*]

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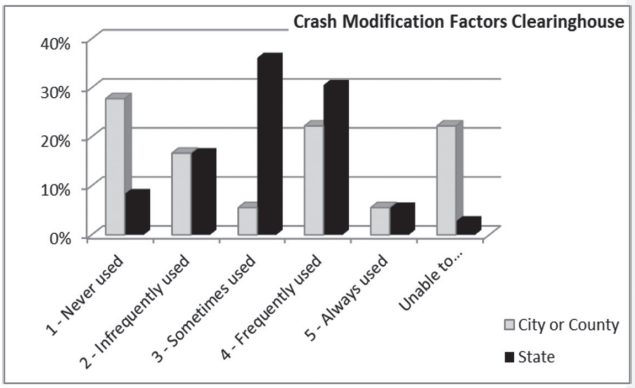
7. Please indicate the extent your jurisdiction uses the following to help identify potentially appropriate pedestrian safety crossing treatments.

Question 7

Consult PEDSAFE Countermeasure Selection Tool.
36 states
18 local

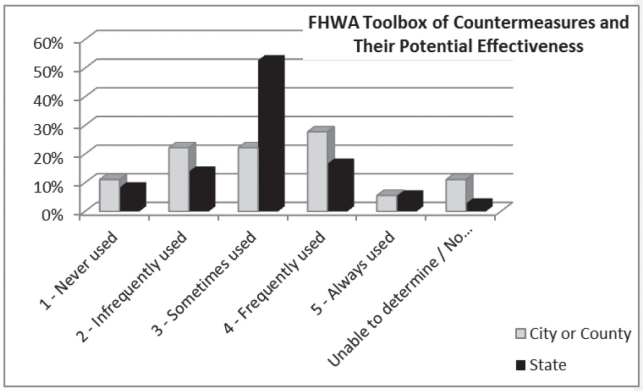


Consult Crash Modification Factors Clearinghouse.

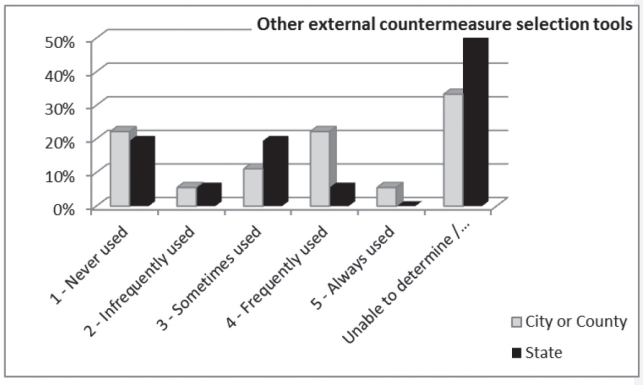


Question 7

Consult FHWA *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes.*



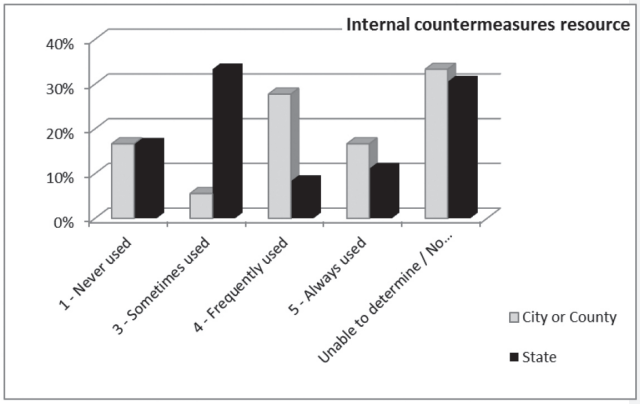
Consult other external countermeasure selection tools. [Please describe.]



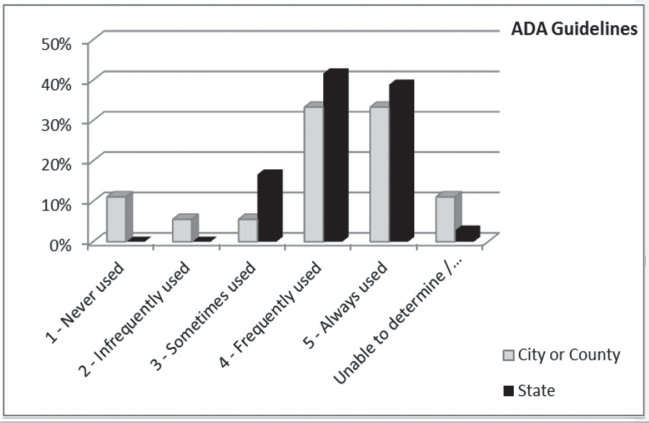
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Question 7

Consult internal countermeasures resource. [Please describe.]

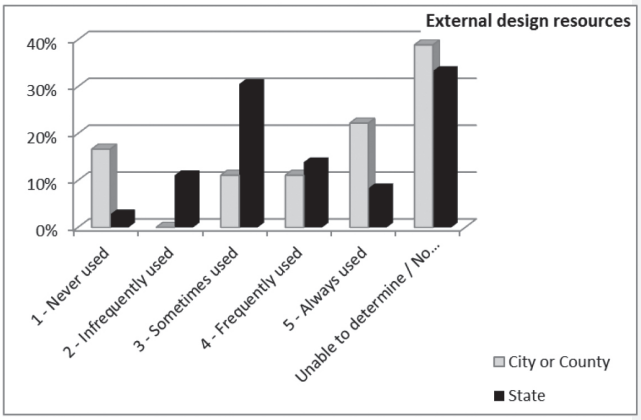


Consult ADA guidelines. [Please describe resources used.]

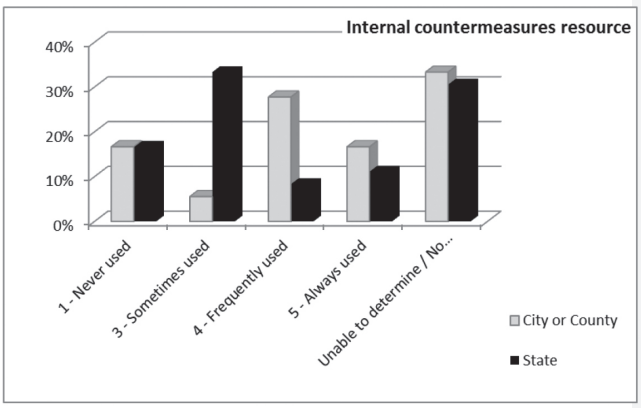


Question 7

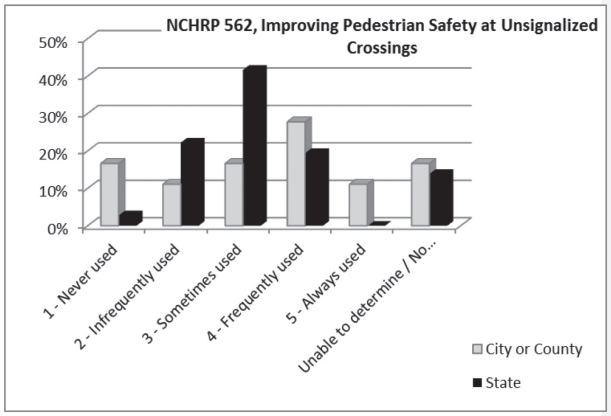
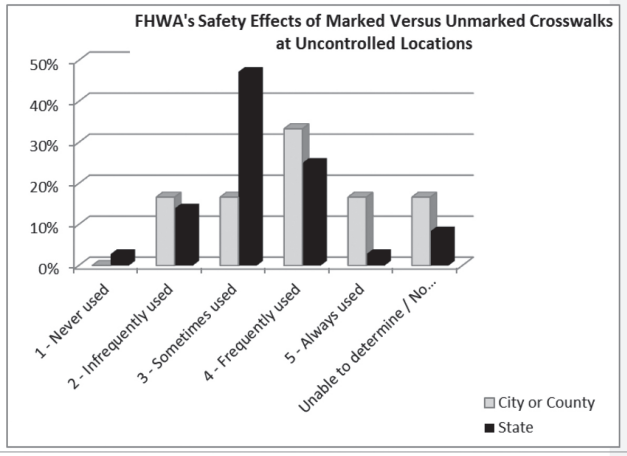
Consult external design resources. [Please describe.]

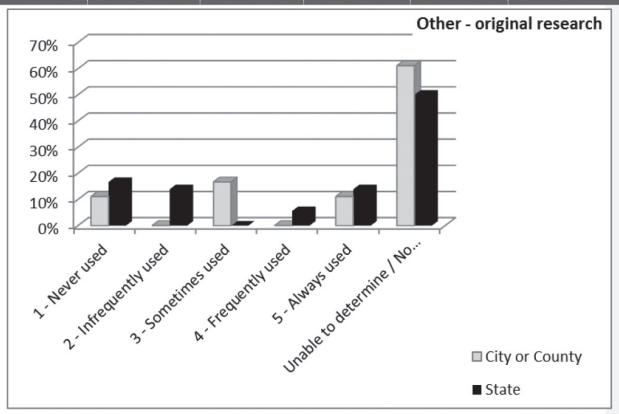
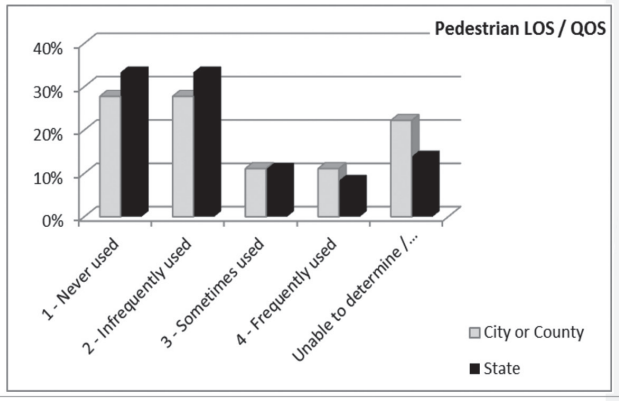


Consult internal design resource. [Please describe.]



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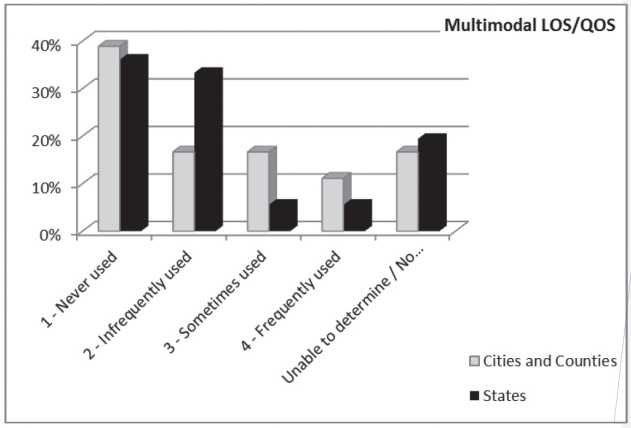
Question 7	
Consult *NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings.*	
Consult FHWA *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations.*	

Question 7	
Consult other original research documents. [Please describe.]	
Perform pedestrian level or quality of service assessment.	

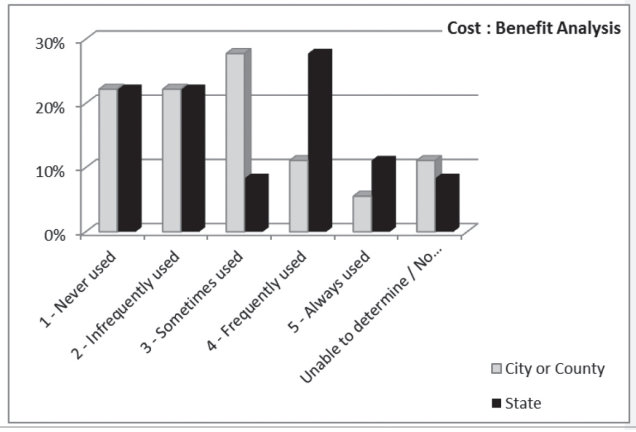
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Question 7

Perform multimodal level or quality of service assessment.

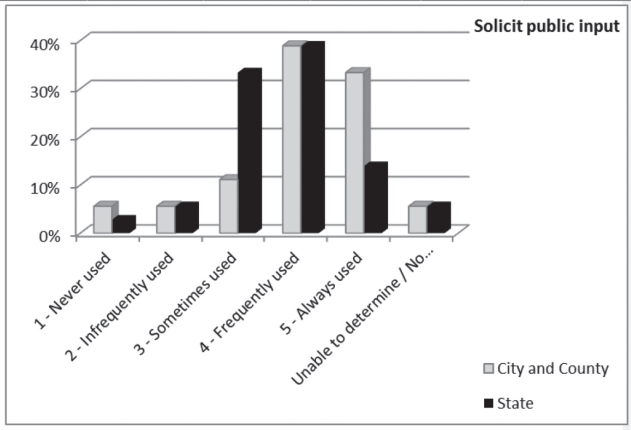


Perform cost–benefit analysis.

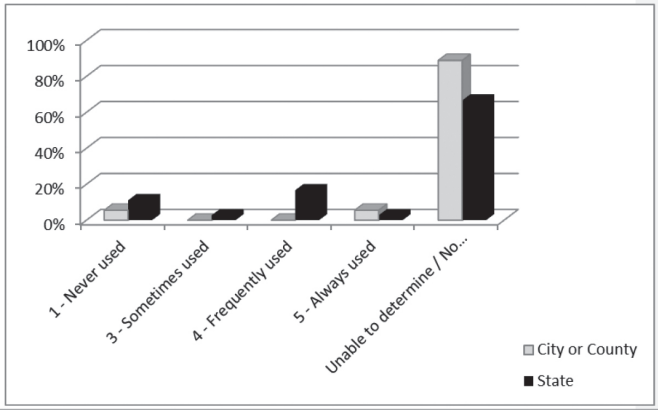


Question 7

Solicit public input.



Other methods. [Please describe.]



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8. What type of resource that does not already exist would be most beneficial to help your jurisdiction select pedestrian crossing improvements?

9. Does your jurisdiction use a formal design or treatment selection review process?

☐ Yes [Please describe.] _____

☐ No

Part II—Treatments Used to Improve Pedestrian Safety at Crossing Locations. Now we would like to ask a few questions about what treatments have been implemented and how they were used.

We will first ask you about design or geometric treatments.

10. Please indicate if your jurisdiction uses the below types of DESIGN features to improve safety for pedestrians crossing streets or highways. If the treatment is used, please answer the remaining questions for each treatment.

[*NOTE THAT RESPONSE SUMMARIES TO THE BELOW QUESTIONS ARE PROVIDED IN THE MAIN TEXT.]*

Question 10	Does your jurisdiction sometimes use the below design features to improve safety for pedestrians?		What are the key situations or location types for when this treatment has been used?	Are there other treatments that are typically used in combination with this treatment?	Is there published guidance for when this treatment is considered for use by your jurisdiction?	Has this treatment been evaluated for safety effects by or for your jurisdiction?
	Yes	No	Please describe. (Input field continues to the right.)	Please describe. (Input field continues to the right.)	If yes, please provide a link.	If yes, please provide a link.
Raised median	❍	❍	•	•	•	•
Pedestrian refuge/ median crossing island	❍	❍	•	•	•	•
Raised crosswalk or speed table	❍	❍	•	•	•	•
Curb extension/ bulb-out	❍	❍	•	•	•	•
Reduce corner radius	❍	❍	•	•	•	•
Road diet	❍	❍	•	•	•	•
Narrow lane width [What width does your jurisdiction consider to be a narrow lane?]	❍	❍	•	•	•	•
Corridorwide speed calming [What measures are used to calm speeds corridorwide?]	❍	❍	•	•	•	•
Pedestrian over-pass/bridge	❍	❍	•	•	•	•
Pedestrian under-pass/tunnel	❍	❍	•	•	•	•
Enhanced illumination at pedestrian crossings	❍	❍	•	•	•	•

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Question 10	Does your jurisdiction sometimes use the below design features to improve safety for pedestrians?		What are the key situations or location types for when this treatment has been used?	Are there other treatments that are typically used in combination with this treatment?	Is there published guidance for when this treatment is considered for use by your jurisdiction?	Has this treatment been evaluated for safety effects by or for your jurisdiction?
	Yes	No	Please describe. (Input field continues to the right.)	Please describe. (Input field continues to the right.)	If yes, please provide a link.	If yes, please provide a link.
Other design features that are used frequently to improve pedestrian crossings [Please describe.]	❍	❍	•	•	•	•
Other design features that are used frequently to improve pedestrian crossings [Please describe.]	❍	❍	•	•	•	•
Other design features that are used frequently to improve pedestrian crossings [Please	❍	❍	•	•	•	•

11. Do you have any other feedback or experiences to share on any of the above DESIGN treatments and their use to improve the safety of pedestrian crossings? For example, your jurisdiction may have tried a treatment and removed it, or you may have other important knowledge to share about the use or non-use of certain treatments. [Please be sure to mention which treatment(s) you are discussing in your answer.]

11.) Do you have any other feedback or experiences to share on any of the above DESIGN treatments and their use?	Local	State	Total
3 PHS were installed along a regional trail and we are only achieving 78% motorist yielding compliance to a solid red beacon. RRFBs [rectangular rapid flash beacons] at 54 locations are achieving 90% + compliance.	1	0	1
Can't say that we use it frequently, but we have been able to use traffic signals or ped actuated signals to improve a few crossings. Also, at signals, we've used leading pedestrian intervals in a few high ped vol. areas. Lastly, we've used a dynamic No Turn on Red sign to help protect a ped actuated phase at a busy location.	1	0	1
Driver confusion with HAWKs [high-intensity activated cross walk signals], compliance with the various treatment types, and long-term compliance. Issues of overhead versus side-mounted signs effectiveness, with speed and volumes variability. Questions about blind and low vision users, and how they use these type of treatments.	0	1	1
FDOT is moving toward more systematic use of modern roundabouts.	0	1	1
For many of the treatments described it depends when it's used. For example, we look at improve an at-grade crossing, evaluate location, and use before just recommending a grade separated crossing. Some of the corridor-wise speed measures are also implemented during construction projects to deter diverted cut-through traffic.	0	1	1
From a cost/impact perspective the tunnels and pedestrian bridges can be complex and significant resource intensive efforts. Often the schedules are longer than initially anticipated and cost overruns have been encountered on some high profile efforts.	0	1	1
In-pavement crosswalk lights were installed and then removed.	0	1	1
In-pavement pedestrian actuated lights have been used in the past, but have not been used recently due to reliability issues.	0	1	1

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11.) Do you have any other feedback or experiences to share on any of the above DESIGN treatments and their use?	Local	State	Total
In-pavement warning lights are not allowed due to unreliability. Enhanced colors are reserved for school zones. Continental crosswalk markings are recommended for most marked unsignalized crosswalks. Pedestrian hybrid beacons are on a case-by-case basis, but have only been installed at two state highway locations to date. Chris Monsere at Portland State University is just beginning an ODOT-sponsored research project that will look at the safety effects of various crosswalk treatments.	0	1	1
NA or unknown	0	2	2
Need better design guidance for right-turn islands. Some additional pedestrian volume threshold guidance could be helpful.	1	0	1
No	1	5	3
Our HAWKs are operating successfully and our RRFBs have been well accepted. The HAWK crossing Scottsdale Road for the new Scottsdale Quarter on the border of Phoenix and Scottsdale just met the pedestrian warrant of 20 pedestrians per hour. Only a month later there were 360 pedestrians in an hour and it went as high as 660 pedestrians per hour. This two-stage crossing treatment connects two major commercial centers in both cities. Super successful!	1	0	1
Rapid Rectangular Flashing Beacons were replaced with a HAWK signal. Motorists were not slowing down or stopping for pedestrians.	0	1	1
RRFB and HAWK installation at multi-lane roundabouts was studied in response to a lawsuit brought against the agency claiming that the roundabout crossings were not ADA compliant. Complete study is available on the RCOC website at www.rcocweb.org.	1	0	1
SCDOT's Traffic Calming Guidelines apply (http://www.scdot.org/doing/technicalpdfs/publicationsmanuals/trafficengineering/scdot_tcg_06.pdf). We have one Hawk signal and one RRFB installation under our guidelines. PDF copies of these latter two guideline will be supplied as they are not online.	0	1	1
See answers to above. All treatments follow the Better Streets Plan: http://www.sf-planning.org/ftp/BetterStreets/	1	0	1
Street lighting needs to be further investigated.	1	0	1
The geometry of the roadway changes behavior more than artificial speed limits.	0	1	1
Try to tie ped accommodations to signal upgrades funded through HSIP whose cost elements are not B/C driven. For example, add sidewalk connections and countdown ped signals.	0	1	1

TxDOT has guidelines for using Pedestrian Hybrid Beacons (PHB) and Rectangular Rapid Flash Beacons (RRFB):
• an engineering study must be performed and meet the guidelines detailed in Chapter 4F of the *TMUTCD*:
  • an established crosswalk with adequate visibility, markings, and signs
  • a posted speed limit of 40 mph or less (does not include school speed zones)
  • 20 pedestrians or more crossing in one hour
  • location deemed as a high risk area (e.g., schools, shopping centers, etc.)
  • crosswalk is more than 300 ft from an existing, traffic controlled pedestrian crossing.
	0	1	1

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11.) Do you have any other feedback or experiences to share on any of the above DESIGN treatments and their use?	Local	State	Total
We do have evaluations of many of our projects; these are whole project evaluations and links can be found here: http://www.cambridgema.gov/CDD/Transportation/projects/completedprojects.aspx. http://www.cambridgema.gov/CDD/Transportation/projects/traffccalmingprogram.aspx	1	0	1
We use these treatments when we determine they are appropriate on a case-by-case basis.	0	1	1
We've tried pavement lighting as well as pedestrian detection mats based on weight. Both were maintenance nightmares.	0	1	1
With street lighting, the push by LED light manufacturers to provide only full cutoff lighting is very disappointing since the vertical lighting aspect is critical to pedestrian safety, as well as security. Without the vertical lighting element, pedestrian visibility is reduced to shadows, rather than full visibility of pedestrians for better recognition of the person crossing and for identification. Good illumination of pedestrians and their features is critical for safety, but little emphasis is being placed on this. Unfortunate the dark skies issues are dominating the need for safety, particularly in dense urban areas.	1	0	1
No Answer	8	15	23
Total	18	36	54

Now we would like to ask you about traffic control devices (signals, signs/beacons, and markings).

12. Please indicate if your jurisdiction uses the below types of TRAFFIC CONTROL DEVICES to improve conditions for pedestrians crossing streets or highways. Again, if the treatment is used, please answer the other questions with respect to each treatment.

Question 12	Does your jurisdiction sometimes use the below types of traffic control devices to improve safety at pedestrian crossings?		What are the key situations or location types for when this treatment has been used?	Are there other treatments that are typically used in combination with this treatment?	Is there published guidance for when this treatment is considered for use by your jurisdiction?	Has this treatment been evaluated for safety effects by or for your jurisdiction?
	Yes	No	Please describe. (Input field continues to the right.)	Please describe. (Input field continues to the right.)	If yes, please provide a link.	If yes, please provide a link.
High-visibility crosswalks (e.g., continental, zebra, bar pairs)	❍	❍	•	•	•	•
Advance stop/yield bars and signs	❍	❍	•	•	•	•
Install traffic signal without pedestrian countdown signal	❍	❍	•	•	•	•
Install traffic signal with pedestrian countdown signal	❍	❍	•	•	•	•
Hybrid beacon (formerly called HAWK signal)	❍	❍	•	•	•	•
Rectangular rapid flash beacon	❍	❍	•	•	•	•
Overhead or roadside-mounted flashing beacon	❍	❍	•	•	•	•
Leading pedestrian interval to pedestrian walk phase (traffic signal)	❍	❍	•	•	•	•

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Question 12	Does your jurisdiction sometimes use the below types of traffic control devices to improve safety at pedestrian crossings?		What are the key situations or location types for when this treatment has been used?	Are there other treatments that are typically used in combination with this treatment?	Is there published guidance for when this treatment is considered for use by your jurisdiction?	Has this treatment been evaluated for safety effects by or for your jurisdiction?
	Yes	No	Please describe. (Input field continues to the right.)	Please describe. (Input field continues to the right.)	If yes, please provide a link.	If yes, please provide a link.
Pedestrian-only walk phase or pedestrian scramble	❍	❍	•	•	•	•
"No Turn on Red" restrictions	❍	❍	•	•	•	•
In-roadway "Yield to Pedestrians" signs	❍	❍	•	•	•	•
Pedestrian warning signs	❍	❍	•	•	•	•
Parking restrictions	❍	❍	•	•	•	•
In-pavement flashing lights (associated with crosswalks)	❍	❍	•	•	•	•
Other traffic control device frequently used to improve safety at pedestrian crossings [Please describe.]	❍	❍	•	•	•	•

13. Do you have any other feedback or experiences to share on any of the above TRAFFIC CONTROL DEVICE treatments and their use to improve the safety of pedestrian crossings? For example, your jurisdiction may have tried a treatment and removed it, or you may have other important knowledge to share about the use or non-use of certain treatments. [*Please be sure to mention which treatment(s) you are discussing in your answer.*]

13.) Do you have any other feedback or experiences to share on any of the above TRAFFIC CONTROL DEVICE treatments and their use?	Local	State	Total
We have found that actuated beacons yield better results than beacons that flash all the time.	0	1	1
A separate document has been developed titled *Traffic Safety for School Areas Guidelines*—see http:/azdot.gov/docs/business/adot-traffic-safety-for-school-area-guidelines.pdf?sfvrsn=0	0	1	1
As previously noted, we've installed a dynamic no turn on red restriction for motorists for a ped actuated phase on a heavy turning movement location. Have not done a compliance study, but observations have been positive and we have received positive feedback from the public.	1	0	1
Based on preliminary information, the lone RRFB installation is being considered for removal and replacement by a yet-to-be-determined device or devices of some sort.	0	1	1
CDOT is using a combination flashing yellow arrow and blank-out sign with the message "yield to pedestrian" at several high volume intersections. The sign is activated when a ped pushes the button. A NO TURN ON RED sign first shows up and is displayed with the red arrow.	1	0	1
Countdown ped signals were removed from our PHB locations because cyclists were using it to run the crossing.	1	0	1
FDOT is "data driven" and relies heavily on counts, projections, and crash statistics to justify implementing pedestrian control at appropriate locations. The agency is moving toward a context-based approach that better recognizes conditions where pedestrians are as much a part of the system as motorists to allow pedestrian treatments as a default setting. However, we're not there yet.	0	1	1

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13.) Do you have any other feedback or experiences to share on any of the above TRAFFIC CONTROL DEVICE treatments and their use?	Local	State	Total
For many of the treatments described it depends where and when it's used—what are the site conditions and the proposed treatment appropriate. For example, in-road lighting and in-road signage depends on roadway type, location, and local community interest of installation and maintenance. As a state standard, all roundabouts and traffic signals have lighting installed at its approaches, enhancing both driver and pedestrian visibility.	0	1	1
For the "Yield to Pedestrians," we allow one community to utilize a removable sign on a county road. There are other local communities in Oakland County that use these signs on their roads.	1	0	1

Here are the guidelines for PHB and RRFB again:
• an engineering study must be performed and meet the guidelines detailed in Chapter 4F of the *TMUTCD*:
  • an established crosswalk with adequate visibility, markings, and signs
  • a posted speed limit of 40 mph or less (does not include school speed zones)
  • 20 pedestrians or more crossing in one hour
  • location deemed as a high risk area (e.g., schools, shopping centers, etc.)
  • crosswalk is more than 300 ft from an existing, traffic controlled pedestrian crossing
	0	1	1

In-street yield signs. No longer being recommended for use due to average life of signs (less than six months) due to the number of times struck; only used on two lane roadways—never on multilane roadways; must be removed seasonally for snow and ice control operations.	1	0	1
In-pavement lights were tried but were unreliable and system was removed (not a proven safety problem, just that they were not reliably turning off/on when desired).	1	0	1
More information is needed on pedestrian crossing treatments for very wide (8–12 lane), high speed (45–55 mph) arterials. We have many of these in urban areas such as the Las Vegas Valley.	0	1	1
Most times, we try a small improvement and then enhance the crossing as needed. All crosswalks must meet warrants, signals, HAWKS, etc.	0	1	1
Often treatments (not exclusive to pedestrian measures or TRAFFIC CONTROL DEVICE) have been applied without benefit of full engineering study regarding pedestrian demand, traffic, user compliance, concentration of crossing traffic, time of day considerations, and other behavioral factors. It is difficult to isolate the effect that treatments may have when a solid baseline condition was never established. Our Safety Evaluation Team has emphasized the need to conduct a meaningful before condition assessment to determine factors such as compliance, yielding behaviors, diagonal crossings, vehicle speeds, etc., so that when the treatment is installed and after condition is assessed—the results will hopefully be meaningful in relation to the baseline conditions.	0	1	1
Question of winter maintenance and durability of in-pavement lighting in winter/snowy climates and snowplows.	0	1	1
Roving eyes used and removed	0	1	1
See answer to #11 regarding the use of in-pavement flashing lights	0	1	1
See answers to above. Also, we find that signalizing uncontrolled intersections or performing signal upgrades tend to increase visibility of pedestrians and overall safety of intersections.	1	0	1
See last question.	1	0	1
Trouble with in-roadway lights: Maintenance issues, crest vertical curves, higher volume roads where cars block the view.	0	1	1

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13.) Do you have any other feedback or experiences to share on any of the above TRAFFIC CONTROL DEVICE treatments and their use?	Local	State	Total
VDOT has found in-pavement warning lights to be a significant maintenance headache. They are no longer recommended, especially with the advent of newer technologies such as RRFBs. Also—we are likely to start shifting away from longitudinal lines ("continental") crosswalks, and toward "Bar Pairs" crosswalks. NCHRP research has demonstrated that Bar Pairs crosswalks perform very similar to Longitudinal Lines crosswalks in terms of driver behavior, but at reduced installation and maintenance cost (less thermoplastic).	0	1	1
We are currently conducting research on the placement of Yield to Pedestrian signs in the roadway to improve driver yield compliance.	0	1	1
We removed an exclusive pedestrian phase at T intersection in the university area due to low compliance. It was also without diagonal crossings, which we probably will try before removal now.	1	0	1
We use these treatments when we determine they are appropriate on a case-by-case basis.	0	1	1
We've relied heavily on rectangular rapid flash beacons over pedestrian hybrid beacons and they work well, especially when combined with median islands.	0	1	1
West Virginia has a higher number of exclusive pedestrian walk phases than other states. We have seen many instances in our state of motorists not yielding to pedestrians even at signalized intersections with countdown pedestrian heads.	0	1	1
NA or unknown	0	2	2
No	1	2	3
No answer	8	14	22
Total responding	18	36	54

14. Please share any other thoughts or comments on the topic of pedestrian safety crossing improvements.

14.) Please share any other thoughts or comments on the topic of pedestrian safety crossing improvements.	Local	State	Total
We have found that infrastructure improvements alone will not accomplish the goal of enhancing pedestrian safety. There really needs to be a 3 "E" approach. Another thing we have learned is that some of the newer traffic control devices are not always understood by the end user.	0	1	1
A large portion of pedestrian fatalities in PA happens at night, in unlighted areas on roadways that separate a parking area from an adult beverage dispensary. We need guidance as to how to bridge those agency gaps that can make a difference: Liquor Control Board, Department of Education [Driver's ed.], Department of Health [teaching/outreach for better ped outcomes].	0	1	1
Additional Content on Project Prioritization and Highway Safety Improvement Efforts STI/SPOT reference for TIP Projects http://www.ncdot.gov/performance/reform/prioritization/ HSIP: https://connect.ncdot.gov/resources/safety/Pages/NC-Hihway-Safety-Program-and-Projects.aspx https://connect.ncdot.gov/resources/safety/Pages/NC-Highway-Safety-Program-and-Projects.aspx (Reference Bike-Ped Intersection Reports)	0	1	1
Federal guidance should be promoted that would allow implementation of devices and treatments not based solely on crashes or volume matrix.	1	0	1
How are jurisdictions handling large complex intersections? Are they installing more traffic controls or changing intersection geometry to make intersections smaller? How are other cities combining bike safety improvements with ped safety improvements?	1	0	1
I would like to be a part of this peer review/group if one is established.	0	1	1

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14.) Please share any other thoughts or comments on the topic of pedestrian safety crossing improvements.	Local	State	Total
In Albany, we have some locations where pedestrian crossings are challenging. Streets with steep slopes or other locations that have long blocks. It would be good to have guidance on how to address these types of locations.	1	0	1
Most of our Traffic Safety Engineers are concerned about Pedestrian Safety, but lack the justification to use limited funding on pedestrian improvements. Credible crash modification factors are key for implementation of pedestrian safety improvements.	0	1	1
Most of the answers to the questions posed in the previous two sections can be found by reviewing our VTrans 2015 Pedestrian Crossing Treatment Guidelines, which can be found here: http://vtransengineering.vermont.gov/bureaus/mab/local-projects/bike-ped	0	1	1
Our small city does not have the resources to do much comprehensive planning for pedestrian safety crossing improvements (or, I suppose, we haven't chosen to do so). With just a few staff focusing on the topic, and with a heavy workload, we mostly try to take advantage of opportunities as they come.	1	0	1
Pedestrian safety is high on our priority list. We have installed a number of RRFBs at school crossings recently. They are effective in getting drivers' attention and our community loves them!	1	0	1
Some of the pedestrian safety crossing improvements, including design or geometric treatments and speed calming devices "Your Speed" electronic signs, are also utilized by other local jurisdictions in the county on their locally owned roads. If needed, contact information could be provided upon request.	1	0	1
Texas is looking at a systemic approach to pedestrian safety improvements.	0	1	1
This is a great survey. I can't wait to see the results! Thank you.	0	1	1
This seems to be a continuous, on-going challenge of balancing local demands with trunk highway functionality. There is also the big question of which treatments are truly effective and which are just "feel good" treatments.	0	1	1
We continue to look for new ideas, which have been tested and found to improve pedestrian safety, and have experiments with many new innovations—sometimes successful and other times not so much. Have to deal with drivers who grew up being taught that you stand on the corner and wait for traffic to clear before crossing, and expect the same currently—little notion to yield to pedestrians as required by law. Lack of driver education, and other efforts to teach drivers. Pedestrians also must recognize that they have some responsibility to ensure they can cross the street safely—never assume that the driver sees you and will stop.	1	0	1
We look at locations on a case-by-case basis.	0	1	1
We look forward to the results of this research.	0	1	1
We may be able to provide some limited further information on topics. Although resources and time are limited.	0	1	1
We're always looking for more tools for our toolbox.	1	0	1

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14.) Please share any other thoughts or comments on the topic of pedestrian safety crossing improvements.	Local	State	Total
While we've been quite successful deploying medians, curb extensions, rapid rectangular flashing beacons, and the like, we continue to favor roadway cross sections that we know are difficult for pedestrians to cross. I think our favorite is the 5-lane section with two-way center turn lane. Because there is no REQUIREMENT to provide a high-quality ped crossing at regular intervals these features are not included in initial construction. Then local agencies are forced to seek limited grant funding to retrofit for pedestrian crossings. We also face significant challenges due to freight mobility policies. There is even a freight mobility committee that gets to vote up or down on certain roadway design features—specifically curb extensions, medians, and roundabouts. Some roadway typologies cannot be fixed; 40 mph+ facilities with pedestrian generators, such as regional shopping centers cannot be reclaimed for pedestrians. We need strong guidance/requirements prohibiting high-speed facilities adjacent to roadside development that generates significant pedestrian trips: grocery stores, schools, recreational facilities transit corridors, etc. We should build it correctly to begin with.	0	1	1
Work to better integrate pedestrian in design. Often addressed by a program advocate outside of project development and this creates issues related to delivery and funding.	0	1	1
NA	0	2	2
No answer	10	20	30
Total	18	36	54

15. Is your jurisdiction willing to provide further information about these topics?

☐ Yes

☐ No

16. If yes, please provide contact information for the best person in your jurisdiction to contact for follow-up information.

- Name
- Title
- E-mail
- Telephone

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APPENDIX B

Detailed Synthesis of Literature Review of Treatments

Roadway Design Features

The following tables provide summaries of individual studies as follows:

Treatment descriptions, location types where studied, study type, and the measured safety effects, which may include crashes, or behavioral/operational measures such as motorist speed, motorist yielding to pedestrians in crosswalks, pedestrian delay, pedestrian compliance with crosswalks, and other safety indicators.

Narrow Lane Width

Narrow Lane Width	Location Type	Study Type	Measured Safety Effects	Citation
1- Projects that increased the total number of through lanes by narrowing lanes 2- Projects to provide space for installation of center two-way left-turn lane	-Urban arterial streets with posted speed limits of 45 mph or less -Roads with two-lane undivided cross sections to roads with eight through lanes	Observational evaluation of 35 improvement projects that used lane widths of 10 ft or less	1- Intersection crashes increased. No effect on segment crashes. 2- Total crashes reduced by 24 to 53%.	Harwood (1990)
Cross-sectional study to identify potential predictors of 85th percentile operating speed	19 (of 24 initially planned) horizontal curve sites and 36 straight section sites located in several suburban areas of Texas	Cross-sectional analysis	The study attempted to determine explanatory cross-section, roadside, activity and access, and posted speed limit and signing effects on 85th percentile speeds at horizontal curve and tangent midpoints. With posted speed limit allowed as a predictor in the models, speed limit was the only significant explanatory variable for operating speed at tangent sections. On curves, in addition to posted speed, deflection angle and access density class also helped predict operating speed. With speed limit not allowed in the models, lane width was the only significant predictor of speed on tangent sections, but explained much less of the variance in speed than did speed limit. On curve sections, when posted speed was not included, the effect of median presence and roadside development were the only other significant predictors of speed, and again, the model explained less of the speed variation than when posted speed limit was allowed in the model.	Fitzpatrick et al. (2001) and final report to TxDOT
Varied	Varied	Varied	Speed measurements	See Engineering Speed Management Countermeasures: A Desktop Reference of Potential Effectiveness in Reducing *Speed* (2014)

Reference for Narrow Lane Width

Engineering Speed Management Countermeasures: A Desktop Reference of Potential Effectiveness in Reducing Crashes, Federal Highway Administration, Washington, D.C., July 2014 [Online]. Available: http:/safety.fhwa.dot.gov/speedmgt/ref_mats/eng_count/2014/reducing_crashes.cfm.

Fitzpatrick, K., P.J. Carlson, M.D. Wooldridge, and M.A. Brewer, "Design Factors That Affect Driver Speed on Suburban Streets," *Transportation Research Record: Journal of the Transportation Research Board, No. 1751,* Transportation Research Board of the National Academies, Washington, D.C., 2001, pp. 18–25.

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Harwood, D.W., *NCHRP Report 330: Effective Utilization of Street Width on Urban Arterials,* Transportation Research Board, National Research Council, Washington, D.C., 1990, 55 pp.

Road Diet

Road Diet	Location Type	Study Type	Safety Effects	Citation
-Most sites had reductions from four to three lanes. -Some sites from four to two or six or four lanes	-New York City Urban and Suburban; 460 road segments and 324 adjacent intersections with road diets -Both controlled and uncontrolled locations	-5 years before, 2 years after road diet installations -Collision data collected for treatment and comparison sites.	-Roadway Segments: ANCOVA adjusted decrease in pedestrian crashes of 62% (CMF of 0.38, 0.17 s.e.) at road segments. -Decrease in (all types) of injurious and fatal collisions at road segments (CMF of 0.27, 0.08 s.e.) -Intersections: Nonsignificant ANCOVA adjusted decreasing trend in total pedestrian crashes at treatment sites. -Decrease in (all types) injurious and fatal collisions of 73% (CMF of 0.27, 0.08 s.e.) at intersections	Chen et al. (2013)
Comparison of pedestrian safety and crashes at 2,000 uncontrolled intersections and midblock sites with marked and unmarked crossings; roads included four to eight lanes, medians and median islands, and no median islands	Urban and suburban sites in 30 cities across the U.S.	Comparative study of 5 years of pedestrian crashes at 1,000 marked crosswalks and 1,000 matched unmarked comparison sites	Two and three lane roads were associated with reduced pedestrian crash risk when compared with roads with four or more lanes.	Zegeer et al. (2001)
Conversions from four-lane, undivided corridors to fewer motorized lanes and converting space to other uses such as center turn lanes, pedestrian refuges, bike lanes, or parking	-Corridors in large urban areas -Rural highways passing through small urban areas	Guide on road diet treatments and synthesis of multiple study results for accident modifications	-Road diet treatments can be expected to reduce total crashes by an average of 19% on corridors in large urban areas; and 47% for rural highways passing through small urban areas. -Actual crash reductions vary depending on rural/urban nature of area, crash history, and traffic volume. -Road diets with greater operating speed decreases have potential to lower crash severity.	Knapp et al. (2014); Harkey et al. (2008)
Reductions from four- to three-lane roads including reallocating road space to provide room for sidewalks and bike lanes	-Simulated urban arterials with four to three lane reductions -Daily traffic volumes of 10,000, 15,000, 17,500, and 20,000 vpd were chosen for the sensitivity analysis. -These were converted to hourly volumes of 500, 750, 875, and 1,000 vehicles per hour per direction.	Used simulation software and synthesis of other studies to conduct a sensitivity analysis to determine at what hourly volume the arterial vehicle LOS would decline with addition of road diet treatment.	-A two-way, peak hour volume of around 1,750 vpd (875 per direction) was the threshold when a decrease in motor vehicle LOS was observed. -This could be mitigated with signal timing optimization.	Knapp and Giese (2001)

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Raised Medians and Pedestrian Median Islands

Raised Medians/Median Islands	Location Type	Study Type	Safety Effects	Citation
-Suburban: Study sites were four- to six-lane arterials with raised medians. Comparison sites were four- to six-lane arterials with center two-way, left-turn lanes, and two- to six-lane undivided arterials. -Central business district: Study sites were mostly six-lane arterials with raised medians. Comparison sites were four- to six-lane arterials with two-way, left-turn lanes and undivided three-, four-, and six-lane arterials.	-CBD and suburban areas in Atlanta, GA; Phoenix, AZ; and Los Angeles, CA -Traffic volumes ranged mostly from 20,000 to 50,000 vpd.	-Cross-sectional with separate analysis performed for suburban area types and CBDs to account for different pedestrian volumes. -Compared group mean crash rates for pedestrian and vehicle crashes, using ANOVA. -Sample of 32,894 vehicle and 1,012 pedestrian crashes	-Suburban Arterials: Pedestrian collision rates were significantly lower on arterials with raised medians compared with undivided arterials, and lower compared with arterials with two-way, left-turn lanes. Vehicle collisions were significantly lower on arterials with raised medians compared with both undivided arterials and those with two-way, left-turn lanes. -CBD Arterials: Pedestrian collision rates were significantly lower on arterials with raised medians or with two-way, left-turn lanes compared with undivided arterials. Vehicle crash rates were lowest on arterials with two-way, left-turn lanes.	Bowman and Vecellio (1994)
-Raised medians on roads ranging from four to eight lanes at 2,000 uncontrolled crossing sites -140 crossings with raised medians and marked crosswalks; 135 crossings with raised medians and unmarked crosswalks; 1,725 sites without raised medians (860 marked and 865 unmarked)	-Urban and suburban areas in 28 cities -Daily counts at each site were expanded to estimated daily pedestrian volumes.	-Cross-sectional analysis of 5 years of pedestrian crash data -The study primarily aimed to assess the safety effects of marking crosswalks at uncontrolled locations, but was also able to examine effects of raised medians at both marked and unmarked locations.	The study controlled for motor vehicle and pedestrian annual volumes (pedestrian volumes were estimated from hourly counts, and expanded by daily counts at some locations) and suggests that pedestrian crash reductions in the range of 46% might be expected from adding raised medians to multilane roads (CMF = 0.54).	Zegeer et al. (2002)
Four refuge islands	Two unsignalized, four-leg intersections on urban and suburban residential roads in Sacramento, CA	Observational before and after analysis of behavioral effects	-A slight but nonsignificant increase in the proportion of drivers who yielded to pedestrians from 33% to 42% -An increase in the proportion of pedestrians who crossed in the crosswalk when refuge islands were installed at two, four-leg, unsignalized intersections -No effect on crossing delay after refuge islands were installed at two unsignalized, four-leg intersections in an urban, residential area	Huang and Cynecki (2000)

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Raised Medians/Median Islands	Location Type	Study Type	Safety Effects	Citation
Pedestrian refuge islands	Two signalized intersections in urban San Francisco, CA	Observational before and after analysis of behavioral effects	-No significant impacts of pedestrian refuges on driver yielding, on pedestrian–vehicle conflicts, nor on the proportion of trapped pedestrians at two urban, signalized intersections -An increase in crossing delay at one of the two intersections studied	Pécheux et al. (2009)
Combinations of high-visibility crosswalks, median refuge, Danish offsets, and pedestrian channelization	Eight sites on minor and major arterials in the Las Vegas Metro Area	Observational before and after analysis of behavioral effects	-On minor and major arterials when median refuges were part of the treatment package (eight locations in all; various treatment combinations) there were -Statistically significant increases in motorists yielding to pedestrians, and -Statistically significant increases in the proportion of pedestrians who looked for vehicles before crossing.	Pulugartha et al. (2012)
Curb extension, pedestrian refuge island, and stop bars were installed.	One site at a multilane arterial in the coastal zone in Santa Barbara, CA	Observational before and after analysis of behavioral effects	-An increase in the proportion of drivers who yielded in the far lane, but not the near curb lane after refuge islands, curb extensions, and stop bars were installed (from 61.5% in the before condition, to 82% in the after condition) -No significant difference in yielding by near-lane drivers -Crossing delay decreased by a statistically significant average of 4.9 s.	van Hengel (2013)
Removable pedestrian islands and pedestrian crossing signs	One rural, two-lane site in a county in Minnesota	-Before and after -Free-flow speed data (although collected at different time periods) was collected about 2 weeks after installation and one set about 6 weeks after installation.	-Significant reduction in mean speed -Improved driver compliance to speed limit, both in the short term and the long term at site with pedestrian islands and crossing signs	Kamyab et al. (2003)
Major reconstruction of roadway included a 7.5-ft-wide, 900-ft-long raised median between the two interior intersections; narrowing road width, adding new signals and intersection designs, and adding curbs and sidewalks.	Urban four-lane roadway with four major intersections at 1,000-ft intervals in New Jersey. Traffic volume was less than 10,000 ADT.	A collision analysis projecting future collision rates and costs including before and after analysis of behavioral effects	A 2 mph decrease in 85th percentile speed resulting from the major reconstruction/redesign including raised median	King et al. (2003)
Pedestrian refuge islands	28 sites in urban and suburban Toronto, Canada	3 years before and 6 years after crash comparison, with no analysis control for volume, time trends, severity, or other factors	-Pedestrian collisions dropped from 22 in the 3-year period before installation to six collisions afterward. -There were 46 vehicle–island crashes during the after period. -The authors mentioned that design and lane alignment changes might be able to mitigate motorist crashing into island effects.	Bacquie and Egan (2001)

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Raised Crosswalk/Speed Table

Raised Crosswalk/Speed Table	Location Type	Study Type	Safety Effects	Citation
Raised crosswalks, and one site that also had an overhead beacon that was previously installed	Three sites: two institutional streets (University Campus) in Durham, NC, and one T-intersection in Montgomery County, MD, on a residential collector street	Comparative cross-sectional analysis of behavioral effects	-Vehicle operating speeds (50th percentile) were from 4 to 12.4 mph lower at each of the Durham treatment sites compared with control sites (no before data were available) and also trended lower at the Maryland site. -Motorist yielding to pedestrians was also significantly higher at the North Carolina site with both a raised crosswalk and the flashing beacon compared with its control location, but the numbers of pedestrians didn't allow firm conclusions at the other location in North Carolina or in Maryland.	Huang and Cynecki (2000)
Speed humps installed just prior to two-way bicycle path crossings.	Several approaches to two-way bicycle crossings in the city of Helsinki, Finland	Observational study of driver scanning behavior while approaching bicycle crossings	Speed humps caused drivers to slow and look in both directions more often.	Summala et al. (1996)

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Curb Extensions/Bulb-Outs

Curb Extensions	Location Type	Study Type	Safety Effects	Citation
Known as "neck-downs" in New York City, and installed at corners of intersections and midblock crossings since 1968	Six locations with similarly designed neck-downs around urban New York City, from Manhattan to Staten Island	Analysis of 5 to 10 years of collision data across all six study sites. Treated sites were compared with nearby sites without neck-downs. Total of 204 pedestrian crashes.	-Pedestrian crash data were still too limited to identify statistically significant pedestrian crash effects. -Researchers analyzed effects by each location separately, and the trends were mixed with regard to pedestrian crash frequency and severity and total crash frequency and severity. -There were indications that overall crash severity may be lower.	King (1999)
Curb extensions	Eight residential and arterial crosswalk locations in Massachusetts, Washington, North Carolina, and Virginia	Before–after treatment (periods unreported) to measure behavioral effects	No significant effects on motorist yielding, speed, or pedestrian wait time could be detected.	Huang and Cynecki (2000)
Curb extension, pedestrian refuge island, and stop bars were installed.	One site: a multilane arterial in the coastal zone in Santa Barbara, CA	Before–after analysis of behavioral effects	-Significant improvements in driver yielding in the far lane of the crossing for staged crossings (from 61.5% in the before condition, to 82% in the after condition) -No improvement was observed in the near lane. -Pedestrian wait times and the distance at which motorists yielded in advance of the crosswalk were also reported to improve by a statistically significant average of 4.9 s.	van Hengel (2013)
Uncontrolled marked crosswalk had a curb extension on only one side, but advanced stop bars were at both sides of the two-lane street with average speeds exceeding the speed limit.	One suburban intersection crosswalk in Albany, OR Traffic volume was 17,000 vpd.	Observational. No data were collected prior to installation of curb extension; thus, the researchers used the untreated side of the same intersection as the control. They observed 99 crossings.	-Significantly fewer vehicles passed before one yielded to pedestrians crossing on the curb extension side, indicating a safety and delay benefit. -Fewer vehicles stopped at the advance stop bar on the treatment side compared with the untreated side.	Johnson (2005)

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Corridorwide Speed Calming

Corridorwide Speed Calming	Location Type	Study Type	Safety Effects	Citation
Street narrowing, chokers, curb extensions, transverse rumble strips at the beginning of treated sections, cobblestones for short sections, sometimes speed humps or other devices, traffic signals, parking	Multiple cities that evaluated the effects of areawide urban traffic calming measures, including on both local and main streets including traffic restricting/diverting measures and traffic-calming measures	Meta-analysis of 33 studies. One of the aims of the projects studied was to reclassify and restore the local functions and remove through traffic from residential areas and concentrate it on a few streets designated as main roads.	Results of the meta-analysis indicated that these types of schemes reduced the number of total injury collisions for all road users by about 15%. Effects were greatest on residential streets (about 25%) and lower on main roads (10%)	Elvik (2001)
12-ft humps, 14-ft humps, 22-ft humps, longer tables, raised intersections, circles, narrowing, one-lane slow points, half closures, diagonal diverters	Numerous projects throughout the United States	An overview of pre-1999 traffic-calming project evaluations carried out in the United States. Sample size, research design, data collection methods, and durations were not standardized. Ewing cautions that the statistics be used as ballpark estimates of impact.	85th percentile downstream vehicle speeds (in mph) -12-ft humps: 179 sites: Average after calming = 27.4 mph, a reduction of 7.6 mph and 22% -14-ft humps: 15 sites: average after calming = 25.6 mph, a reduction of 7.7 mph and 23% -22-ft tables: 58 sites: average after calming = 30.1 mph, a reduction of 6.6 mph and 18% -Longer tables: 10 sites: average after calming = 31.6 mph, a reduction of 3.2 mph and 9% -Raised intersections: three sites: average after calming = 34.3 mph, a reduction of 0.3 mph and 1% -Circles: 45 sites: average after calming = 30.3 mph, a reduction of 3.9 mph and 11%. -Narrowing: seven sites: average after calming = 32.3 mph, a reduction of 2.6 mph and 4% -One-lane slow points: five sites: average after calming = 28.6 mph, a reduction of 4.8 mph and 14% -Half-closures: 16 sites: average after calming = 26.3 mph, a reduction of 6.0 mph and 19% -Diagonal diverters: seven sites: average after calming = 27.9 mph, a reduction of 1.4 mph and 4%	Ewing (1999, Table 5.1)
Bulb-outs or curb extensions, raised intersections, and raised crosswalks	Midblock and intersection locations in seven states in the United States	Study synthesis	-Traffic-calming devices resulted in lower overall vehicle speeds. -Traffic-calming measures did not produce a statistically significant effect on average pedestrian waiting time.	Huang and Cynecki (2000)
Roundabout intersection designs, road diets, speed humps and tables, chicanes, and lateral shifts	Numerous sites throughout United States	Speed management action plan guidance and synthesis of evidence	-Roundabout intersection designs, road diets, speed humps, and tables have the most evidence that they lower speeds and crashes. -Chicanes and lateral shifts have been found to lower speeds.	Thomas et al. (2015, Speed Management Toolkit)

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Pedestrian Overpass/Bridge and Underpass/Tunnel

Pedestrian Overpass/ Underpass	Location Type	Study Type	Safety Effects	Citation
Pedestrian overpass/bridge and underpass/ tunnel	Tokyo, Japan, and San Francisco, CA	Review of pedestrian safety research	-An important measure of effectiveness for overpasses and underpasses is how much they are used by pedestrians. -"Measure of convenience (*R*), defined by the ratio of the time it took to cross the street on an overpass divided by the time it took to cross at street level." -About 95% of pedestrians opt for the overpass if $R = 1$, meaning that it takes the same amount of time to cross using the overpass as it does at street level. If the overpass route takes 50% longer ($R = 1.5$), almost no one uses it. Underpasses were used even less often for similar values of *R*.	Campbell et al. (2004) citing Moore and Older (1965); Mead et al. (2014)
Pedestrian overpass	31 sites in Tokyo, Japan	Review of pedestrian safety research citing a before and after comparison of pedestrian crashes. Crashes occurring in 200-m (218-yard) and 100-m (109-yard) sections on either side of each site were tabulated.	-After overpasses were installed, pedestrian crossing accidents decreased substantially, although nonrelated accidents increased by 23% in the 200-m sections. It is not known whether this increase could have been the result of other factors unrelated to the overpass. -Daytime pedestrian crashes were reduced more than nighttime crashes. This may be related to the volumes of pedestrians crossing the road.	Campbell et al. (2004); Mead et al. (2014)
Pedestrian overpass	Three pedestrian overpasses in San Francisco	Panel of disabled residents	Potential hazards or barriers include inadequate or nonexistent railings on bridge approaches; steep cross slopes; lack of a level platform at the base on bridge ramps where wheelchairs can stop before entering the street; inadequate sight distance to see opposing flow of pedestrians and a lack of level rest areas on spiral ramps; maze-like barriers on bridge approaches that are used to slow down bike traffic, but can also impede the progress of wheelchair-bound or visually impaired users; and lack of sound screening on the overpass so that the visually impaired can hear people coming the other way and avoid crashes.	Campbell et al. (2004) citing Swan (1978); Mead et al. (2014)

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Enhanced Illumination at Crossings

Enhanced Illumination	Location Type	Study Type	Safety Effects	Citation
Adding intersection illumination	U.S. sites	Meta-analysis on multiple studies	-42% reduction in pedestrian nighttime crashes -This countermeasure is included in the *Highway Safety Manual,* with a caution that the adjusted standard error measurement is from 0.2 to 0.3.	Elvik and Vaa (2004); CMF Clearinghouse CMF/CRF Details (n.d.)
Study of light conditions	Midblock and intersection locations	Analyzed 58,202 pedestrian crashes (less 23,634 removed because of data issues) to determine effects of light conditions on pedestrian crash severity	Controlling for pedestrian and driver attributes, vehicle attributes, speed limit and roadway attributes, and weather conditions, street lighting reduced the odds of a fatal injury by 42% at midblock locations and 54% at intersections compared with dark conditions without street lighting.	Chu (2006)
Smart lighting system that used a pedestrian detection device in order to automatically increase illumination	One midblock crosswalk in Las Vegas, NV. The site was chosen because the majority of motorists failed to yield to pedestrians and a high percentage of collisions occurred at night.	Before–after. Data were collected before and after the treatment was installed at dawn and dusk hours, and included seven measures of effectiveness involving pedestrian and driver behavior at the crosswalk.	-A statistically significant increase in the percentage of diverted pedestrians (pedestrians who purposefully used the crosswalk) -A significant increase in the percentage of motorists yielding to pedestrians -A significant increase in the percentage of motorists yielding to pedestrians at greater than 10 ft before the crosswalk -Author concluded that the countermeasure helped to improve pedestrian safety, likely owing to the increased visibility and attention to pedestrians provided by enhanced lighting at the site.	Nambisan et al. (2009)

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Traffic Control Devices

High-Visibility Crosswalks

High-Visibility Crosswalk Markings	Location Type	Study Type	Safety Effects	Citation
High-visibility crosswalk markings	Urban—72 sites, New York City	Two-group pretest/posttest using ANCOVA modeling to account for regression to the mean effect Before—5 years before crash data After—2 years after crash data	After adjusting for comparison group (to account for potential regression to the mean): -Statistically significant reduction of 48% in pedestrian crashes (CMF of 0.52; 0.17 s.e.) compared with if high-visibility crosswalks had not been added -No statistically significant effect on all crashes (0.99 CMF; 0.15 s.e.) or on multi-vehicle crashes (1.26 CMF; 0.20 s.e.)	Chen et al. (2013)
Two high-visibility types: continental markings and bar pairs	University campus (Texas A & M) midblock crossings -Road "feel"—urban, mixed, and rural -30–45 mph posted limits -40–50 ft road width. -Various other conditions, including presence of sidewalk (none, one side, two sides); number of lanes (two lanes, four lanes); with or without bike lanes; undivided or divided	Comparison of visibility—through measure of detection distances of two types of high-visibility crosswalk markings (continental, bar pairs) and standard markings (transverse lines), by 78 experimental subject drivers of an instrumented vehicle—on approaches to crosswalk markings newly installed at three locations each (nine total) on open roads on the University of Texas Also obtained subject ratings of how easy it was to see each type of crosswalk	-Detection distances for continental and bar pairs were statistically similar and also statistically significantly longer than for transverse line markings at day and at night. -Detection distances for all marking types were also longer at daytime. -The presence of traffic also had the effect of reducing detection distance. -Age, gender, driver eye height, and vehicle type were found to have minimal significance by the research team. -Participants also preferred the continental and bar pair markings to the transverse markings as reported in Iragavarapu, Fitzpatrick, and Chrysler (2011)	Fitzpatrick et al. (2011); Iragavarapuet al. (2011)
High-visibility crosswalks (yellow continental)	Urban School Zones—San Francisco, CA. 54 treated intersections. Included multiple lane sizes and speeds, controlled and uncontrolled, local (residential) and non-local streets, and a range of ADTs.	Empirical Bayesian (EB) method, before-and-after collision analysis. Before—at least 5 years before crash data per site After—at least 3 years after crash data per site Sites installed between 1997 and 2003 54 untreated comparison locations in geographically close proximity and with similar ADTs	Using the EB method to develop a safety performance function for intersections without the treatment and comparing actual crashes with the treatment to expected crashes without the treatment, the treated effect was estimated to be: reduction of 37% in pedestrian collisions (95% CI, 13% to 60%) Stated as a CMF, the effect is 0.63 (0.12 s.e.).	Feldman et al. (2010)

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High-Visibility Crosswalk Markings	Location Type	Study Type	Safety Effects	Citation
Strong yellow green (SYG) crosswalk markings; SYG plus speed feedback: "The school safety program elements included school crossing warning signs on the approach to and at every intersection, 20 mph during School Hours When Children Are Present speed limit signs on every surrounding street, speed humps on the local streets around the school (at least in the 660-ft blocks), interactive speed indicators on selected approaches along arterial street frontages, and strong SYG pavement markings at the speed humps, at all crosswalks, at 'SCHOOL' legends on arterial streets, and center lines and stop bars along streets adjacent to the schools." Pavement markings and signs	Urban—15 sites with at least one arterial street frontage of the four blocks surrounding the school, 42–48 ft in width, with two-way, 24-hour volumes of 12,000– 20,000 vehicles per day, Chicago, IL -12 locations, crosswalk markings only -3 locations, crosswalk markings plus speed feedback signs	Comparison of traffic speeds during peak a.m. and p.m. school travel times, before and after crosswalks implemented; no comparison group	-For all locations, the average mean speed (aggregated and weighted by volume) decreased by < 1 mph, from 26.3 mph before the installations, to 25.6 mph after (2.7%). -The percentage of traffic over the speed limit on arterials was 78.1% before and 77.5% after the installations, a reduction of only 0.8%. -At locations with SYG markings plus speed feedback signs, the aggregate peak hour speed was 24.3 mph before the installation, and 25.0 mph after, an *increase* in speed of 2.9%. -The percentage of traffic going faster than the 20 mph school zone speed limit also increased by 2.9% after the installations. -For the 12 arterial segments with SYG and no feedback signs, the aggregate mean peak hour speed was 27.1 mph before the installations and 25.8 mph after, a decrease of 4.8%. -The percentage of traffic going faster than the 20 mph speed limit decreased slightly at arterial locations without feedback signs, from 79.4% before the installation to 77.5% after, a decrease of 2.4%. -On local streets (that typically also included traffic calming/speed humps), speeds also increased slightly. The authors concluded that the SYG treatment and/or SYG plus speed feedback signs did not have a calming effect on speeds in school walk zones. However, they acknowledge the lack of comparison sites using traditional white markings.	Chicago DOT (2005)
High-visibility ladder style crosswalk plus novel overhead illuminated crosswalk sign. standard crossing signs, *MUTCD* W11A, and median islands were already present.	Urban—two sites, Clearwater, FL T-intersections (stop-controlled on side streets) one 25 mph arterial street with beach traffic	Cross-sectional comparison of motorist yielding at treated locations compared with one location with standard pedestrian signage (W11A) and crosswalk design, and one location with no crosswalk or warning signs	-Drivers found to be 30%–40% more likely to yield than drivers at the control locations. -At night, there was a smaller and nonsignificant difference in driver yielding of 8%. -Significantly higher percentage of pedestrians used the high-visibility crosswalks (35%) compared with others at similar locations. -There were no apparent differences in pedestrian overconfidence, running, or conflicts.	Nitzburg and Knoblauch (2001)

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Advanced Stop/Yield Bars/Signs

Advance Stop/Yield	Location Type	Study Type	Safety Effects	Citation
Crosswalk lines and removable advance stop lines and "Stop Here for Pedestrians" signs with an arrow pointing at an angle toward the road. Stop markings (an X) were also painted on the roadway 50 m in advance of the crosswalks on each side, but there were no traffic control devices at the crosswalk.	Dartmouth, Nova Scotia. The first experiment was carried out at a six-lane crossing connecting two shopping malls; speed limit was 50 km/h (31 mph). The second experiment, conducted in the same manner 1 year later, reassessed behaviors at the first location (markings had been removed for 6 months), and added a crossing of a five-lane urban street connecting a bus stop and residential area.	Observations were collected during daylight hours on weekdays at pretreatment baseline, following treatment application, and following removal of the markings and signs and reapplication two more times.	-Although the percentage of motorists who yielded increased by only a slight amount, the introduction of the sign plus stop making condition resulted in a large increase in the percentage of motorists who stopped at least 10 ft from the crosswalk (from 50% to 95%) when they did stop. -The markings and signs produced an 80% decrease in vehicle–pedestrian conflicts. [During the second and third baseline conditions (signs and lines removed) conflicts increased again, but not as high as at initial baseline.] -Average pedestrian crashes and injuries also trended lower in the after period, but there were no controls for other potential causes. -Based on the results of this study, the Nova Scotia Department of Transportation began using advance yield markings throughout the province in order to mark crosswalks.	Van Houten (1988)
Advance stop lines and signs, education, and enforcement	34 uncontrolled crosswalks in three Canadian cities in the Newfoundland (NL) and New Brunswick (NB) provinces	Before–after analysis of crash data and behavioral effects. B = 3.5 years; A= 2 years following the program.	-Motorist yielding increased before to after in all three cities. Yielding increased from 54% to 81% in St. Johns (NL), from 9% to 68% in Fredericton (NB), and from 44% to 71% in Moncton–Dieppe (NB). -Given the treatment combination, it is unclear to what extent the advance stop lines and signs and the education and enforcement measures contributed to the increase in motorist yielding behavior. -Average pedestrian crashes and injuries also trended lower in St. Johns and Fredericton and in the after period, but there were no controls for other potential causes.	Malefant and Van Houten (1990)
"Stop Here for Pedestrian" signs, followed by application of advance stop lines	Two marked crosswalks in Dartmouth, Nova Scotia	Pretreatment data were collected at baseline, and then following the addition of the signs, and the cumulative effect of adding the stop lines 50 ft in advance of the crosswalks.q	-The signs and advance stop lines had little effect on the percentage of motorists who yielded to pedestrians, but were associated with an increase in motorist yielding distance. -Pedestrian–vehicle conflicts decreased following installation of the stop lines. The baseline conflict rate before either treatment was 53%, decreasing to 10% at one location and to 6% at the second location following both treatments.	Van Houten and Malefant (1992)
Advance yield markings (shark teeth) used with symbol signs	Three crosswalks in Nova Scotia, Canada, where yellow flashing beacons were already in place: one midblock crosswalk spanning three lanes of traffic in each direction divided by a refuge island and two uncontrolled crossings of four-lane streets at T-intersections with minor roads controlled by a stop sign	Observational study of behavioral effects. The researchers experimented with yield marking placement.	-Marking and sign placement were effective at distances between 10 and 25 m in advance of the crosswalks. -Decreases in vehicle–pedestrian conflicts of 74%, 87%, and 67.1% at the three sites -A small increase in the percentage of motorists yielding, but higher percentages of motorists yielded at least 3 m in advance of the crosswalks	Van Houten, et al. (2001)

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Advance Stop/Yield	Location Type	Study Type	Safety Effects	Citation
Flashing beacons. Advance yield line markings with white background "Yield Here to Pedestrians" signs, fluorescent yellow-green "Yield Here to Pedestrian" signs (no markings), and fluorescent yellow-green "Yield Here to Pedestrians" signs.	12 urban and 12 rural locations throughout Nova Scotia, Canada, at uncontrolled approaches on multilane roads.	Before–after study of behavioral effects. Once baseline data were collected for all 24 crosswalks, they were put into treatment groups of four, with one of the groups serving as a control throughout the experiment. Follow-up data were collected at 6 months following treatment installation.	-Average number of vehicle–pedestrian conflicts decreased from 11.1% and 12.8% to 2.7% and 2.3%, respectively, at sites with the advance yield bar and either white or fluorescent sign. -No reduction of vehicle–pedestrian conflicts when the more conspicuous fluorescent yellow-green sign was used instead of the white sign. -Advanced stop lines with either type of sign were also associated with a statistically significant increase in motorist yielding from 69% to 85%. -The fluorescent yellow-green signs without advance yield bars were not associated with significant improvement in this study. The authors conclude by recommending the installation of advanced yield markings 7 m to 18 m in advance of the crosswalk, in order to better increase pedestrian visibility of oncoming vehicles when crossing.	Van Houten et al. (2002)
Combinations of advance yield markings and Danish offset, high-visibility crosswalk markings, and median refuge islands	One unsignalized intersection and one midblock location in Las Vegas, NV	Cross-sectional observational study of driver and pedestrian behavioral effects.	-Results indicated advance yield markings were more successful when coupled with Danish offsets (i.e., median crossing that turns to face oncoming traffic) as opposed to a combination with pedestrian refuge islands. -A reduction in the number of pedestrians trapped in the roadway was observed at one of the study sites. -Both sites experienced an increase in pedestrians' observing behavior.	Nambisan et al. (2008)
Stop lines and red visibility curb zones that prohibit on-street parking in the immediate vicinity of the intersection	Two San Francisco intersections	Part of review of multiple studies on multiple countermeasures	-No effects on driver yielding, vehicle stop position, and pedestrian–vehicle conflicts resulting from lines placed 4–10 ft before crosswalks. This distance may not have been noticeably different from the crosswalk lines to motorists.	Pecheux et al. (2009)
Curb extensions, pedestrian refuge island, advance stop lines-.	One site in Santa Barbara, CA	Before–after study of behavioral effects. Used staged crossings. Results were analyzed using cross tabulations and analysis of variance.	-Crossing delay decreased by a statistically significant average of 4.9 s following the installation. -No significant difference in yielding of near-lane drivers was observed, but a statistically significant increase in yielding was observed for far-lane drivers, from 61.5% in the before condition, to 82% in the after condition. -A significant increase in motorist yielding distance	van Hengel (2013)

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In-Roadway "Yield to Pedestrians" Signs

Advance Stop/Yield	Location Type	Study Type	Safety Effects	Citation
In-roadway "Yield to Pedestrians" signs	Three sites in first year, expanding to four sites in second year in Madison, WI	2-year evaluation of different forms of then-experimental in-street "Yield to pedestrians" signs	-Motorist yielding increased at three of the four sites, but because of differences in the treatment applications, site geometrics, and pedestrian usage, the researchers could not draw further conclusions.	Year 2 Field Evaluation of Experimental "In-Street" Yield to Pedestrian Signs *(1999)*
Pedestrian safety cones with the message "State Law – Yield to Pedestrians in Crosswalks in Your Half of the Road" in middle of crosswalk	Use of the cones was evaluated at six sites in New York State, and one site in Portland, OR	Before–after study of behavioral effects. Comparison with other treatments.	-Pedestrian safety cones were the most successful in increasing the percentage of yielding drivers. Motorist yielding increased from 69.8% pretreatment to 81.2% posttreatment, which was significant at the 0.001 level. -Pedestrians who ran, aborted, or hesitated decreased, but the decrease was not statistically significant. The authors concluded that pedestrian safety cones were generally effective in increasing the percentages of pedestrians for whom motorists yielded.	Huang et al. (2000)
In-roadway "Yield to Pedestrians" signs	Three sites in Cedar Rapids, IA, with traffic volumes from 5,400 to 25,000 ADT	Before–after study of behavioral effects	-While motorist yielding generally improved, and speeds were reduced for some locations and directions, improvements were not uniform. -At one location, driver yielding from one direction increased only from 64% to 67% of the first vehicles arriving, whereas at the same crossing but opposite direction, yielding by the first arriving vehicle increased from 70% before to 84% after the treatment was installed. Speed effects by direction were also different at another location.	Kannel et al. (2003)
Removable pedestrian island and crossing signs combination	Rural two-lane highway in Mahnomen County, MN	Researchers collected pre- and posttreatment speed data to assess short- and long-term effects of the treatments.	-A statistically significant reduction in mean speeds and a near doubling in speed limit compliance at the treatment site for both the long and short term in response to the combination of pedestrian island and pedestrian crossing signs.	Kamyab et al. (2003)

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Advance Stop/Yield	Location Type	Study Type	Safety Effects	Citation
"Yield-to-Pedestrian" channelizing devices placed on the centerline of a roadway in advance of marked crosswalks	Five locations each in four community types in Pennsylvania: urban, suburban, small city, and college town. Sites included both unsignalized intersections and midblock locations.	Before–after study of behavioral effects	-Driver yielding increased from 30 to 34% at intersection sites and from 17 to 24% at midblock crosswalks, and the effects did not appear to be related to community type. Pedestrians yielding to vehicles also decreased from 11 to 16% at intersections, and from 8 to 13% at the midblock crossings. The researchers also found an increase in pedestrians using the crosswalks. The researchers concluded that the signs were more effective at intersections than midblock locations, but that they had positive effects at both location types. However, they also noted that follow-up data collection was complicated by damaged, moved, or missing signs.	Strong and Kumar (2006)
Impactable yield signs. All intersections are stop-controlled and have two-way flow. At one location, the signs were implemented at both a marked crosswalk and unmarked crosswalk of the same intersection.	Installed at four crossings at three intersections in different areas of San Francisco. Each was a medium-sized, low-speed intersection located in an institutional, commercial, or industrial area. Street parking was present at all intersections. One T and two four-legged intersections were studied, with one of the four-leg sites also being a skewed intersection.	Before–after study of behavioral effects	-The only significant result that was common to all four sites was the increase in the rate of motorists yielding. At baseline, yielding rates varied from 20% to 40%, and at second follow-up, had increased to from 60% to 73% at all sites. -No significant effect on conflicts between drivers and crossing pedestrians, and there were no consistent effects on the other measures of effectiveness, including waiting time for pedestrians, percent of trips in the crosswalk, or time taken by pedestrians to cross a given crosswalk. The researchers cautioned that conflicts may be the best proxy for crash or safety risk, and that crash effects are the ultimate measure of effectiveness.	Banerjee and Ragland (2007)
In-roadway "Yield to Pedestrians" signs	Three crossings along the same street in Miami, FL. Carried an average of 29,500 vpd.	Studied the effects of placing the "Yield to Pedestrians" signs at different distances from the crosswalk—at the crosswalk, and 20 ft in advance, 40 ft in advance, and all three locations at the same time	-Test results found significantly more yielding at all three locations and that the signs placed at the crosswalk line, 20 ft in advance of the crosswalk line, 40 ft in advance of the crosswalk line, or at all three locations at the same time did not result in significantly widely different levels of yielding. -At location one, motorist yielding increased from 32% at baseline, to 70% when 40 ft away, 75% when 20 ft away, 78% at the crosswalk, and 79% when applied at all three locations. Similar results were found at the second location: before, 21% of motorists yielded improving to 54% at 40 ft, 63% at 20 ft, 65% when signs were placed at crosswalk line, and 56% when signs were at all three locations. At the third location, 34% of motorists yielded increased to 69% with signs at the crosswalk line; 43%, 20 ft distant; 43%, 40 ft distant; and 52% with signs at all three locations.	Ellis et al. (2007)
Signs used in gateway configurations	Sites in East Lansing, MI. Two study sites. The gateway configuration consists of one sign in the middle of the roadway, and two signs installed in the gutter pans on each side of the roadway.	Staged crossings with three conditions were alternated and evaluated at the two study sites: no in-street sign (baseline), one in-street sign in the median (typical configuration), and three in-street signs in the gateway configuration.	-At both sites, motorist yielding averaged 25% when no signs were present. The presence of one in-street sign was associated with motorist yielding of 57% at both locations. -The gateway (three signs) configuration was associated with 79% and 82% at the two locations. Thus, the gateway configuration using three signs was associated with the highest motorist yielding rates.	Bennett et al. (2014)

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Advance Stop/Yield	Location Type	Study Type	Safety Effects	Citation
In combination with PHB	Same study as above, but at two sites at suburban and urban locations in Detroit that had a PHB and in-street sign	Same as above, but with PHB comparison	At the suburban site, motorist yielding was 1% in the crosswalk-only condition. The addition of one in-street sign was associated with motorist yielding of 37%, and the use of the gateway treatment was associated with motorist yielding of 72%. This compared favorably to the PHB installed at the site. When the PHB was activated, motorists yielded 62% of the time. When one in-street sign was used along with the PHB at this location, motorist yielding increased to 85%. At the more urban location, an average of 10% of motorists yielded at baseline conditions. PHB activation was associated with a motorist yielding rate of 84%, and the addition of an in-street sign brought motorist yielding to 94.5%.	Bennett et al. (2014)
In-roadway "Yield to Pedestrians" signs	Three university sites in Grand Forks, ND	Observational behavioral effects	Yielding was between 62% and 86% when the sign was not present, and between 72% and 98% when the signs were present (all locations considered). Yielding was higher when the signs were placed at the crosswalk (between 97% and 98%) compared with when it was placed further away (between 72% and 98%). Data collected about motorist speed indicated that minimum and maximum motorist speed was higher when no sign was present than when any sign was present at all but one of the eight studied locations.	Gedafa et al. (2014)

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Pedestrian Warning Signs

Ped Warning Signs Treatments	Location Type	Study Type	Safety Effects	Citation
Pedestrian warning signs	Sites in central North Carolina	Pre/post-treatment study of observational behavioral effects	The use of this new sign was associated with increased numbers of cars that slowed down or stopped for pedestrians, although there was no decrease in conflict events following sign installation	Clark et al. (1996)
Pedestrian warning signs	One site with two sign designs: the first was a pictograph of a walking pedestrian, which was added to a pedestrian-activated amber flashing beacon suspended over the roadway at the crossing site. It was coupled with a "Yield When Flashing" sign placed 50 m ahead of the crosswalk.	Experimental: Evaluated the effects of two types of experimental signs on motorist yielding behavior	Results indicated that both measures were effective in increasing motorist yield percentage, with the most effective treatment being the combination of the two. Only the "Yield When Flashing" sign was effective in reducing vehicle–pedestrian conflicts; the researchers theorized it was a result of the sign's placement within adequate stopping distance of the crosswalk.	Van Houten et al. (1998)
Internally illuminated overhead crosswalk signs installed in conjunction with high-visibility crosswalks	Two midblock crossing locations in Clearwater, FL	Using case-control research design, they compared motorist and pedestrian behavior at the treatment sites with two similar sites, one that featured standard pedestrian crossing signage and crosswalk design, and one that had no crosswalk.	-The researchers found that during the day, drivers at the experimental crossing locations were 30%–40% more likely to yield than drivers at the control locations. At night, there was a smaller and statistically insignificant increase in driver yielding of 8%. -There was a significant increase in pedestrians using the crosswalk at the treatment sites compared with control sites, although the individual effects of having the signs in place could not be analyzed separately from the high-visibility crosswalk.	Nitzburg and Knoblauch (2001)
Overhead yellow crosswalk sign and sign with amber lights around the edge that were activated by a pedestrian pushbutton	One intersection in Seattle, WA, and one in Tucson, AZ	Before–after study of driver yielding	-For the overhead sign: an increase in driver yielding from 45.5% before installation to 52.1%, which was significant at the 0.06 level. Following the installation of the sign, there was a statistically significant decrease in the percentage of pedestrians who ran, aborted, or hesitated in crossing. The researchers concluded that the overhead crosswalk sign was effective at encouraging driver yielding behavior. -For the amber lighted sign, the percentage of motorists yielding decreased in response to this sign. Neither of the two treatments led to a statistically significant increase in crosswalk use; however, the authors concluded that the overhead crosswalk sign and pedestrian safety cones were generally effective in increasing the percentages of pedestrians for whom motorists yielded. They cautioned that site characteristics would need to be taken into account when choosing or designing treatments to draw motorists' attention to pedestrians in crosswalks.	Huang et al. (2000)

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In-Pavement Flashing Lights/Flashing Crosswalks

In-Pavement Flashing Lights Treatment	Location Type	Study Type	Safety Effects	Citation
In-pavement flashing lights	Multiple cities	Evaluation of many studies of the in-pavement flashing crosswalks	-Short-term improvements in motorist yielding have been reported from most sites studied, but the addition of flashing lights alone may be insufficient to bring motorist yielding rates to a desirably high level—both daytime and nighttime rates often remained well below 50%. -Improvements at most locations were generally greater for nighttime when data were collected at both day and night, but yielding rates at night were also often much poorer, initially. -Initial gains in yielding rates also tended to decline over time and effects on motorist speed have varied across different studies. -Reported yielding rates also tended to be higher when observations included pedestrians already in their crossing or stepping out, compared with waiting to cross. Motorist yielding rates to pedestrians midway across also varied widely from site to site, and also tended to decline from initial improvements over a longer time period.	Thomas (2006)
In-pavement flashing lights	Multiple cities	Evaluation of many studies of the in-pavement flashing crosswalks	-Only one study from a higher-volume arterial in Honolulu, HI, assessed impacts on pedestrian delay and motorized traffic flow. Pedestrians activated the flashing lights to create a gap for crossing, when in the before period, they waited for a gap to cross, thus helping reduce the delay to pedestrians. If pedestrians were frequent enough, this could potentially induce a greater impact to traffic flows than some other types of control. -Proportions of pedestrians using the crosswalks improved at some locations and not at others. The crosswalk location and convenience to desired routes likely has a bearing on this result, in addition to any perceptions of enhanced safety.	Thomas (2006)
In-pavement flashing lights	Sites in Vermont	Observational field study	-Found that while the system installed increased yielding and decreased approached speeds, they were removed due to multiple malfunctions and damage during winter (before an evaluation could be completed); DOT's view that they preferred a treatment that would be visible during all seasons.	Kipp and Fitch (2011)

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Overhead or Roadside-Mounted Flashing Beacons

Overhead/Roadside Beacons	Location Type	Study Type	Safety Effects	Citation
Pedestrian-activated flashing beacons	Two crosswalks; urban and suburban sites in Dartmouth, Nova Scotia	Experimental: two strategies for increasing the percentage of motorists yielding to pedestrians at crosswalks equipped with pedestrian-activated flashing beacons. One strategy involved adding an illuminated sign, with the standard pedestrian symbol next to the beacons. The second strategy involved placing signs 50 m before the crosswalk that displayed the pedestrian symbol and requested motorists to yield when the beacons were flashing.	Both interventions increased yielding behavior and the effect of both together was greater than either alone. However, only the sign requesting motorists to yield when the beacons were flashing was effective in reducing motor vehicle–pedestrian conflicts.	Van Houten et al. (1998)
One with a pedestrian pushbutton, and the other equipped with infrared sensors to automatically detect pedestrians	Two types of flashing beacons at two sites were evaluated as part of a study of 13 treatments deployed at 29 sites throughout San Francisco.	Before–after study: before 1–4 years; after 1–2 years	-At one of the sites, the percentage of diverted pedestrians saw a statistically significant decrease following treatment, while the other site saw no impact. The same site measured a statistically significant decrease in trapped pedestrians, while the other site saw no impact. At both sites, there was a statistically significant increase in the percentage of yielding drivers. Both average pedestrian delay and pedestrian–vehicle conflicts decreased significantly at both sites. -It is important to note that both sites also had advance stop lines and one of the sites had an in-street "Yield to Pedestrians" sign.	Hua at al. (2009)
Overhead or roadside-mounted flashing beacons	One site in Las Vegas, NV, with a flashing yellow signal at a midblock location with several other countermeasures: a high-visibility crosswalk, Danish offset, median refuge, and advanced yield markings	13 pedestrian and driver measures of effectiveness were studied by field observers before and after the installation of the call button and analyzed using a two-proportion z-test.	There was a significant reduction in the percentage of drivers blocking the crosswalks, as well as a significant increase in driver yielding distance in all distance categories (<10, 10–20, and >20 ft); however, there was no statistically significant increase in the percentage of drivers yielding to pedestrians. Several pedestrian-related outcomes were also observed: an increase in the number of pedestrians looking for vehicles while crossing both halves of the street and an increase in the number of pedestrians diverted to use the crosswalk.	Vasudevan et al. (2011)
Internally illuminated (not flashing beacon) overhead crosswalk signs that were installed in conjunction with high-visibility crosswalks	Two midblock crossing locations in Clearwater, FL	Using case-control research design, they compared motorist and pedestrian behavior at the treatment sites with two similar sites, one that featured standard pedestrian crossing signage and crosswalk design, and one that had no crosswalk.	-During the day, drivers at the experimental crossing locations were 30%–40% more likely to yield than drivers at the control locations. At night, there was a smaller and statistically insignificant increase in driver yielding of 8%. There was a significant increase in pedestrians using the crosswalk at the treatment sites compared with control sites. -Although the individual effects of having the signs in place could not be analyzed separately from the high-visibility crosswalk, the researchers concluded that the treatments had a positive effect on pedestrian safety at the two intersections that were studied.	Nitzburg and Knoblauch (2001)

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Rectangular Rapid Flash Beacon (RRFB)

RRFB	Location Type	Study Type	Safety Effects	Citation
Stutter-flash LED beacons	RRFBs were installed at two Miami-Dade County, FL, multilane crosswalks.	Baseline data were collected pretreatment, and during the posttreatment phase the researchers alternated the activation of the beacons at the sites in order to take further control measurements. Observers measured the numbers of yielding motorists, vehicle–pedestrian conflicts, trapped pedestrians, and motorist yielding distance.	-At the two sites, motorists yielding to resident pedestrians increased from 0% and 1% to 65% and 92%, respectively. -There was also a reduction in the number of vehicle–pedestrian conflicts and trapped pedestrians, leading the authors to conclude that the stutter-flash beacon was effective in increasing pedestrian safety at multilane crosswalks.	Van Houten et al. (2008)
RRFB	Evaluation of RRFBs at two sites in Miami, FL. Traffic volume was 25,215 and 38,996.	Before–after study (time period unknown). Assessed pedestrian and driver behavioral effects.	-Statistically significant improvements in all of the studied MOEs -Driver yielding for daytime and nighttime staged pedestrian crossings increased from 4.2% before to 55.2% after at one location, and from 4.1% before to 60.1% at the second location. -Yielding to local resident pedestrians went from 12.5% and 5.4% to 73.7% and 83.4%, respectively. -The number of conflicts and pedestrians trapped in the roadway also declined significantly from 44% to 0.5% at one location. The percentage of conflicts also declined at both locations.	Pecheux et al. (2009)
One of the systems was pedestrian-activated, while the second used an automated pedestrian detection system.	Two types of flashing beacons at two sites were evaluated as part of a study of 13 treatments deployed at 29 sites throughout San Francisco.	Before–after study: before, 1–4 years; after, 1–2 years	-The pushbutton-activated beacon led to a significant reduction in vehicle–pedestrian conflicts, from 6.7% pretreatment to 1.9% posttreatment, as well as a significant increase in vehicles yielding, from 70% pretreatment to 80% posttreatment. -Only 17% of pedestrians activated the beacon, although an additional 27% of pedestrians crossed when the beacon (47% total) was activated. -The automated flashing beacon led to a significant reduction in vehicle–pedestrian conflicts (from 6.1% pretreatment to 2.9% posttreatment), a significant reduction in the number of trapped pedestrians (from 4.1% pretreatment to 0% posttreatment), and a significant increase in vehicle yielding (from 82 % pretreatment to 94% posttreatment. -Of the 13 countermeasures tested, both the pushbutton and automated flashing beacons were among the six countermeasures from this study that were considered the most effective in increasing pedestrian safety.	Hua at al. (2009)

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RRFB	Location Type	Study Type	Safety Effects	Citation
RRFB	One four-lane site at the intersection of Pinellas trail crossing in St. Petersburg, FL. Traffic volume 15,000 ADT.	Before–after using video surveillance of behavioral effects. Data were collected on more than 1,000 pedestrians and bicyclists during daylight hours for 7 to 10 days during the before and after periods.	-There were benefits to trail users (a majority of which were bicyclists) with a significant reduction in crossing delay, and a statistically significant increase in motorist yielding—from 2% pretreatment to 35% posttreatment, overall, and 54% when the beacon was activated. -There was also an improvement in the ability of pedestrians to cross the entire intersection (from 82% pretreatment to 94% posttreatment).	Hunter et al. (2009)
RRFB	22 multilane, uncontrolled crosswalks—19 in St. Petersburg, Florida, one in Washington, DC, and two in Mundelein, IL. 19 had speed limits of 35 mph, two of 30 mph, and one of 40 mph. ADTs ranged from < 5,000 vpd to 30,000 at the DC location, which also had a 30 mph posted limit.	The researchers measured driver yielding behavior, pedestrian–vehicle conflicts at baseline (pretreatment) and compared it with posttreatment data collected at eight times over the following two years to assess long-term effects. They were also compared with side and overhead beacons.	-Yielding increased rapidly following installation across all sites, from an average 4% of drivers yielding before treatment, to an average of 84% at two years after installation, demonstrating the longevity of effect. The range across all sites was from 72% to 96%. -Compared with standard overhead beacons: Motorist yielding increased from 15.5% with the overhead beacon to 78.3% when two RRFBs were installed, and increased further to 88% when four RRFBs were installed. -At the site of the side-mounted beacon, motorist yielding increased from 12% with the side-mounted beacon, to 72% with the installation of two RRFBs. -Data collected at night showed an increase in driver yielding behavior from 4.8% pretreatment to 84.6% (two-beacon RRFB) and 99.5% (four-beacon) posttreatment.	Shurbutt and Van Houten (2010)
RRFB	Two Bend, OR, crosswalks at intersections along a 45-mph four-lane, bypass, limited access highway with a center median, bike lanes, and sidewalks. The 85th percentile speeds (before RRFBs were installed) were 54 mph and 52 mph. One crosswalk was at an intersection in the City of Bend—at a suburban to urban transition zone—on a four-lane facility with a center median. The posted speed limit is 35 mph; the 85th percentile speed was 44 mph.	Before–after study (time periods unknown) of driver yielding.	-Prior to the installation of the RRFBs, average motorist yield rates were 18% across all three locations. (Average for each site ranged from 5.8% to 24.7% at the crossings before RRFB.) -These rates increased to an 80% average for all three sites following treatment. (Average range for individual sites was from 74.3 to 82.9%.)	Ross et al. (2011)
RRFB	Urban and suburban arterials in Portland, OR. Two sites: site 1 a five-lane, 35-mph urban arterial, with 30,700 vpd, and a narrow median refuge; and site 2 a TWLTL lane, 40-mph, suburban arterial, with 26,400 vpd, a median island, and a Danish offset crossing island.	Reported on motorist yielding and pedestrian use of RRFBs when they were activated by the pedestrians versus not activated.	-Site 1: Motorist yielding was 92% when beacons were activated and 75% when beacons were not activated. -Site 2: Motorist yielding was 91% when the RRFBs were activated and 45% when not activated. -Pedestrians activated the beacon 94% of the time at site 1 and 83% of the time at site 2. -Researchers also documented that motorists yielded more often to pedestrians in the second stage of their crossing at both locations. -At site 2 (the Danish offset), 82% of pedestrians who crossed the roadway chose to use the crosswalk, which compared favorably with a 71% compliance rate for marked midblock crosswalks in general.	Foster et al. (2014)

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RRFB	Location Type	Study Type	Safety Effects	Citation
RRFB	Six locations in Calgary, Canada. Traffic volumes ranged from 4,800 to 14,600 vpd, and streets had from one to five lanes.	Observations of driver yielding using staged crossings	The RRFBs were observed to increase yielding by an average of 15%, to nearly 100% motorist yielding at the majority of the study sites. Overall, the average motorist yielding increased from 83% to 98% following the installation of the RRFB, indicating that the RRFBs were effective at increasing pedestrian safety at these six sites.	Domarad et al. (2013)
RRFB with school zone signs	Multilane crossings in Texas with PHBs, RRFBs, and traffic control signals (TCS) installed. 22 RRFB sites in three different Texas cities. Posted speed limits ranged from 30 mph (two sites in one city) to 45 mph (two sites in different cities) with the remainder being 35 or 40 mph.	Report on driver yielding rates at multilane crossings. Researchers used staged pedestrians and employed the same protocol for crossing and observing driving yielding across all sites.	-Yielding rates for 22 RRFB sites varied more across different cities (34% to 92% yielding) compared with yielding rates for TCS (seven sites, 95% to 100% yielding) or PHBs (32 sites, 73 to 92% yielding). -Yielding rates also varied by one- or two-way cross sections, with a decreasing yielding effect for two-way compared with one-way, even controlling for total crossing distance. -There was a correlation of increased yielding with higher speed limits, even when two anomalous sites with low volumes and very low driver yielding rates were removed from the analysis. Closer analysis revealed that the results were related to very slight differences in yielding (1 percentage point between the two averages) on roads with posted speeds of 40 versus 35 mph, and were considered not practically significant. -All of the RRFB sites in this study also had School Crossing signs, which the researchers thought could have contributed to an overall average yielding of 86%, which they indicated was higher than national averages.	Fitzpatrick et al. (2014)

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Pedestrian Hybrid Beacon

PHB	Location Type	Study Type	Safety Effects	Citation
Pedestrian Hybrid Beacon (PHB)	Five PHB sites in urban Tucson, AZ	Before–after observational field studies	-Red signal or beacon devices (including PHBs, traffic signals, and half signals) were more effective than all other devices evaluated at gaining motorist compliance with formerly uncontrolled crosswalks. -Motorist compliance values ranged between 90% and 100% at all study sites, with an average of 97% across all sites. -Research team found a wide range of motorist compliance values relating to the warning devices studied.	Fitzpatrick et al. (2006)
PHB	21 PHB treatment sites and 102 un-signalized control sites in Tucson, AZ	Collision data used for 3 years pretreatment and 3 years following treatment, and for the same periods for the nearby control sites, in order to calculate reduction in expected collisions using the Empirical Bayes method.	-A statistically significant reduction in total crashes of 29%, as well as a statistically significant 69% reduction in pedestrian crashes. -A 15% reduction in severe crashes, although the decline was not statistically significant. PHB was effective at leading to a reduction in total collisions at treatment sites.	Fitzpatrick and Park (2010)
PHB	Three urban sites in Charlotte, NC	Researchers collected observational behavioral effects data from pedestrian crossings during weekday morning and evening peak times at five time points: before the installation, and at 1, 3, 6, and 12 months following installation.	-Increase in the percentage of yielding motorists, a decrease in the percentage of trapped pedestrians, and a decrease in pedestrian–vehicle conflicts at all three sites; however, these changes were significant at only one of the three sites. -A statistically significant increase in average vehicle speed was also observed at one of three sites. -Analysis of pre- and post-installation crash data showed no significant change in pedestrian–vehicle crashes, although the sample size was small in both cases. -Changes in pedestrian and motor vehicle actions were more consistent after the PHBs had been in place for 3 months or more. -PHBs were effective at increasing motorist yielding and reducing trapped pedestrians and pedestrian–vehicle conflicts.	Pulugurtha and Self (2013)
22 sites with RRFBs and school crossing signs The study also examined 32 PHB sites, and 14 sites with TCS.	Multilane sites throughout Texas. Focused on 22 sites in three cities, different median treatments, numbers of lanes, one-way versus two-way, and posted speed limits from 30 mph to 45 mph.	Cross-sectional study of driver yielding rates at treated crosswalks Researchers used staged pedestrians and employed the same protocol for crossing and observing driving yielding across all sites. Traffic volumes and pedestrian volumes were not factored in the analyses. There also appeared to be some confounding between cities, speed limits, and potentially other characteristics.	-Over all sites, motorist yielding to PHBs averaged 89%. -Model results indicated that wider crossing distances were associated with slightly higher driver yielding rates at most sites ($P < .01$). Two-way roads were associated with lower yielding than one-way (significant at $< .10$). The posted speed limit did not have a significant predictive effect on driver yielding rates. -Researchers also analyzed the time effect, using a subset of the sites from Austin. Results suggested that driver yielding rates increase each day since installation, but these could be associated with unique characteristics in Austin.	Fitzpatrick, Brewer, and Avelar (2014)

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Install Traffic Signal Without Pedestrian Countdown Timer

Traffic Signal/ No PCS	Location Type	Study Type	Safety Effects	Citation
Five timing patterns: concurrent, none, exclusive, early release, and late release	1,297 urban signalized intersections involving a total of 2,081 pedestrian crashes in 15 U.S. cities	A comprehensive study of pedestrian signal heads	-Compared with traffic signals without pedestrian signal heads, traffic and pedestrian signals with concurrent timing had no statistically significant effect on pedestrian crashes. -Exclusive timing was associated with about half of the pedestrian crashes compared with concurrent timing or traffic signals with no pedestrian signals, and this difference was statistically significant. This was only true at locations with pedestrian volumes of more than 1,200 people per day. -There was insufficient sample size with early release or late release signal timing to determine the safety effect of those timing schemes.	Mead at al. (2014) citing Zegeer et al. (1982) and Zegeer et al. (1983)
Concurrent and exclusive signal timing, compared with no pedestrian signal	320 intersections from three cities in Israel	Comparative crash analysis	Intersections with exclusive phases for pedestrians had fewer crashes where vehicle and pedestrian volumes were higher.	Zaidel and Hocherman (1987)
Traffic signals with pedestrian indicators	Multiple U.S. cities	Literature review and analysis of pedestrian crashes	-Inconclusive: reduced pedestrian crashes at some locations, had little to no effect at others and may increase crashes at other sites -The presence of a pedestrian signal in itself did not have a statistically significant effect on pedestrian and vehicle delay, but the signal timing scheme did.	Robertson and Carter (1984)
Installing signals at previously unsignalized intersections	447 new traffic signals installed at nonsignalized intersections throughout New York City based on *MUTCD* warrants	Two group pretest posttest research design to compare collision statistics. Pedestrian collision statistics were collected for the 5 years preceding signal installation and 2 years following it, and the authors used ANCOVA in their analysis in order to control for potential regression-to-the-mean effects.	Analysis of their results indicated that the average pedestrian crash rate increased by 11.9% at treatment sites and by 60% at comparison sites. This resulted in an ANCOVA-adjusted increase in pedestrian collisions of 1% at signalized sites, results that were not significant at the 0.05 level.	Chen et al. (2013)
Traffic signal without pedestrian countdown signal	Multiple sites in multiple cities at multilane, midblock crossings	Cross-sectional analysis of behavioral effects comparing different signal types	-Traffic control signals were associated with high motorist yielding rates when applied at midblock crossings. Motorist yielding averaged 98% across seven sites with traffic control signals in three cities. -Yielding rates were lower for pedestrian hybrid beacons with an average of 89% motorist yielding across 32 sites in four cities, and for RRFBs at 86% across 22 sites in three cities.	Fitzpatrick et al. (2014)

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Install Traffic Signal with Pedestrian Countdown Signal (PCS)

Traffic Signal with PCS	Location Type	Study Type	Safety Effects	Citation
The first comparison group, about half (629) of the control intersections that were *planned* to receive PCS, but had not yet received the treatment. The second comparison group (628 intersections) were *not scheduled* to receive PCS.	Treatment: 14 pilot locations with PCS in San Francisco, CA Comparison group 1: 629 intersections Comparison group 2: 628 intersections Subset of treatment group: seven intersections with 2+ crashes Subset of comparison group: 185 intersections with 2+ crashes	Before–after: computed the ratio of pedestrian injury events for 21 months following installation of PCS to the number that occurred 21 months before installation and for several comparison groups	-The number of pedestrian injury collisions declined by a statistically significant amount following the introduction of PCS (48% ratio of after to before injuries), whereas no significant declines were found in the two comparison groups (97% and 90%). -Subset of treatment group ratio: 42.3% -Subset of comparison group ratio: 55.6% -An additional comparison of the two high-crash subsets revealed that a significant part of the effect was likely to the result of regression toward the mean (RTM), since a significant (but smaller) decline was also observed in the high-crash group that had not been treated (56% ratio of before to after pretreatment injuries) compared with the high-crash group that received the PCS (42% ratio of after to before injuries). The treated intersections were selected on the basis of pretreatment injury levels, which could contribute toward an RTM effect. -The decrease in pedestrian crashes was greater for the treated intersections with high crashes compared with the untreated group with high crashes.	Markowitz et al. (2006)
Traffic signal with pedestrian countdown signal	The researchers compared the rate of pedestrian–motor vehicle collisions at 1,965 Toronto signalized intersections before and after the installations.	Population-based study to evaluate the impact of widespread replacement of traditional signals with PCS on pedestrian–motor vehicle collisions. A total of 9,262 pedestrian–vehicle collisions took place during the 10-year study period.	-Initial study results indicated that installation of PCS had no statistically significant effect on the number of pedestrian–motor vehicle collisions at the intersections where they were installed.	Camden et al. (2011)

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Traffic Signal with PCS	Location Type	Study Type	Safety Effects	Citation
Traffic signal with pedestrian countdown signal	Reanalysis of Camden et al. (2011) study; same 1,965 Toronto signalized intersections	Reanalysis of Camden et al. data	-A baseline pedestrian–motor vehicle crash rate for each intersection (which was required to be treated with a traditional, non-PCS signal before the PCS installation for inclusion) was used for its own control, along with time and season covariates. -PCS were associated with a 26% *increase* in pedestrian–motor vehicle collisions compared with traditional signals (incidence rate ratio = 1.26, 95% CI, 1.11 to 1.42).	Richmond et al. (2014)
Traffic signal with pedestrian countdown signal	Used monthly crash data collected from 2001–2010 to compare the effect of introducing PCS to 362 signalized intersections, with 87 control sites, in Detroit	Crash-based, citywide study was conducted to assess effects on total crashes.	Authors suggested that about 17% total crash reductions were attributable to the implementation of PCS, but these results need validation.	Huitema et al. (2014)
Traffic signal with pedestrian countdown signal	Assessed pedestrian safety effects of widespread installation of new traffic signals at formerly unsignalized New York City intersections according to *MUTCD* (2009) warrants. A total of 447 intersections were in the treatment group, and 442 in the comparable reference (untreated) group.	5 years of before period crashes and 2 years of after period crashes were analyzed. Negative binomial models with General Estimating Equations method controlled for time trends and a variety of other intersection and environmental factors. In addition to using nearby reference locations, the authors mention that although they could not control for traffic volumes, volumes throughout the city in general have remained relatively stable, and at capacity, for 10 years. Built environment and site factors thought to be related to safety outcomes were controlled through the analysis models.	-Pedestrian crashes increased at both treated and comparison intersections, but by a smaller amount at treated (+12%) than comparison (unsignalized) (+67%) locations. These observed data resulted in model estimates of effectiveness of -47% fewer pedestrian–vehicle collisions for installing signals compared with not installing signals. Observed declines for motor vehicle–motor vehicle collisions resulted in model estimates of -60% fewer vehicle–vehicle collisions for installing signals compared with not installing signals. Both of these effects were significant.	Chen et al. (2014)
Split-phase (protected pedestrian crossing and protected left-turn phases) timing	30 treatment intersections; 493 untreated comparison intersections in New York City	5 years of before period crashes and 2 years of after period crashes were analyzed. Same methods as Chen, Chen, and Ewing (2014) for installing traffic signals	Reductions in observed pedestrian crashes of 39% at treatment sites and 8% at comparison sites resulted in an adjusted estimate of the effects of split-phase timing of -47% reduction in pedestrian crashes due to the treatment, and -30% reduction in multiple motor vehicle crashes. Both of these effects were significant.	Chen et al. (2014)
Barnes Dance (all walk phase)	36 treatment intersections; 516 untreated comparison intersections in New York City	5 years of before period crashes and 2 years of after period crashes were analyzed. Same methods as Chen, Chen, and Ewing (2014) for installing traffic signals	Average pedestrian crashes decreased by a larger degree, 51% at Barnes Dance (pedestrian scramble, or All Walk signal with crossing allowed in any direction including diagonally) sites versus 9% reduction at comparison sites. These measures yielded a model-adjusted estimate of effect (using the same methods as above) of: -55% reduction in pedestrian crashes compared with not implementing the Barnes Dance. This effect was significant. -14% higher motor vehicle–motor vehicle crashes relating to Barnes Dance implementation, but the effect was not significant.	Chen et al. (2014)

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Traffic Signal with PCS	Location Type	Study Type	Safety Effects	Citation
Increased pedestrian crossing time	Implemented at 244 intersections in New York City; 1,173 untreated comparison intersections	5 years of before period crashes and 2 years of after period crashes were analyzed. Same methods as Chen, Chen, and Ewing (2014) for installing traffic signals	Where pedestrian crossing time was increased, the average pedestrian crash rate decreased by 50%, whereas at the control sites it decreased by 4%. These observed differences resulted in model predicted effects of: -65% reduction in pedestrian crashes compared with not increasing the pedestrian cycle length. -11% reduction in multiple motor vehicle collisions also resulted, but this downward trend was not statistically significant.	Chen et al. (2014)
Install traffic signal with pedestrian countdown signal	447 formerly unsignalized New York City intersections according to *MUTCD* (2009) warrants. A total of 447 intersections were in the treatment group, and 447 in the comparable reference (untreated) group.	5 years of before period crashes and 2 years of after period crashes were analyzed with comparison group. Regression toward the mean and other trend affects were accounted for by the ANCOVA pretest posttest and comparison group models. These models attempted to control for a variety of other site characteristics and built environment factors by matching these for comparison groups. In addition to using nearby reference locations, the authors mention that although they could not control for traffic volumes, volumes throughout the city in general remained relatively stable, and at capacity, for 10 years.	-Pedestrian crashes increased at both treated and comparison intersections, but by a smaller amount at treated (+12%) than comparison (unsignalized) (+60%) locations. -The observed data resulted in a slight predicted increase in pedestrian crashes (ANCOVA model estimated CMF of 1.01) for installing signals compared with not installing signals. The effect was not statistically significant. -Vehicle–vehicle crashes declined at both treated and untreated intersections: by 49% at treated and 14% at untreated intersections. -The observed data resulted in a CMF estimate of 0.78 (estimated 22% reduction) for vehicle–vehicle collisions for installing signals (effect was statistically significant).	Chen et al. (2013) (earlier study of effects of signals and signal timing strategies)
Split-phase timing (protected left-turn and protected pedestrian phases)	30 intersections in treatment group; 579 in untreated comparison group	5 years of before period crashes and 2 years of after period crashes were analyzed, with untreated comparison group. Same methods as Chen et al. (2013) for installing traffic signals	-Average observed pedestrian crashes decreased by 39% at treated locations and by 12% at the untreated locations. -The effects of split-phase timing were an estimated CMF of 0.74 for pedestrian crashes due to the treatment; however, the effect was not statistically significant. -There was also a downward but not statistically significant reduction in multiple motor vehicle crashes.	Chen et al. (2013) (earlier study of effects of signals and signal timing strategies)
Barnes Dance (all walk phase)	37 intersections in treatment group; 4,266 in untreated comparison group	5 years of before period crashes and 2 years of after period crashes were analyzed, with untreated comparison group. Same methods as Chen et al. (2013) for installing traffic signals	-Average observed pedestrian crashes decreased by 44% at the treated locations and by 9% at the untreated locations. -The model-predicted CMF estimate was a significant 0.65 compared with not implementing the Barnes Dance. -There was no significant effect on motor vehicle–motor vehicle crashes.	Chen et al. (2013)
Increase pedestrian crossing time	244 intersections in treatment group; 915 intersections in untreated comparison group	5 years of before period crashes and 2 years of after period crashes were analyzed, with untreated comparison group. Same methods as Chen et al. (2013) for installing traffic signals.	-Where pedestrian crossing time was increased, the average observed pedestrian crash rate decreased by 50%, whereas at the control sites it decreased by 29%. -These observed differences resulted in a model predicted CMF of 0.49 for pedestrian crashes compared with not increasing the pedestrian cycle length. -A slight increase in multivehicle crashes was not statistically significant.	Chen et al. (2013)

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Traffic Signal with PCS	Location Type	Study Type	Safety Effects	Citation
Impact of PCS (pedestrian countdown timers)	Eight large intersections in south Florida (19,000–65,000 vehicles per day)	Before–after pedestrian behavior comparisons, unknown period	-Increase in the percentage of pedestrians complying with the "Walk" indication (entered during the "Walk" phase and not during flashing or steady "Don't Walk") by a slight, but nonsignificant amount (from 55% to 56.3%) -Significant decrease (from 13.7 to 8.1%) in pedestrians entering during the flashing "Don't Walk" -These differences were apparently offset by a larger increase in pedestrians entering during the steady "Don't Walk" phase (noncompliant) (from 31.3 to 35.5%; attributed to three locations). -The percentage of successful crossings (completed before steady "Don't Walk), all intersections combined, increased significantly, from 56.15% to 63.27%. -Data unavailable to assess potential effects on driver behaviors.	Reddy et al. (2008)
Traffic signal with pedestrian countdown signal	20 crosswalks at five intersections in Montgomery County, MD	Before–after study of behavioral effects and a survey	-Survey revealed that most pedestrians were aware of the countdown signal and a majority (63%) also understood its meaning. -At six of the 20 crosswalks, there were statistically significant increases in pedestrians entering the crosswalk during the "Walk" phase; in two of the 20 crosswalks observed, there was a statistically significant decrease in the number of pedestrians who entered on the "Walk" indication. -Three of the five intersections experienced a statistically significant decrease in the number of phases with pedestrians left in the crosswalk at the release of conflicting traffic. Although the other two intersections experienced an increase, the increases were slight and were not statistically significant. -Number of conflicts between pedestrians and vehicles decreased (statistically significant) in the after periods at four of five intersections observed. -No effect on nonplatooning motorist approach speeds on a late green	Eccles et al. (2004)
PCS with the addition of animated eyes.	One high-volume arterial intersection in Las Vegas with a significant crash history. Crash issues included drivers failing to yield, nighttime crashes, and a high percentage of elderly pedestrians.	Before–after study of pedestrian behavior	-Percentage of pedestrians beginning their crossing during the "Walk" phase increased significantly. -Significant increase in the percentage of pedestrians who looked for vehicles before beginning to cross -Significant increase in those beginning to cross during the "Walk" phase -Percentage of signal cycles in which the call button was pushed also increased significantly. -Not possible to ascertain how much of the effects related to the PCS and how much to the animated eyes.	Mead et al. (2014); Vasudevan et al. (2011)
Traffic signal with pedestrian countdown signal	Urban. Lake Buena Vista, FL. Two intersections with countdown signals and three control intersections without countdown signals. Traffic volume ranged from 30,000 to 68,000.	Cross-sectional comparative study of sites with PCS versus without	-Pedestrians were less likely to comply with the walk signal at the countdown signal locations on multilane, high-ADT sites (speed limits 35 or 50 mph) compared with similar non-PCS sites, and the difference was statistically significant. -At one multilane comparison site, a slightly smaller percentage of pedestrians ran out of time and remained in the crossing at the signal change than at the PCS locations, but the difference was not statistically significant. -3% of pedestrians began running at the flashing "Don't Walk" at the PCS locations compared with 10% at the control locations, and the difference was statistically significant.	Huang and Zegeer (2000)
Traffic signal with pedestrian countdown signal	Four intersections along an arterial corridor in Lawrence, KS	Continuous speed data were collected on approaching traffic at two intersections with PCS and two without to study driver decisions in response to PCS.	-Drivers were significantly less likely to increase their speed in order to reach the intersection before the beginning of the red phase when PCS were present, and some drivers began to slow to a stop before the beginning of the amber phase when PCS were present. Some drivers make safer driving decisions with PCS, even though the countdown information was not intended to be used by them.	Schrock and Bundy (2008)

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Leading Pedestrian Interval (LPI)

LPI	Location Type	Study Type	Safety Effects	Citation
Leading pedestrian interval	Multiple sites in New York City	Evaluation of the LPI on pedestrian crash statistics. Data collected for the 5 years preceding and 5 years following LPI installation for treatment and control intersections.	-LPI had the effect of decreasing both collision occurrence and severity at treatment intersections, especially at intersections with heavy turning volumes. -Results of this study and others led the New York City Department of Transportation to decide to install more LPIs as a pedestrian safety countermeasure.	King (1999)
Leading pedestrian interval	10 intersections in State College, PA. 14 comparison intersections similar in terms of site characteristics, traffic and pedestrian volumes, and crash data.	Before–after crash analysis	Reduction of 59% in pedestrian–vehicle crashes at the 10 treated intersections (significant at the 95% confidence level)	Fayish and Gross (2010)
Leading pedestrian interval	Urban San Francisco high-crash areas. Four intersections with LPIs.	Before–after study (B: 1–4 years/A: 1–2 years) of behavioral effects	Significant reduction in the percentages of vehicles turning in front of pedestrians, from 6.2% pretreatment to 4% posttreatment on average over four sites with 4-s pedestrian head starts	Hua et al. (2009)
Leading pedestrian interval	Suburban, high-volume intersection in Anaheim, CA	Comparison study of "compromised" crossings with and without LPI of 3 s at same crosswalk, data collected December 2006–January 2007 Compromise was defined as one in which the pedestrian is delayed by a turning vehicle or changes travel path or speed in response, and was measured for pedestrians waiting on the curb and in the crosswalk.	-The proportion of pedestrians with crossings compromised while still waiting on curb at beginning of crossing (before they could step out, had "Walk" signal, and motorist still had red) was significantly higher with LPI, for all three volume conditions: low right-turn volumes (1–5 vehicles in queue), high right-turn volumes (6+ in queue), and all right-turn volumes. -The proportion of "Walk" cycles with pedestrians compromised while still waiting on curb increased significantly for all three volume conditions. -The proportion of pedestrians with crossings compromised while in crosswalk was significantly lower for high and all volumes, but significantly higher for low-volume conditions with LPI in place. -The proportion of "Walk" cycles with pedestrians compromised while in crosswalk also was lower for high and all volume conditions, but (nonsignificantly) higher for lower-volume conditions.	Hubbard et al. (2008)
Leading pedestrian interval	Three signalized intersections in St. Petersburg, FL, with a 1-s all-red interval	Field observations	Reduced conflicts and reduced percentage of pedestrians yielding to turning motor vehicles for 3-s head start.	Van Houten et al. (2000)
Leading pedestrian interval	Two intersections in urban Miami, FL	Before–after study (time periods unknown)	Increase in the percentage of yielding by left-turning drivers; a statistically significant increase in the percentage of pedestrians who pushed the call button and who crossed during the first 4 s of the walk phase	Pecheux et al. (2009)

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"Right Turn on Red" (RTOR) Restrictions

NTOR	Location Type	Study Type	Safety Effects	Citation
Western RTOR	Urban and suburban New York, Ohio, and Wisconsin; City of New Orleans, LA; Los Angeles, CA. Seven datasets of crash data at numerous sites.	Comparison of computerized accident data from the periods before and after implementation of the RTOR rule. Up to 4.5 years in after period. Before period was as much crash data as was available. In all cases at least 12 months. A second part of this study involved analysis of police crash reports.	The following increases in crash rates after the RTOR rule were observed: -43% for pedestrian accidents and 82% for bicycles in New York State; 107% for pedestrians and 72% for bicycles in Wisconsin; 57% for pedestrians and 80% for bicycles in Ohio; 82% for pedestrians in New Orleans. -Given the rarity of RTOR–pedestrian crashes, these percentages represented increases in very small numbers. -Authors were able to identify a common crash scenario involving RTOR: Often, a driver who is stopped before turning right focuses on traffic coming from the left in order to identify a gap adequate to permit his right turn. Consequently, the motorist does not see a pedestrian or bicyclist on his right and a conflict occurs when the turn is initiated.	Preusser et al. (1982)
"No Turn on Red" restrictions	110 intersections in Washington, DC; Dallas and Austin, TX; Detroit, Lansing, and Grand Rapids, MI	Collected observational data on more than 67,000 drivers, looking for links between motorist violations of "No Turn on Red" (NTOR) signs and the related crashes with pedestrians.	-3.7% of all drivers making a right turn violated the NTOR signs. When given an opportunity to violate the NTOR sign (i.e., being the first car in line at a signalized intersection with no pedestrians in front of them and no cars coming from the left), 21% of the drivers ignored the NTOR signs. -23.4% of all RTOR violations create a conflict with a pedestrian. Where RTOR is permitted, 56.9% of drivers do not come to a complete stop before turning, compared with 68.2% who fail to do so at STOP-controlled intersections.	Zegeer and Cynecki (1986)
"No Turn on Red" restrictions	Seven of the countermeasures for intersections with RTOR were tested at 34 intersections in six cities in the U.S.	In a later phase of the study, Zegeer and Cynecki developed 30 potential countermeasures to enhance pedestrian safety at intersections permitting RTOR.	-NTOR signs with a red ball were more effective than standard black-and-white ones. -An offset stop bar increased compliance in making a full stop before turning at RTOR locations and also lessened conflicts with traffic on cross streets. -The more costly electronic NTOR/black-out sign used only during school crossing periods or other critical times was slightly more effective than the regular NTOR sign. -Drivers were more likely to comply with the RTOR restriction if it was limited to peak pedestrian periods rather than imposed full time. -In areas with moderate or low RTOR volumes, an alternative "No Turn on Red When Pedestrians Are Present" sign was effective at intersections with low to moderate volumes of RTOR vehicles. In general, the likelihood of a RTOG accident was found to be greater than that of a RTOR accident, based on conflict data.	Zegeer and Cynecki (1986)

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NTOR	Location Type	Study Type	Safety Effects	Citation
"No Turn on Red" Restrictions	26 sites in the Province of Quebec where RTOR was authorized for a period of 9 months	Two-part pilot study: Part 1—observing driver behavior; Part 2—collecting data from a number of U.S. and Canadian agencies concerning the effect that RTOR had on safety and on traffic operations	-In most cases, RTOR does not pose a danger to motorists, cyclists, or pedestrians. Lord reported that pedestrian crashes involving a RTOR maneuver make up less than 1% of all reported accidents in the United States and Canada, and the crashes that do occur are usually not severe. Many of the transportation experts and researchers who were surveyed for this study did not consider RTOR to be a safety problem. -It was less clear that RTOR does not contribute to conflicts, increase delay to pedestrians, and lower the quality of service at signalized intersections	Mead et al. (2014) citing Lord (2003)
Restrictions on right turn on red	Multiple intersections in Alabama and South Carolina	Before–after crash data analysis	-Statistically significantly increase during the after period in South Carolina for right-turning property damage accidents than for accidents not involving right turns, but not in Alabama -No statistically significant difference in the rate of change in fatality or injury accidents in either state when comparing right-turning vehicles to non-right-turning vehicles. Furthermore, there was no evidence of increased pedestrian accidents resulting from RTOR in either South Carolina or Alabama.	Clark et al. (1983)
Traffic signs that limit RTOR during specific time periods and highly visible traffic signs that prohibit RTOR when pedestrians are present	15 signalized intersections in in Arlington County, VA. A third of the intersections (five sites) served as the control group, while the others were equally divided between the two treatments.	Before–after study of behavioral effects comparing sites. At the first group of five treated sites, signs were placed that stated "No Turn on Red, 7 a.m.–7 p.m., Mon–Fri." At the second group of five treated sites, fluorescent yellow-green reflective signs reading "No Turn on Red – When Pedestrians Are Present" were implemented.	-During the pretreatment period, 80% of all observed vehicles turned right on red at these locations. During the before period, 39% of all vehicles observed did not come to a full stop before making a RTOR, and 14% of pedestrians yielded to motorists who were making RTORs. -Following sign installation, there was a small decline in the percentage of motorists who turned right on red at the sites with signs restricting right turns when pedestrians are present, and a large decrease where RTOR was not permitted during specified time periods. -In terms of pedestrian behavior, after installation of the signs, there was a large decrease in pedestrians who yielded to vehicles turning right at time-specific locations, with little change at sites that prohibited RTOR in the presence of pedestrians. -Overall, the researchers concluded that signs that made RTOR dependent on driver discretion related to the presence or absence of pedestrians were less effective.	Retting et al. (2002)
Three types of "No Turn on Red" (NTOR) signs	One site in Miami, FL, tested with three signs. The first two that were used were static signs printed with the messages "No Turn on Red" and "No Turn on Red When Pedestrians in Crosswalk." The third sign was an electric sign that was dark during the protected right-turn phase, displayed the message "Yield to Pedestrians" during the green phase, and displayed a "No Turn on Red" message during phases when a right turn was prohibited and pedestrians had pushed the call button.	Data were collected in four phases. Baseline data were collected with the conditional "No Turn on Red When Pedestrians in Crosswalk" in place. For the next phase, the conditional sign was replaced with the "No Turn on Red" sign. For the second phase the active sign was used, and for the third phase the baseline conditional sign was reinstalled.	Violations were lowest when the active sign was used. Of those drivers who violated the turn restriction, there was a significant increase in drivers coming to a full stop before doing so from 29% during the baseline phase (with the static, conditional sign) to 78% with the electronic sign. The authors concluded that the electronic NTOR sign was of medium effectiveness in increasing pedestrian safety, whereas the two static signs were of low effectiveness.	Pecheux et al. (2009)
Restrictions on right turn on red	The sign was installed concurrently with a high-visibility crosswalk at one intersection in Las Vegas, NV.	Before–after study of behavioral effects	No significant improvement in the percentage of drivers who yielded to pedestrians, but a significant increase in the percentage of drivers who came to a complete stop before making a RTOR, and in the percentage of pedestrians who looked for a vehicle before crossing. The authors concluded that the "Intelligent Transportation System No Turn on Red" sign made drivers and pedestrians more cautious at the intersection.	Dangeti et al. (2010)

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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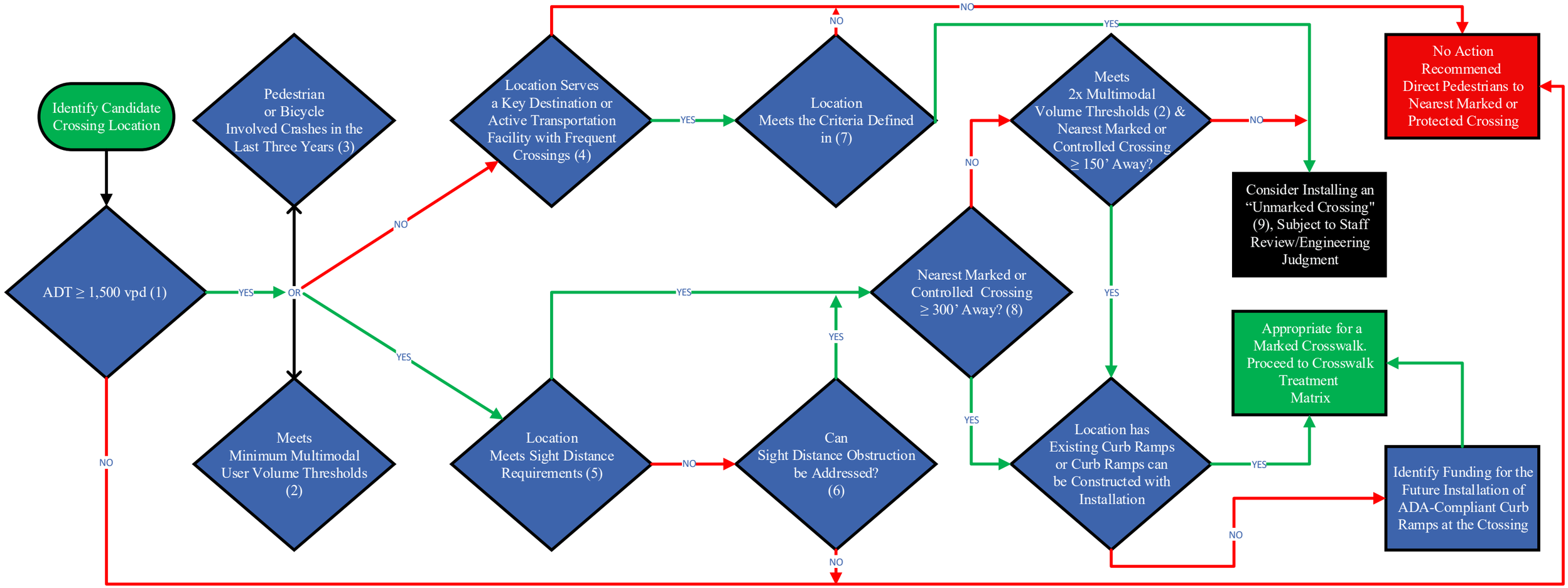
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Uncontrolled Crossing Evaulation Flowchart



ADT = Average Daily Traffic VPD = Vehicles Per Day SSD = Stopping Sight Distance CBD = Central Business District

Multimodal users refer to individuals walking, cycling, using mobility aids, or other riding devices such as scooters or skateboards (motorized or non-motorized).

(1) Exception to the 1,500 vpd minimum roadway volume threshold may be made for School Crossings* or Park Crossings** where the peak hour traffic exceeds 15% of the daily traffic. * A school crossing is defined as a crossing location where the Police Department has assigned a crossing guard. ** A Park Crossing is defined as a crossing location that directly connects to a Town park.

(2) Minimum Multimodal Volume Thresholds:
- 20 crossings per hour*** in any one hour, or
- 15 crossings per hour*** in any two hours, or
- 10 crossings per hour*** in any three hours

*** Young, elderly, and disabled pedestrians count 2x towards volume thresholds
(Young pedestrians are defined as a elementary or middle school-aged children)

In lieu of the Minimum Multimodal Crossing Volumes mentioned above, a location may be considered for a marked crosswalk if it can be reasonably assumed the required crossing volume threshold would be met if a properly marked crosswalk were available. For further details; refer to the Criteria Definition section.

(3) At least one preventable crash involving a multimodal user within 300 feet of the crossing under review has occurred in the past three years. Review the crash history and exclude preventable crashes (e.g., impaired driver, etc.) from consideration.

(4) Key destinations can be existing or proposed and may include, but are not limited to, hospitals, senior centers, recreation or community centers, libraries, parks, or other significant destinations subject to staff review. Active transportation facilities may include sidewalks or multi-use trails.

(5) The available SSD in both directions at the crossing point is equal to or greater than the minimum SSD required as specified in the latest edition of *AASHTO's A Policy on Geometric Design of Highways and Streets*.

(6) Only install an uncontrolled crosswalk if the sight distance obstruction has been removed. If the obstruction is located on private property, coordinate with Code Enforcement to pursue corrective action. If the sight distance issue cannot be corrected consider geometric improvements or a controlled/grade-separated crossing.

(7) For a low volume crossing to be considered for further improvement, all of the following criteria must be met:

- The roadway being crossed is either a two-lane, one-way road; a two-lane, two-way road; a two-lane, two-way road with a dedicated turn lane; or a four-lane road with two through lanes in each direction with or without a raised median
- The roadway has an ADT between 1,500–2,500 vehicles and a posted speed limit of 35 mph or lower
- The crossing location is at least 300 feet from any existing marked or controlled crosswalk and meets AASHTO SSD requirements
- The crossing location has adequate street lighting; if not, a streetlight must be installed before implementing further improvements
- Existing curb ramps are available at both ends of the crossing; if not, curb ramps should be constructed; if immediate construction is not feasible, the crossing design must accommodate future curb ramp installation. Funding for the installation of the future curb ramps must be identified before proceeding
- There is little potential to redirect multimodal users to a more defined crossing location
- The crossing is not located adjacent to a school

(8) In CBDs, this distance may be reduced to 200 feet, subject to engineering judgment.The reduction should only be considered where crossing activity is not expected to significantly disrupt vehicular traffic operations or compromise safety.

(9) An "unmarked crossing" is any treatment that improves a pedestrian's ability to cross a roadway, short of a marked, signed and enhanced crosswalk. The installation of this type of crossing is subject to staff review and engineering judgement and should include ADA compliant curb ramps, appropriate crossing warning signage, and where applicable, roadway geometric improvements to enhance crossing safety. No markings or additional signage beyond the crossing warning signs are provided to promote the use or attempt to attract new users to the crossing. An unmarked crossing is intended to function as a safety improvement at low volume locations where multimodal users are already crossing and are expected to continue to do so.

Uncontrolled Crossing Treatment Matrix (This matrix should only be used if directed by the Uncontrolled Crossing Evaulation Flowchart)

Roadway Configuration	Roadway ADT and Posted or 85th Percentile Speed																			
	1500 – 3000 vpd				3000 – 9000 vpd				9,000-12,000 vpd				12,000-15,000 vpd				> 15,000 vpd			
	≤ 30 mph	35 mph	40 mph	≥45 mph	≤ 30 mph	35 mph	40 mph	≥45 mph	≤ 30 mph	35 mph	40 mph	≥45 mph	≤ 30 mph	35 mph	40 mph	≥45 mph	≤ 30 mph	35 mph	40 mph	≥45 mph
2 Lanes (One Way Road)	B	C	C	E	B	C	C	E	C	C	D	E	C	C	D	E	C	C*	D*	E
2 Lanes (Two Way Road, w/ or w/o Raised Median)	B	C	C*	E*	B	C	C*	E*	C	C*	D*	E*	C	C*	D*	E*	C	C*	D*	E*
3 Lanes (Two Way Road, w/ Raised Median)	B	C	C	E	B	C	D	E	C	C*	D	E	C	D	D	E	C*	D*	D*	E
3 Lanes (Two Way Road, w/o Raised Median)	B*	C*	C*	E*	B*	C*	D*	E*	C*	C*	D*	E*	C*	D*	D*	E*	C*	D*	E*	E*
4 Lanes (Two Way Road, w/ Raised Median)	B	C	D	E	B	C	D	E	C	D	D	E	C	D	D	E	D	D*	E	E
4 Lanes (Two Way Road, w/o Raised Median)	C*	C*	D*	E*	C*	D*	D*	E*	C*	D*	D*	E*	D*	D*	E*	E*	D*	D/E	E*	E*
5 Lanes (Two Way Road, w/ Raised Median)				E	C	D	D	E	C/D	D	D	E	D	D	E	E	D	E	E	E
5 Lanes (Two Way Road, w/o Raised Median)									D	D*	E*	E*	D*	E*	E*	E*	D*	E*	E*	E*
6 Lanes (Two Way Road, w/ or w/o Raised Median)									E/F*	E/F*	E/F*	E/F*	E/F*	E/F*	E/F*	E/F*	E/F*	E/F*	E/F*	E/F*

Number of Lanes and Roadway Configuration Definitions

Note: The lane count reflects the total number of lanes a pedestrian must cross at the crossing point, including both through and turn lanes

2 Lanes (One Way Road): A two lane roadway with two through lanes in a single direction at the crossing point.

2 Lanes (Two Way Road with or without Raised Median): A two lane roadway with one through lane in each direction without a dedicated turn lane with or without a raised median at the crossing point.

3 Lanes (with Raised Median): A two lane roadway with one through lane in each direction with a dedicated turn lane and a raised median at least six feet wide at the crossing point.

3 Lanes (without Raised Median): A two lane roadway with one through lane in each direction with a dedicated turn lane, a striped median or a raised median less than six feet wide at the crossing point.

4 Lanes (Two Way Road with Raised Median): A four lane roadway with two through lanes in each direction without a dedicated turn lane, but has a raised median at least six feet wide at the crossing point.

4 Lanes (Two WayRoad without Raised Median): A four lane roadway with two through lanes in each direction without a dedicated turn lane or a raised median at least six feet wide at the crossing point.

5 Lanes (Two Way Road with Raised Median): A four lane roadway with two through lanes in each direction with a dedicated turn lane and a raised median at least six feet wide at the crossing point.

5 Lanes (Two Way Road without Raised Median): A four lane roadway with two through lanes in each direction with a dedicated turn lane, a striped median or a raised median less than six feet wide at the crossing point.

6 + Lanes (Two Way Road with or without Raised Median): A six or more lane roadway with three or more through lanes in each direction with or without dedicated turn lanes or a raised median at the crossing point.

Notes:

1. This matrix only applies to uncontrolled pedestrian crossings.
2. The letters shown in the matrix represent the minimum recommended combination of treatments based on ADT, roadway design, and the posted or 85th percentile speed.
3. If 85th percentile speed > posted speed limit, use the 85th percentile speed for selecting treatments.
4. Striped medians or two-way left-turn lanes shall never be considered a refuge for a crossing pedestrian.
5. Additional treatments beyond those mentioned in each category may be used based on engineering judgment.

Treatment Descriptions		
A	Unmarked Crosswalk	**Specific Guidance**: Install only Pedestrian (W11-2) or Trail (W11-15) crossing warning signs with diagonal downward-pointing arrow plaques (W16-7p), at each end of the crossing. If engineering judgment determines a need to alert road users ahead of the crossing, additional W11-2 or W11-15 signs with “AHEAD” plaques (W16-9p) may be installed in advance of the crossing in accordance with the latest edition of the TMUTCD. For undivided multi-lane roadways, consider providing a median refuge island to enhance pedestrian safety. The crossing location must have adequate street lighting installed prior to implementing mprovements. No pavement markings are installed with this category.
B	Marked Crosswalk	**Specific Guidance:** Install a marked crosswalk only, using standard or continental patterns. Higher visibility crosswalk markings may be used at locations where the higher visibility would provide additional safety benefits.The minimum crosswalk width shall be 6 feet; however, if curb ramps exceed this width, the crosswalk should match the ramp width. In areas with high pedestrian volumes, consider increasing the width to 8–10 feet. Crosswalk markings must extend across the full width of the roadway. Installing street lighting at the crossing location should be considered to improve nighttime visibility. No signs are installed with this category.
C	Marked Crosswalk with Signs	**Specific Guidance:** Install a marked crosswalk as described in Category B, along with Pedestrian (W11-2), Trail (W11-15), or School (S1-1) crossing warning signs at each end of the crosswalk, supplemented with diagonal downward-pointing arrow plaques (W16-7p). The School (S1-1) warning sign shall be used only at designated school crossing locations. If engineering judgment determines a need to alert road users ahead of the crossing, additional W11-2 , W11-15, or S1-1 signs with “AHEAD” plaques (W16-9p) may be installed in advance of the crossing in accordance with the latest edition of the TMUTCD. "Stop Here for Pedestrians" (R1-5b) signs and corresponding stop lines shall be installed on each approach, positioned 20 to 50 feet in advance of the crosswalk. The stop line shall be a solid white line, 24 inches wide, extending across all approach lanes. For multi-lane roadways with a raised median, an additional warning or regulatory sign should be placed within the median to enhance crosswalk visibility. Street lighting at the crossing should also be considered to improve nighttime visibility and pedestrian safety.
D	Heightened Awareness Crossing	**Specific Guidance:** Install all treatments described in Categories A and B, with the addition of Rectangular Rapid Flashing Beacons (RRFBs) supplemented with Pedestrian (W11-2), Trail (W11-15), or School (S1-1) crossing warning signs and diagonal downward-pointing arrow plaques (W16-7p), either post- or overhead-mounted. The School (S1-1) warning sign shall be used only at designated school crossing locations Additional RRFBs may be installed in advance of the crosswalk with corresponding warning signage and “AHEAD” (W16-9p) plaques based on engineering judgment. If the roadway is undivided, RRFBs shall be installed on both sides of the crosswalk, i.e. one on the left side and one on the right side of the roadway. If the crosswalk contains a pedestrian refuge island or other type of median, an RRFB shall be installed in the median along with both sides of the crosswalk.RRFBs shall only be used to supplement crossing warning signs located at or immediately adjacent to an uncontrolled marked crosswalk. Adequate street lighting shall be installed at the crossing location.
E	Signalized Crossing	**Specific Guidance**: Do not install a marked crosswalk at an uncontrolled crossing. Marked crosswalks shall only be installed in conjunction with a Pedestrian Hybrid Beacon (PHB) or a traffic signal and must be supplemented with appropriate signage and pavement markings as specified in the latest edition of the TMUTCD. The TMUTCD provides comprehensive guidance on the application and installation of PHBs and related traffic control devices at pedestrian crossings. A PHB or traffic signal shall only be installed on a Town roadway when the location meets the applicable warrants established in the TMUTCD.
F	Grade-Separated Crossing	**Specific Guidance:** Do not install a marked crosswalk at an uncontrolled crossing. Consider installing a grade-separated pedestrian crossing such as an overpass (bridge) or underpass (tunnel) to enhance pedestrian safety. A comprehensive engineering analysis, beyond the scope of this policy, should be performed to assess the need for and feasibility of this treatment.
*	Geometric Improvements	**Specific Guidance:** Consider implementing geometric improvements, such as curb extensions and/or a median refuge island, in conjunction with crosswalk treatments to shorten crossing distances and enhance pedestrian visibility to drivers.
	Consider Lane Reduction	**Specific Guidance:** Evaluate existing and projected roadway volumes to assess the feasibility of a lane reduction prior to implementing potential crossing improvements.