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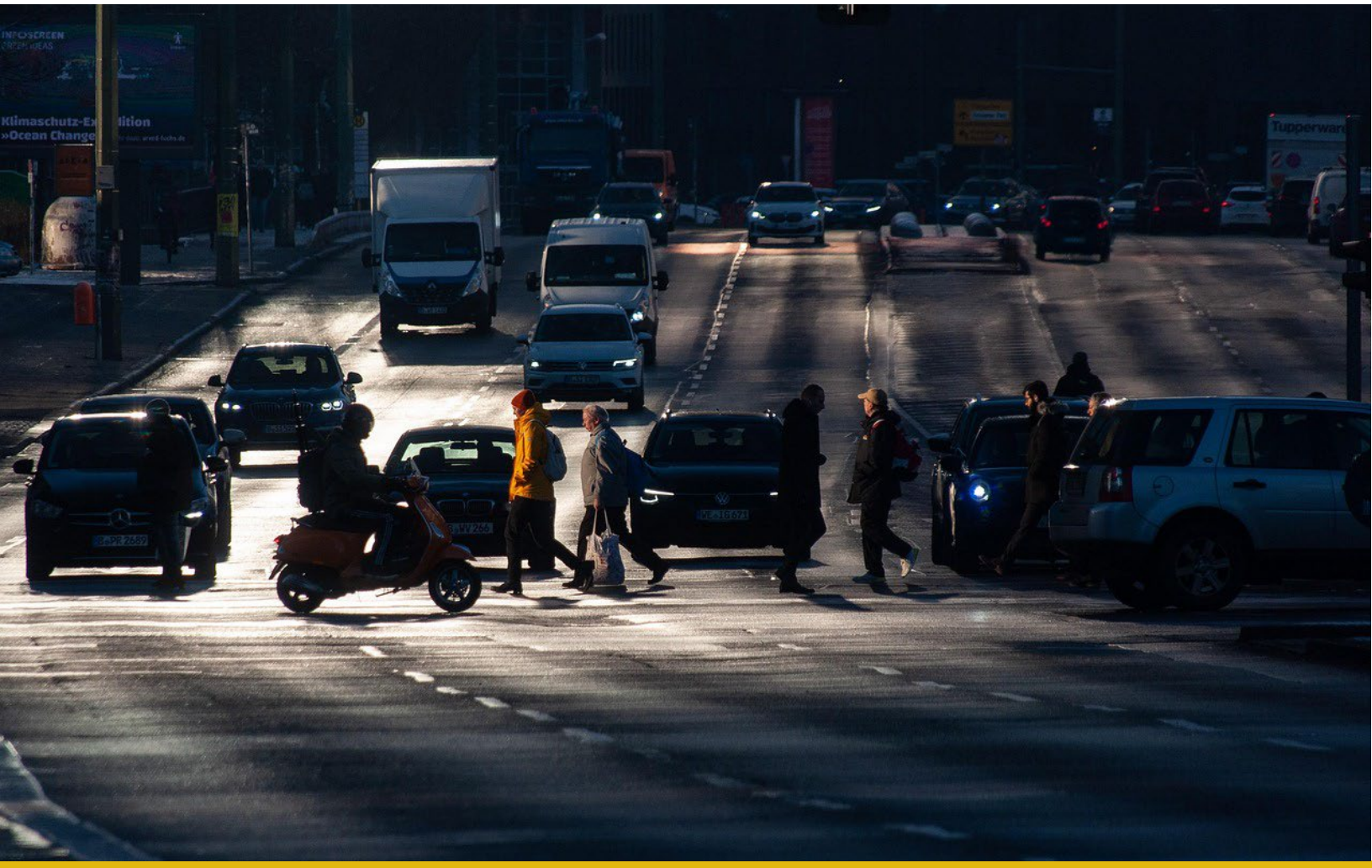

Uncontrolled Pedestrian Crossing ITS Countermeasures

ENTERPRISE TRANSPORTATION POOLED FUND STUDY TPF-5(490)

FINAL REPORT – April 2025

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16. Abstract

A significant increase in traffic-related pedestrian fatalities has occurred in the United States since 2010. Of particular concern are uncontrolled pedestrian crossings at mid-blocks and other uncontrolled approaches, as the majority of pedestrian fatalities occur at non-intersection locations. The objective of this research was to review existing guidance for selecting intelligent transportation system (ITS) countermeasures at uncontrolled pedestrian crossings and uncontrolled approaches, and to identify associate gaps and needs. The project completed a review of existing guidance for selecting ITS pedestrian safety treatments, conducted an interactive meeting with state department of transportation (DOT) traffic safety professionals, and identified potential gaps and needs. The guidance reviewed commonly includes ITS treatments such as blinker signs, flashing beacons, rectangular rapid flashing beacons (RRFBs), and pedestrian hybrid beacons (PHBs). However, the interactive meeting with state DOT traffic safety professionals revealed limited deployment of ITS pedestrian treatments, inconsistency in application of these ITS treatments, and hesitancy with the use of some ITS technologies because drivers and pedestrians may not be familiar with these treatments. Overall, there appears to be a lack of on-road ITS pedestrian treatments for uncontrolled approaches. There may be an opportunity to further develop infrastructure-based pedestrian detection approaches such as cameras, radar, and LiDAR, especially at locations with known safety issues.

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Project Champion

Cory Johnson from the Minnesota Department of Transportation was the ENTERPRISE Project Champion for this effort. The Project Champion served as the overall lead for the project.

ENTERPRISE Members

The ENTERPRISE Board consists of a representative from each of the following member entities.

- Illinois Department of Transportation
- Iowa Department of Transportation
- Kansas Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Ontario Ministry of Transportation
- Texas Department of Transportation
- Wisconsin Department of Transportation

Project Input

ENTERPRISE would like to thank the following state transportation agencies that provided input to the project through an interactive meeting with traffic safety professionals to share relevant practices:

- Kansas Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Tennessee Department of Transportation
- Wisconsin Department of Transportation

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Executive Summary

A significant increase in traffic-related pedestrian fatalities has occurred in the United States since 2010. Of particular concern are uncontrolled pedestrian crossings at mid-blocks and other uncontrolled approaches. Various on-road ITS countermeasures are available to help address pedestrian safety, but the extent to which intelligent transportation systems (ITS) countermeasures are documented in existing design guidance resources was of interest to ENTERPRISE members. This research reviewed existing guidance for selecting ITS countermeasures at uncontrolled pedestrian crossings and uncontrolled approaches, conducted an interactive meeting with state department of transportation (DOT) traffic safety professionals to gather input, and identified potential needs and gaps.

The results of this study revealed that many transportation agencies utilize their own state or local guidance for selecting pedestrian treatments, along with national guidance. ITS treatments such as blinker signs, flashing beacons, Rapid Rectangular Flashing Beacons (RRFBs), and Pedestrian Hybrid Beacons (PHBs) are often included in guidance. However, the interactive meeting with state DOT traffic safety professionals revealed limited deployment of ITS pedestrian safety treatments, inconsistency in application of ITS treatments, and hesitancy with the use of some ITS technologies (e.g., RRFBs and PHBs) because drivers and pedestrians may not be familiar with these treatments.

The considerations that are typically currently used to select pedestrian crossing treatments include reactive measures such as distance to nearest crossing, vehicle and pedestrian volumes, roadway configuration, crash history, known safety issues, and even public requests. A paradigm shift is occurring toward the use of proactive metrics such as pedestrian demand (e.g., proximity to parks, schools, transit facilities, commercial areas or other activity generators), land use context, and population income or other demographics when designing roadways and selecting pedestrian safety treatments.

Table ES-1 provides a summary of potential needs and gaps, including gaps in current guidance, possible research, and public education needs as observed from this research.

Table ES-1: Potential Needs and Gaps

Gap Area	Possible Gap
In-pavement Lighting, Flashing Beacons, and Blinker Signs	In-pavement lighting, flashing beacons on signs, and LED border/blinker signs are often included in state or local guidance resources, however these ITS treatments are not included in leading national guidance. State and local guidance often includes design flexibility for applying these ITS treatments, which may not be a gap since it allows for engineering judgment and consideration of local contexts.
Comprehension of ITS Treatments and Public Education	Additional research on driver and pedestrian comprehension of ITS treatments, particularly Rapid Rectangular Flashing Beacons (RRFBs), Pedestrian Hybrid Beacons (PHBs), and future technologies may be useful. Research and guidance on the use of public education strategies to improve comprehension is also a possible gap.

Gap Area	Possible Gap
Guidance and ITS Treatments at Non-intersection Locations	Overall, there appears to be a lack of guidance for pedestrian safety improvements specific to non-intersection locations. There is also a lack of on-road ITS pedestrian treatments for uncontrolled approaches (i.e., locations not controlled by any sign, signal, marking, or other control devices.) Non-intersection locations are inherently complex because of long distances between intersections and the unpredictability of pedestrian crossing behavior. Unique challenges exist at high-speed roadways and at locations that experience growth that cuts off pedestrian access to activity generators.
Scalable Guidance Using Multiple Contexts and Proactive Metrics	There is a need for guidance that is scalable, reflecting multiple conditions and situations. There is also a need for guidance that utilizes qualitative, proactive metrics such as pedestrian demand, demographics, land use context, latent demand, proximity to pedestrian generators, and other subjective characteristics to select pedestrian safety treatments. The NCHRP 03-143: Framework and Toolkit for Selecting Pedestrian Crossing Treatments research is developing a framework and toolkit for selecting pedestrian crossing treatments based on objective and subjective characteristics.
Emerging Technologies	Emerging technologies such as vehicle-based detection and mobile applications hold potential to improve pedestrian safety. However, these approaches often depend upon vehicles equipped with detection and CAV technology, or pedestrians and drivers simultaneously operating mobile applications. There may be an opportunity to further develop infrastructure-based pedestrian detection approaches such as cameras, radar, and LiDAR, especially at locations with known safety issues.
Interactions Among ITS, Traffic Safety, Transportation Planners, and Multimodal Groups	A gap was noted regarding interactions among agency ITS, traffic safety, and multimodal groups within transportation agencies. The interactive meeting with traffic safety professionals revealed that ITS groups tend to focus more on freeway deployments compared to pedestrian-related technologies. It would therefore be beneficial for transportation planners, traffic safety, multimodal, and ITS groups to increase interactions to learn from one another and explore pedestrian safety technologies.
Automobile Industry	Recommendations for the automobile industry from traffic safety professionals engaged in this project included additional vehicles with pedestrian detection and assistive braking, detection that is effective in dark conditions, changes to vehicle size and configuration to reduce the severity to pedestrians when a collision occurs, and an improved culture to prioritize vehicle safety.

Chapter 1: Introduction

A significant increase in traffic-related pedestrian fatalities has occurred in the United States since 2010. Federal data show that U.S. pedestrian fatalities increased from 4,302 in 2010 to an estimated 7,624 in 2021. See Figure 1.1. Traffic-related pedestrian fatalities represent nearly 18% of all traffic deaths in 2021, the highest annual proportion during this period from 2010 to 2021 (Petraglia & Macek, 2023).

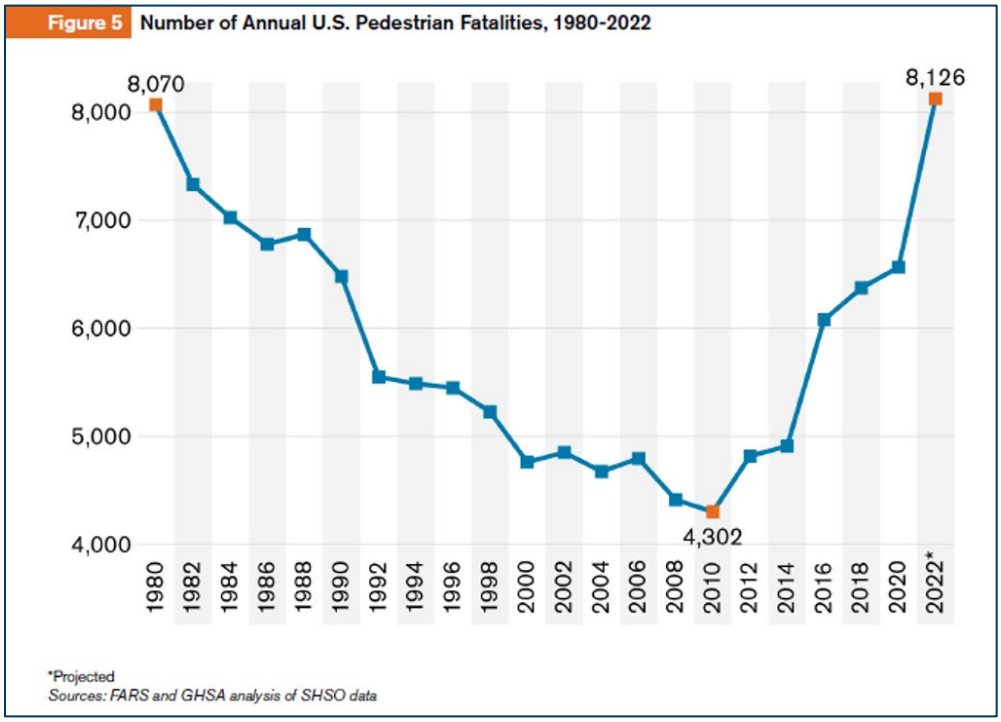


Figure 1.1 Annual U.S. Pedestrian Fatalities 1980-2022

Source: *Pedestrian Traffic Fatalities by State: 2022 Preliminary Data* (Petraglia & Macek, 2023)

Of particular concern are uncontrolled pedestrian crossings at mid-blocks and other uncontrolled approaches, as the majority of pedestrian fatalities occur at non-intersection locations. For example, 76.8% of pedestrian fatalities in 2021 were not at an intersection and 75.8% of pedestrian fatalities in 2020 were not at intersections (Petraglia & Macek, 2023).

A number of intelligent transportation systems (ITS) countermeasures are available to help address pedestrian safety issues at uncontrolled pedestrian crossings. ENTERPRISE members were interested in having guidance on what ITS treatments are most appropriate for various traffic volumes, pedestrian volumes, and geometric conditions.

The objective of this research was to review existing guidance for deploying ITS countermeasures at uncontrolled pedestrian crossings and identify additional needs beyond the available guidance, such as additions to published resources, new guidance, or new research. The focus of the research was “on-road” ITS countermeasures rather than vehicle-based technologies.

1.1 Project Approach

This project was completed through the following research activities:

- **Review Existing Guidance Resources:** As a first step, a literature search was conducted to identify existing guidance specific to the selection of ITS countermeasures at uncontrolled pedestrian crossings.
- **Gather Input from Traffic Safety Professionals:** Next, the project team convened an interactive meeting with traffic safety professionals who are familiar with pedestrian facility design and pedestrian safety countermeasures. The meeting was designed to gather input on guidance resources used, ITS countermeasures deployed in their respective states, gaps in guidance, and other needs specific to pedestrian safety.
- **Identify Needs or Gaps in Guidance:** Using information gathered through the review of guidance resources and the interactive meeting with traffic safety professionals, the research identified a set of needs and gaps relative to guidance for considering ITS countermeasures to improve pedestrian safety at uncontrolled pedestrian crossings and other uncontrolled locations.

Figure 1.2 Project Approach

See Figure 1.2 for the project approach.

1.2 Report Organization

This report summarizes the research findings and is organized as follows:

- Chapter 2: Review of Existing Guidance – Summarizes findings from a of a review of existing guidance for implementing safety countermeasures at uncontrolled pedestrian crossings and uncontrolled approaches, with a focus on the use of ITS strategies.
- Chapter 3: Input from Traffic Safety Professionals – Provides a summary of input gathered during an interactive meeting with traffic safety professionals from selected state departments of transportation (DOTs), including guidance used in designing pedestrian facilities and implementing safety improvements, ITS technologies deployed, and gaps in current guidance.
- Chapter 4: Potential Needs and Gaps in Guidance – Describes collective observations from the review of existing guidance resources and the input provided by traffic safety professionals.
- Chapter 5: Summary and Implementation – Provides a summary of key findings and suggested implementation of the results.

Chapter 2: Review of Existing Guidance

This section provides key definitions for conditions where pedestrian safety treatments may be considered and provides a summary of guidance resources reviewed in the initial phase of this research.

2.1 Key Definitions

When considering ITS countermeasures to improve pedestrian safety, numerous geometric and traffic conditions are considered when determining potential safety treatments. The following conditions were the focus of identifying and reviewing selected guidance resources:

- **Uncontrolled Pedestrian Crossing Locations:** According to the Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations published by FHWA in 2018, "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 crossing types can occur at intersections (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" (Blackburn, Zegeer, & Brookshire, 2018).
- **Uncontrolled Approaches:** The Florida DOT Traffic Engineering Manual defines an "uncontrolled approach" as a condition where "all lanes of traffic moving toward an unsignalized intersection or a midblock location from one direction (including any adjacent parking lane) that are not controlled by any sign, signal, marking, or other control devices" (FDOT, 2025). In contrast to "uncontrolled pedestrian crossing locations" as defined above, "uncontrolled approaches" also include midblock locations that are not marked as crossings. These locations are candidates for adding a marked crossing, with possible additional safety countermeasures.

These two conditions vary in terms of the types of safety treatments that may be appropriate. Treatments can range from installing marked crosswalks, lighting enhancements, signage, roadway improvements such as refuge islands or curb extensions, and ITS treatments, to name just a few. Further, because every location is unique (e.g., road geometry, vehicle speeds, presence of sidewalks, surrounding contexts), detailed analysis considering multiple factors is typically needed to determine appropriate treatments.

2.2 Existing Guidance

Existing guidance for designing pedestrian facilities and selecting safety countermeasures to accommodate pedestrian crossing activity covers a wide range conditions and situations. Resources to guide decision-making include national guidance, state and local guidance, and general traffic engineering guidelines. The design of pedestrian facilities, which has traditionally focused on engineering factors (e.g., road geometry, traffic volumes, posted speeds, vehicle-pedestrian crash history) is trending toward the use of additional considerations (e.g., latent demand, equity, land use, pedestrian demographics) to implement pedestrian safety treatments. The following sections provide an overview of selected, existing

resources for guiding the selection of safety countermeasures at uncontrolled pedestrian crossing locations and uncontrolled approaches, including general design guidance that addresses both of these conditions.

2.2.1 Uncontrolled Pedestrian Crossing Locations

The leading national guidance for considering countermeasures at uncontrolled pedestrian crossing locations is the Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations published by the Federal Highway Administration (FHWA) in 2018. This resource provides guidance including best practices for each step involved in selecting countermeasures for uncontrolled pedestrian crossings. The steps for selecting countermeasures include collecting data and engaging the public, inventorying conditions and prioritizing locations, analyzing crash types and safety issues, and selecting countermeasure(s). The selection of one or more appropriate countermeasure(s) is based on roadway configuration, vehicle average annual daily traffic (AADT), posted speed limit, and safety issue(s) to be addressed. See Figure 2.1 and Figure 2.2.

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)	● 2 4 5 6	● 5 6 7 9	○ 5 6 ● 9	● 4 5 6	● 5 6 7 9	○ 5 6 ● 9	● 4 5 6 7 9	○ 5 6 7 9	○ 5 6 ● 9
3 lanes with raised median (1 lane in each direction)	● 2 3 4 5	● ■ 5 7 9	○ ■ 5 ● 9	○ 3 4 5 7 9	○ ■ 5 ● 9	○ ■ 5 ● 9	○ ■ 4 5 7 9	○ ■ 5 ● 9	○ ■ 5 9
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	● 2 3 4 5 6 7 9	● ■ 5 6 7 9	○ ■ 5 6 9	○ 3 4 5 6 7 9	○ ■ 5 6 ● 9	○ ■ 5 6 9	○ ■ 4 5 6 7 9	○ ■ 5 6 9	○ ■ 5 6 9
4+ lanes with raised median (2 or more lanes in each direction)	● ■ 5 7 8 9	● ■ 5 7 8 9	○ ■ 5 8 9	○ ■ 5 7 8 9	○ ■ 5 ● 8 9	○ ■ 5 8 9	○ ■ 5 ● 8 9	○ ■ 5 8 9	○ ■ 5 8 9
4+ lanes w/o raised median (2 or more lanes in each direction)	● ■ 5 6 7 8 9	○ ■ 5 6 7 8 9	○ ■ 5 6 8 9	○ ■ 5 6 7 8 9	○ ■ 5 6 ● 8 9	○ ■ 5 6 8 9	○ ■ 5 6 ● 8 9	○ ■ 5 6 8 9	○ ■ 5 6 8 9

Given the set of conditions in a cell,

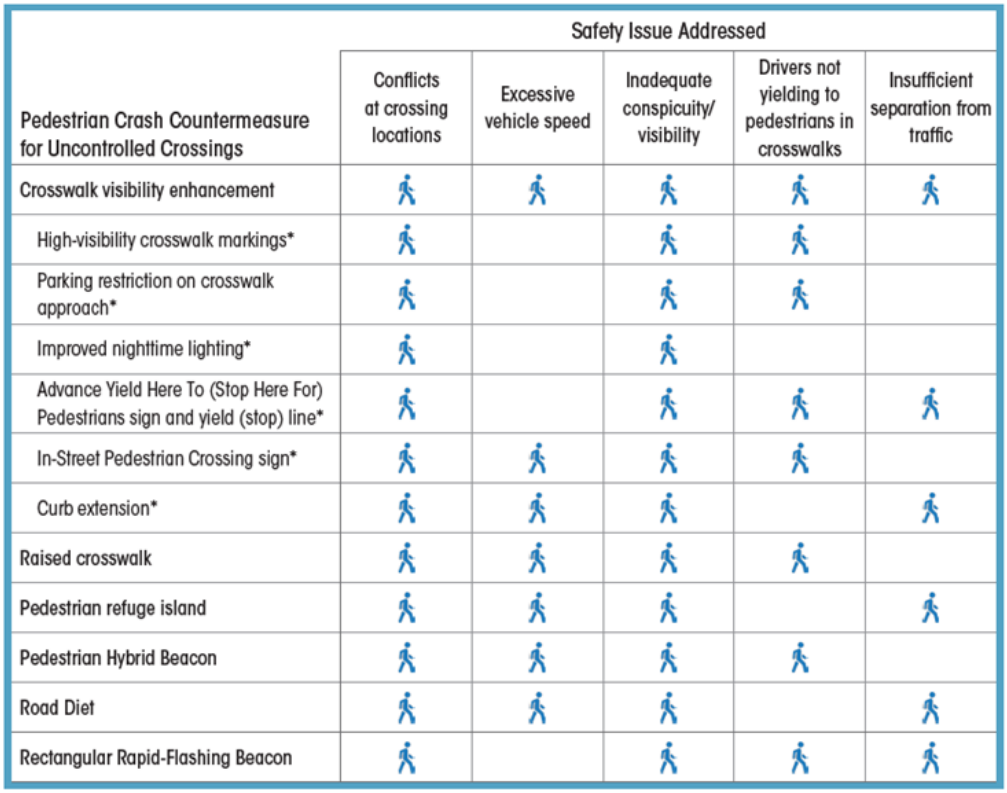
- # Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk 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.

Figure 2.1 Application of Pedestrian Crash Countermeasure by Roadway Feature
Source: *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* (Blackburn et al., 2018)



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.

Figure 2.2 Safety Issues Addressed per Countermeasure
Source: *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* (Blackburn et al., 2018)

The FHWA guide promotes the following six (6) effective and lower-cost countermeasures, with technology-based (i.e., ITS) countermeasures noted:

1. Crosswalk visibility enhancements
2. Raised crosswalks
3. Pedestrian refuge islands
4. Road Diets
5. Rectangular Rapid-Flashing Beacons (RRFB) ***=>> ITS countermeasure***
6. Pedestrian Hybrid Beacons (PHB) ***=>> ITS countermeasure***

RRFBs are active (user-actuated) or passive (automated detection) amber LEDs that use an irregular flash pattern at mid-block or uncontrolled crossing locations. RRFBs are particularly effective at multilane crossings with speed limits less than 40 mph. RRFBs can reduce pedestrian crashes by 47% (FHWA, 2018b). PHBs are a beneficial intermediate option between RRFBs and a full pedestrian signal. The PHB is often considered for installation at locations where pedestrians need to cross and vehicle speeds or volumes are high, but traffic signal warrants are not met. PHBs can reduce pedestrian crashes by 55% (FHWA, 2018a). See Figure 2.3 and Figure 2.4.

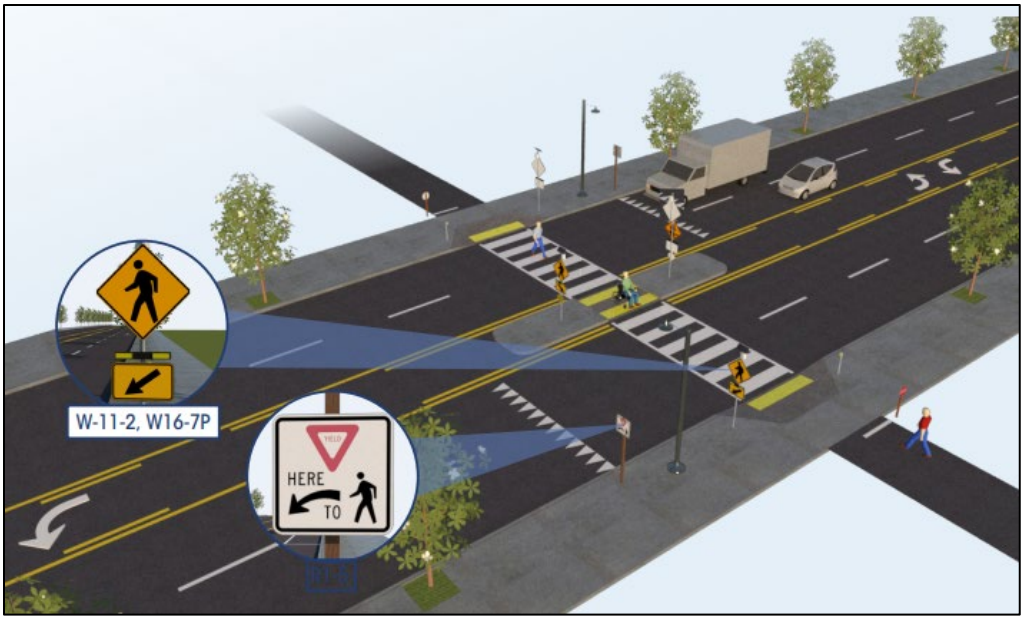


Figure 2.3 Rectangular Rapid-Flashing Beacon
Source: *Countermeasure Tech Sheet FHWA-SA-18-065* (FHWA, 2018b)

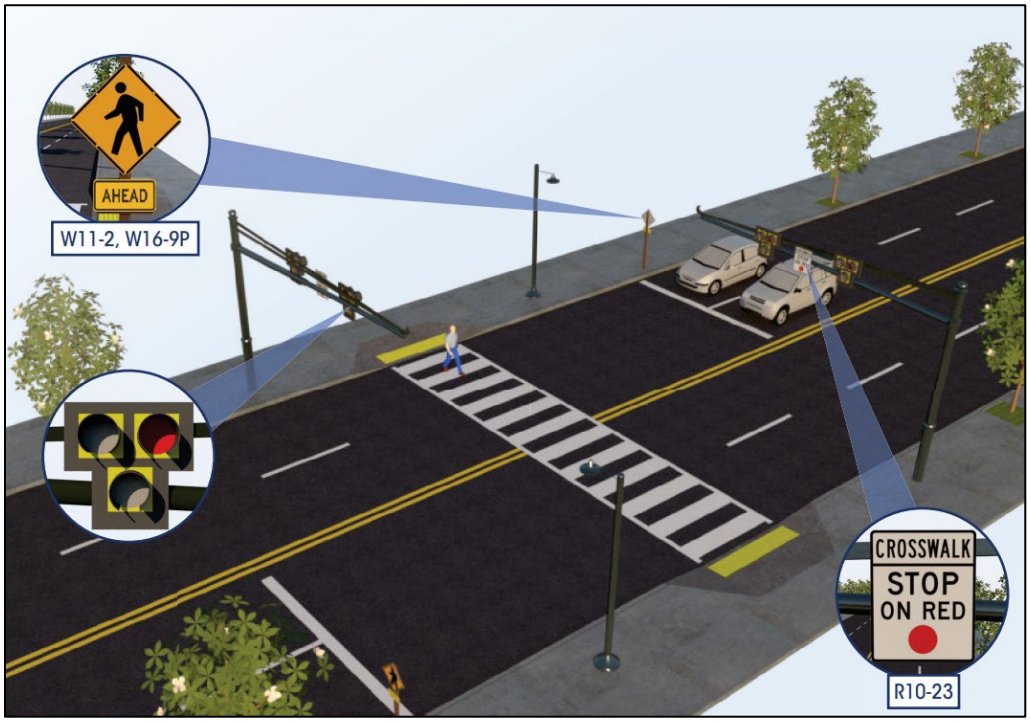


Figure 2.4 Pedestrian Hybrid Beacon
Source: *Countermeasure Tech Sheet FHWA-SA-18-064* (FHWA, 2018a)

FHWA promoted all six of the above listed low-cost, effective countermeasures, including RRFBs and PHBs, through its Every Day Counts (EDC-5) program. These innovations are also featured as part of the FHWA Safe Transportation for Every Pedestrian (STEP) initiative and STEP resources.

In addition to national guidance provided by FHWA, some state DOTs and local transportation agencies have created reference guides and system-wide action plans to guide the selection of safety countermeasures at uncontrolled pedestrian crossings. These resources are typically based on the FHWA's national guidance and adapted to local contexts. See Table 2-1 for an overview of selected examples of state and local guidance resources for selecting safety countermeasures at uncontrolled pedestrian crossings.

Table 2-1 State and Local Guidance for Countermeasures at Uncontrolled Pedestrian Crossings

Guidance Resource(s)	Overview
Action Plan for Implementing Pedestrian Crossing Countermeasures (East Central Wisconsin Regional Plan Commission, 2021) Action Plan for Implementing Pedestrian Crossing Countermeasures at Uncontrolled Locations (North Carolina DOT, 2018) Action Plan for Implementing Pedestrian Crossing Countermeasures at Uncontrolled Locations (Washington State DOT, 2018)	These action plans, created for selected state and local agencies, provide specific recommendations for improving conditions for walking at pedestrian crossing locations, which occur where sidewalks or designated walkways cross a roadway. Recommendations in these action plans follow the FHWA Safe Transportation for Every Pedestrian (STEP) guidance for implementing lower-cost countermeasures that can be deployed based on specific needs. The plans also build on existing agency goals and strategies for improving safety, support the examination of existing conditions, and use a data driven approach to match countermeasures with demonstrated problem locations.
Pedestrian Crosswalk Policy Development Guidelines (Miner & Arvidson, 2020a) and Uncontrolled Pedestrian Crosswalk Quick Reference Guide (Miner & Arvidson, 2020b)	This report and quick reference guide, developed for the Minnesota Department of Transportation (MnDOT) and the Minnesota Local Road Research Board (LRRB), were developed from the FHWA-published Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations, to help agencies determine when to use different countermeasures for uncontrolled pedestrian crosswalks based on roadway type, vehicle volumes, and posted speed limits. The quick reference guide includes photos, deployment location context, benefits, estimated cost, and design considerations.

Upon review of selected federal, state, and local guidance resources for selecting safety countermeasures at uncontrolled pedestrian crossings, the ITS countermeasures identified in the selected guidance resources reviewed include PHBs and RRFBs. The primary factors used for consideration in selecting candidate locations and countermeasures include roadway configuration, traffic volumes (i.e., AADT); posted speed limit, and crash history or other known safety issues.

2.2.2 Uncontrolled Approaches and General Design Guidance

As noted in Section 2.1 Key Definitions, uncontrolled approaches are locations that are not controlled by any sign, signal, marking, or other control devices. In contrast to "uncontrolled pedestrian crossing locations," "uncontrolled approaches" also include midblock locations that are not marked as crossings. These locations are candidates for adding a marked crossing, possibly with additional countermeasures.

The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) – 11th Edition (FHWA, 2023) provides guidance for implementing pedestrian safety accommodations and crossing treatments, including the installation of a marked crossing (Chapter 3C) which indicates that at uncontrolled approaches, an engineering study should be performed before a marked crosswalk is installed. ITS pedestrian treatments covered in the MUTCD include, for example, flashing beacons and light-emitting diode (LED) units used for enhanced conspicuity on signs (Chapter 2A), PHBs (Chapter 4J), RRFBs (Chapter 4L), pedestrian-actuated warning beacons (Chapter 4S), and in-roadway warning lights (Chapter 4U).

In addition to the MUTCD, multiple state and local resources provide guidance for implementing safety improvements specific to uncontrolled locations and midblock locations, as well as general design guidance to address pedestrian safety. Resources selected for review included those specific to pedestrian treatments at uncontrolled approaches and/or midblock locations, those that incorporate emerging factors to guide selection of treatments, and those that include ITS countermeasures. See Table 2-2 for an overview of selected guidance resources, with ITS treatments in each resource as noted.

Table 2-2 Resources for Uncontrolled Approaches, Midblock Locations, and General Design Guidance

Guidance Resource	Overview
Guidance for Determining Pedestrian Crossing Treatment at Uncontrolled Locations (Montana DOT, 2019)	This Montana DOT memorandum provides guidance for determining pedestrian crossing treatments at uncontrolled locations. The type of treatment may range from marked crosswalks and signage to pedestrian actuated beacons or pedestrian signals. **ITS treatments: flashing beacons, pedestrian actuated beacons (i.e., RRFBs, PHBs), and pedestrian signals.**
Uncontrolled Pedestrian Crossing Guidelines (City and County of Denver, 2022)	These guidelines serve as the policy document that guides staff in determining where and how to improve an uncontrolled crosswalk within the City and County of Denver on City and County of Denver owned and maintained streets. It provides guidance to determine if a marked crosswalk is appropriate at a particular location and identifies a range of enhancement treatments that may be appropriate depending on site characteristics. **ITS treatments: RRFB, PHB, or signal.**
Guidelines for Installing Pedestrian Treatments at Midblock Locations (Alluri, Kadeha, Wu, & Kitali, 2020)	This Florida DOT study explored pedestrian safety treatments used at midblock locations to assist FDOT in developing guidelines to improve pedestrian safety. The resource identified arterial corridors that are prone to pedestrian crashes, recommended pedestrian treatments to be installed at these locations, and developed guidelines to assist in selecting

Guidance Resource	Overview
	the midblock locations and pedestrian treatments. **ITS treatments: RRFBs, PHBs, flashing signal beacons, and in-road flashing warning lights.**
Establishing Procedures and Guidelines for Pedestrian Treatments at Uncontrolled Locations (Qi, Fries, Zhou, Rab, & Baireddy, 2017)	This document provides best practices for approving pedestrian crossings and pedestrian-crossing treatments at uncontrolled locations and developed procedures and guidelines to be used by the Illinois Department of Transportation (IDOT) and local agencies. **ITS treatments: flashing beacons, RRFBs, PHBs.**
Pedestrian Crossing Accommodations at Unsignalized Approaches (Virginia DOT, 2022)	This Virgina DOT resource provides consistent, uniform guidance to designers for determining when to install marked crosswalks, what type of crosswalk to install, and what other traffic control devices or geometric improvements should potentially be considered in conjunction with the marked crosswalk at unsignalized intersection approaches and unsignalized mid-block locations. **ITS treatments: RRBs, PHBs.**
FDOT Traffic Engineering Manual Section 5.2: Treatments for Pedestrian Crosswalks at Midblock and Unsignalized Intersections (Florida DOT, 2025)	Section 5.2 of the Florida DOT Traffic Engineering Manual establishes criteria and guidelines for the consistent installation and operation of pedestrian treatments at midblock and unsignalized intersections on the State Highway System. These treatments include marked pedestrian crosswalks, signs, traffic control devices, and other measures. **ITS treatments: yellow flashing beacons, RRFBs, PHBs.**
Tools for the Planning and Design of Pedestrian Crossing Enhancements (Michigan DOT, 2022b) and Best Design Practices for Walking and Bicycling in Michigan (Michigan DOT, 2022a)	These Michigan DOT resources provide an overview of the planning and design process for implementing pedestrian crossing enhancements in Michigan as well as best design practices. **ITS treatments in best design practices document: RRFBs, PHBs, midblock signals.**
Vermont Agency of Transportation Guidelines for Pedestrian Crossing Treatments (Vermont Agency of Transportation, 2019)	This Vermont Agency of Transportation (VTrans) resource provides guidance on the location of marked and unmarked crossings, and the associated pavement markings and signs. It includes guidance for signalized intersections, unsignalized intersections, marked crosswalks at mid-block locations, and unmarked crossings. **ITS treatments: RRFBs, PHBs.**

Additional information about selected guidance resources (Montana DOT, City and County of Denver, and Florida DOT) is provided below.

Montana DOT: The Montana DOT (MDT) memorandum on Guidance for Determining Pedestrian Crossing Treatment at Uncontrolled Locations (Montana DOT, 2019) provides guidance for determining treatments that range from marked crosswalks and signage to pedestrian actuated beacons or pedestrian signals. The process to determine eligibility for pedestrian crossing treatment is based on site location, pedestrian crossing demand, pedestrian types (school age, elderly, etc.), vehicle speeds, and other site conditions such as continuity with adjacent pedestrian facilities. See Figure 2.5.

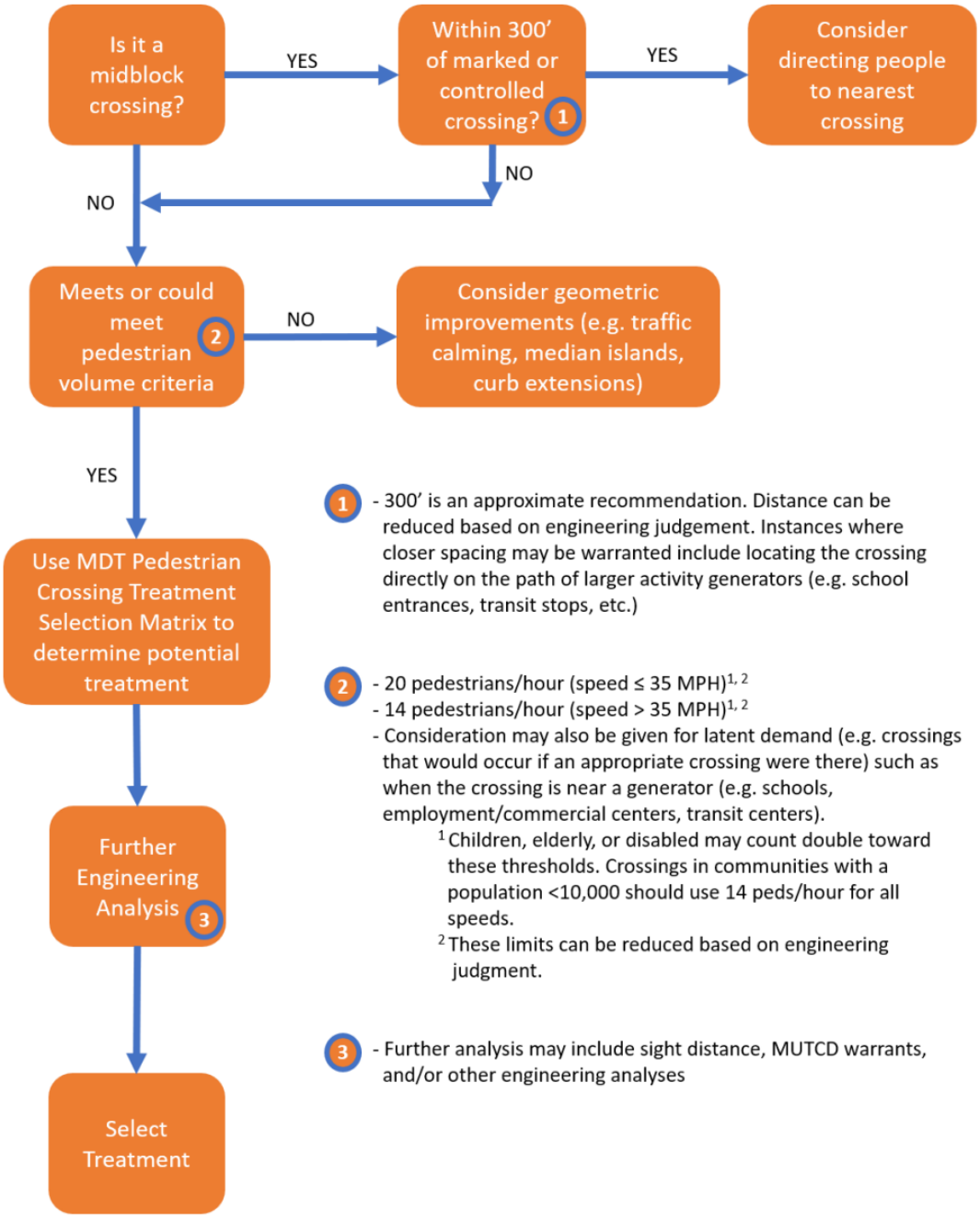


Figure 2.5 Selecting an Uncontrolled Pedestrian Crossing Treatment
Source: *Guidance for Determining Pedestrian Crossing Treatment at Uncontrolled Locations* (MDT, 2019)

Once treatment eligibility is established, the process for selecting the type of treatment is based on vehicle speed, average daily traffic, and width of the roadway. The type of treatment may range from marked crosswalks and signage to pedestrian actuated beacons or pedestrian signals. See Figure 2.6 for the MDT Pedestrian Treatment Selection Matrix.

MDT PEDESTRIAN CROSSING TREATMENT SELECTION MATRIX

2 Lane Facility					
Speed MPH	0 - 8,000 ADT	8,000 - 11,000 ADT	11,000 - 14,000 ADT	14,000 - 17,000 ADT	>17,000 ADT
0 - 30	C	C	C	E	A
35	C	C	E	E	A
40+	E	E	A	A	A

3 Lane Facility					
Speed MPH	0 - 8,000 ADT	8,000 - 11,000 ADT	11,000 - 14,000 ADT	14,000 - 17,000 ADT	>17,000 ADT
0 - 30	C	[C], E	[C], E	[C], A	[E], A
35	C	[C], E	[C], E	[E], A	[E], A
40+	E	[E], A	[E], A	[E], A	A

4 Lane Facility					
Speed MPH	0 - 8,000 ADT	8,000 - 11,000 ADT	11,000 - 14,000 ADT	14,000 - 17,000 ADT	>17,000 ADT
0 - 30	C	E	A	A	A
35	E	E	A	A	A
40+	E	A	A	A	A

5 Lane Facility					
Speed MPH	0 - 8,000 ADT	8,000 - 11,000 ADT	11,000 - 14,000 ADT	14,000 - 17,000 ADT	>17,000 ADT
0 - 30	[C], E	[C], A	[E], A	A	A
35	[C], E	[C], A	[E], A	A	A
40+	[E], A	[E], A	A	A	A

*Treatment recommendations based on NCHRP Report 562, FHWA's *Safety Effects of Marked vs. Unmarked Crosswalks*, the MUTCD, and input from MDT Staff.

LEGEND	
An engineering study should be completed prior to selecting and installing any crossing treatments.	
C	Consider marked crosswalk with appropriate signage.
E	Consider marked crosswalk with enhancements, such as traffic calming, refuge islands, curb extensions, advanced yield markings, raised crosswalks, flashing beacons, or other high-visibility treatments.
A	Consider pedestrian-acuated beacons (i.e., rectangular rapid flashing beacons or pedestrian hybrid beacons) or pedestrian signal. MUTCD warrants for pedestrian hybrid beacons and pedestrian signals should be evalulated.
[X]	treatment option in brackets indicates treatment is applicable with installation of raised median

NOTES	
1	Use observed speed data if possible; otherwise use the posted speed limit of the street being crossed to determine the appropriate row to use
2	Higher degrees of treatments may be warranted if pedestrian crossing volumes are greater than 25 people per hour or if there is a significant amount of users with special needs (e.g. elderly, school-age children)
3	Refer to the MUTCD and MDT Road Design Manual for additional information on selecting & designing the appropriate treatment

Figure 2.6 MDT Pedestrian Crossing Treatment Selection Matrix

Source: *Guidance for Determining Pedestrian Crossing Treatment at Uncontrolled Locations* (MDT, 2019)

City and County of Denver: The Uncontrolled Pedestrian Crossing Guidelines (City and County of Denver, 2022) provides guidance to determine if a marked crosswalk is appropriate and identifies enhancement treatments. In addition to roadway configuration, average daily traffic, and distance to nearest marked crossing, the guidance introduces other key factors to select improvements, such as pedestrian volumes, latent demand (e.g., pedestrian demand, locations serving activity generators, proximity to transit stops/stations, connection to bike networks), and sight distance. See Figure 2.7 and Figure 2.8.

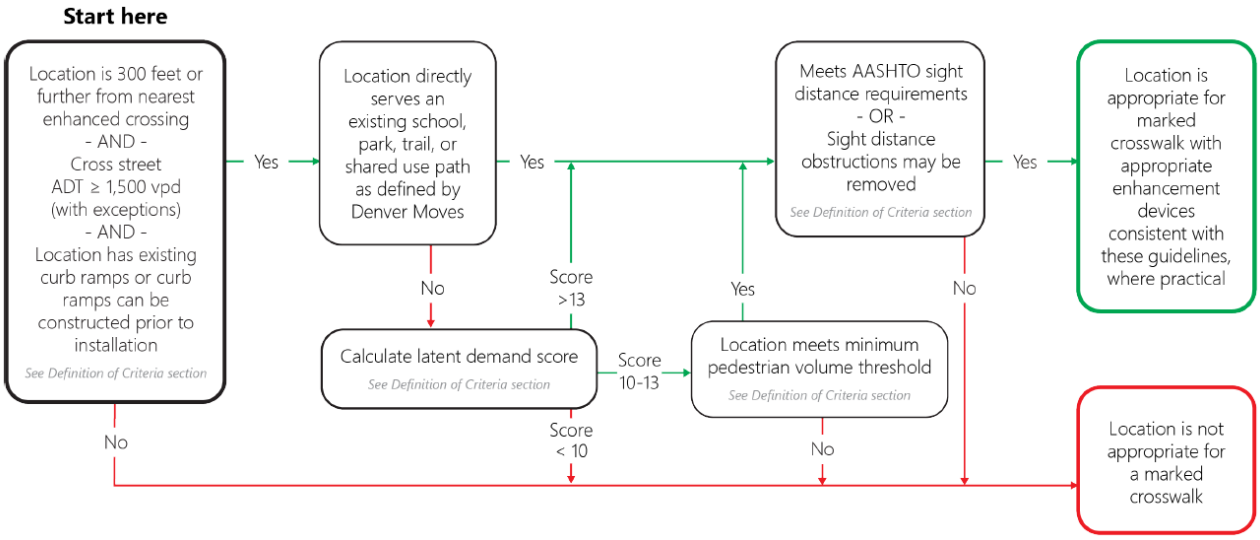


Figure 2.7 Candidate Location Flowchart
Source: *Uncontrolled Pedestrian Crossing Guidelines* (City and County of Denver, 2022)

Category	Variable	Definition	Data Source	Scoring Assignment	
Pedestrian Demand	Pedestrian Demand Index	Crossings in areas with high pedestrian demand, based on the Denver Moves Pedestrian Demand Index.	Pedestrian Demand Index	**Pedestrian Demand Index**	**Demand Score**
				< 5	0
				5 - 6	5
				> 6	7.5
Destination Criteria	Activity Generator Destination	Crossings within 300 feet of a school, park, health center, senior center, recreation or community center, library, grocery store, pharmacy, or neighborhood-embedded commercial district; or within a quarter mile of a regional park.	Field visit, Google Maps, GIS data	**Proximity**	**Activity Score**
				None	0
				One destination	5
				> One destination	7.5
	Transit Destination	Crossings within 300 feet of a bus stop or 500 feet of a rail station.	Field visit, Google Maps, GIS data	**Proximity**	**Transit Score**
				None	0
				Bus stop	2
				Rail station	5
	Connection to Bike Network	Crossings that combine access with the existing and planned bike network.	Field visit, Google Maps, GIS data	**Location**	**Bikeway Score**
				Not on bike network	0
				On bike network	5
TOTAL				**Score (0 - 25)**	

Figure 2.8 Latent Demand Scoring Matrix
Source: *Uncontrolled Pedestrian Crossing Guidelines* (City and County of Denver, 2022)

Florida DOT: The FDOT Traffic Engineering Manual Section 5.2: Treatments for Pedestrian Crosswalks at Midblock and Unsignalized Intersections (Florida DOT, 2025) provides FDOT's current engineering guidance for determining pedestrian treatments. An engineering study is conducted before installing a marked crosswalk or other pedestrian treatments.

The Guidelines for Installing Pedestrian Treatments at Midblock Locations (Alluri et al., 2020) resource documents a study that explored pedestrian safety treatments used at midblock locations to assist Florida DOT in developing guidelines to improve pedestrian safety. The guidelines provide a series of flowcharts and conditions to guide the user in selecting appropriate safety treatment(s). Conditions such as presence of pedestrian generators/attractors, presence of bus stops, pedestrian crash hot spots, and location in low household income neighborhoods are factors used to help determine appropriate treatments. See Figure 2.9, Figure 2.10, and Figure 2.11.

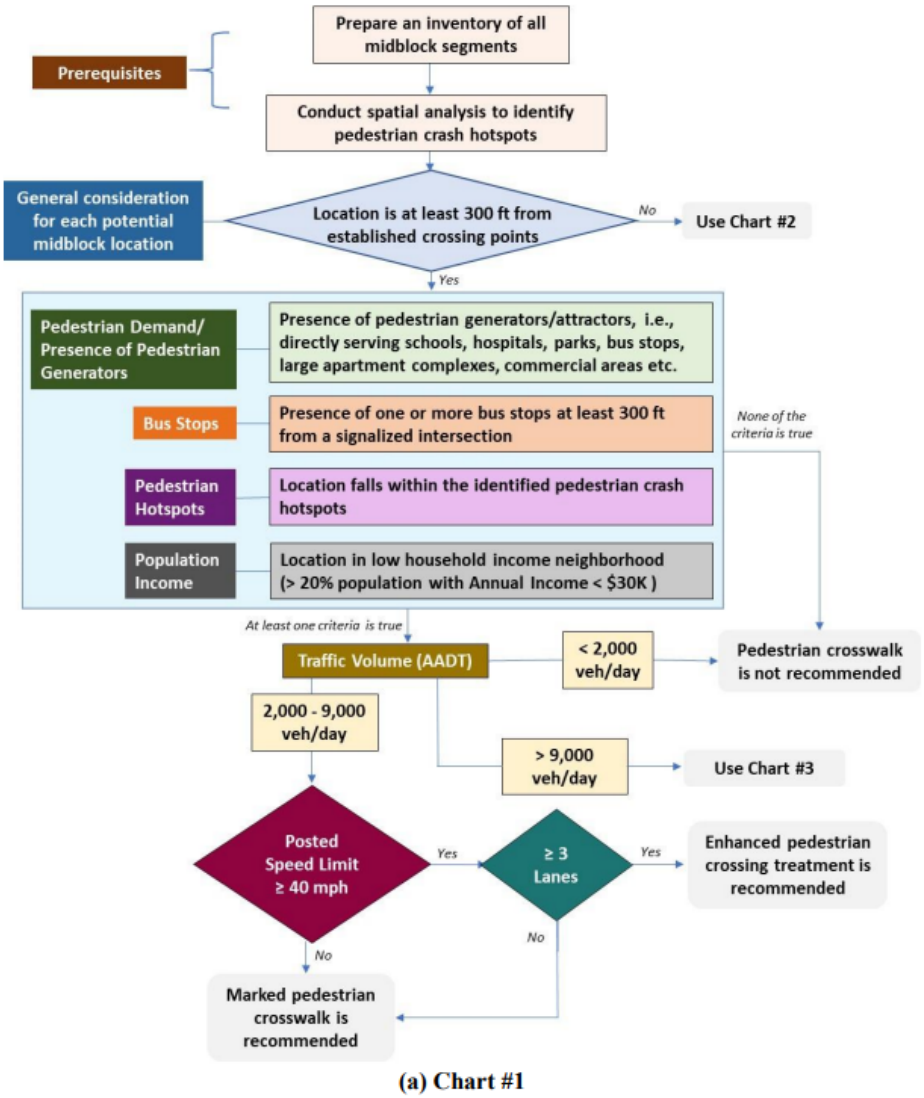
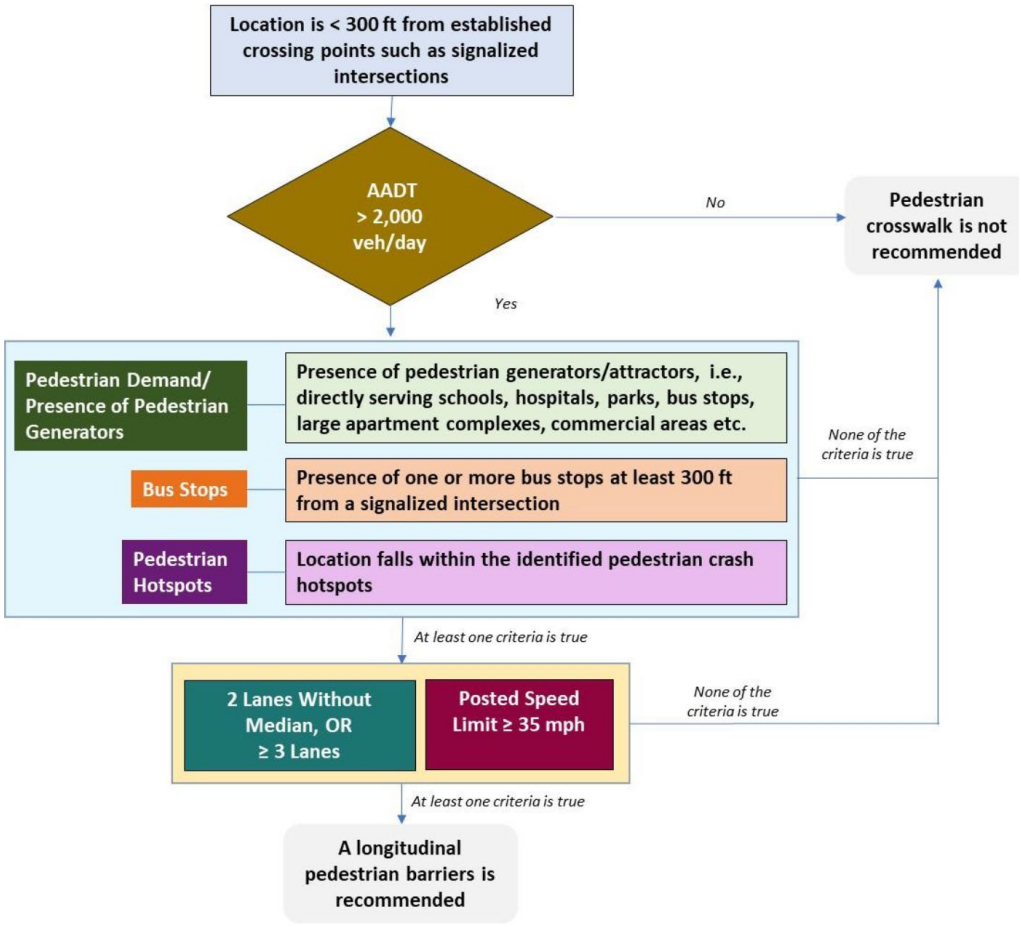


Figure 2.9 Chart #1 for Determining Pedestrian Treatments at Midblock Locations

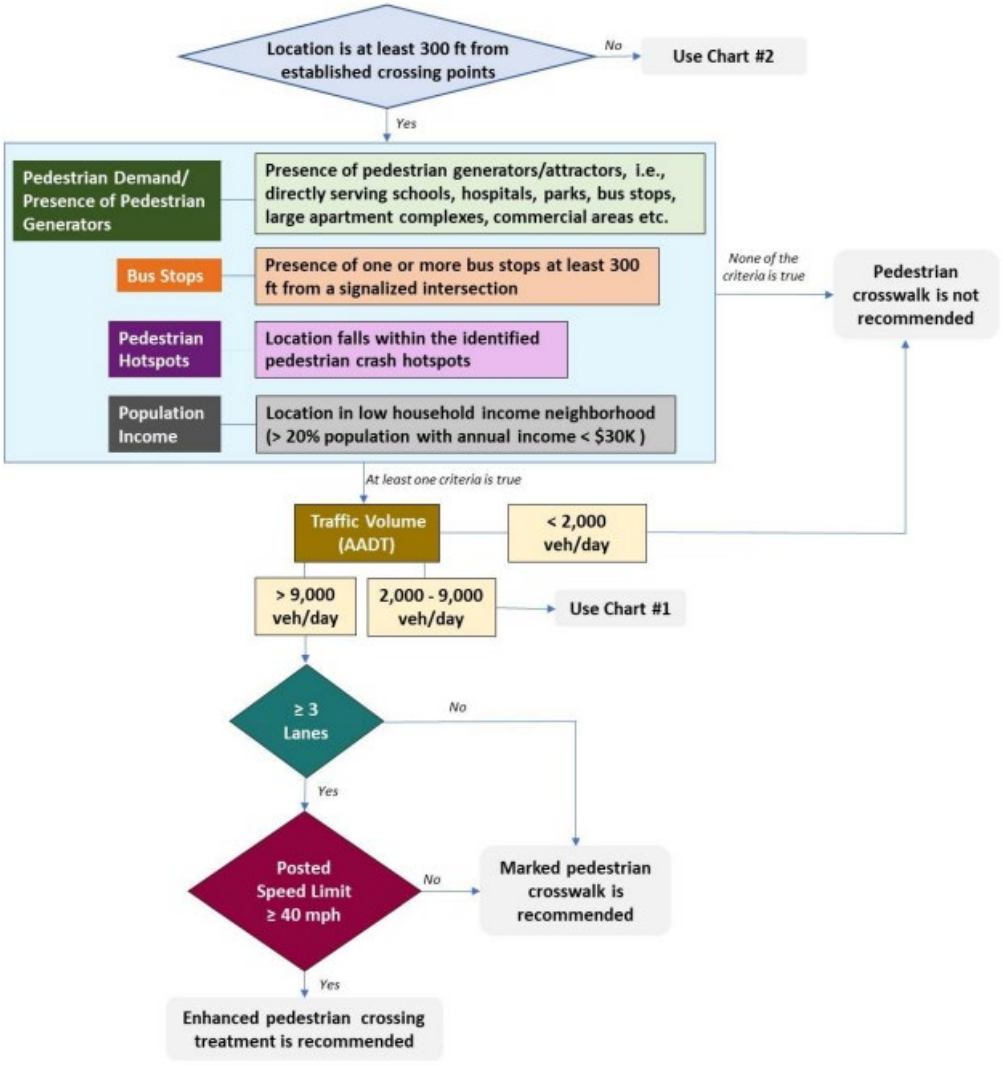
Source: *Guidelines for Installing Pedestrian Treatments at Midblock Locations* (Alluri et al., 2020)



(b) Chart #2

Figure 2.10 Chart #2 for Determining Pedestrian Treatments at Midblock Locations

Source: *Guidelines for Installing Pedestrian Treatments at Midblock Locations* (Alluri et al., 2020)



(c) Chart #3

Figure 2.11 Chart #3 for Determining Pedestrian Treatments at Midblock Locations

Source: *Guidelines for Installing Pedestrian Treatments at Midblock Locations* (Alluri et al., 2020)

In addition to the safety treatments identified in state and local guidance, a study Assessment of Safety Benefits of Technologies to Reduce Pedestrian Crossing Fatalities at Midblock Locations that investigated pedestrian midblock crashes at nighttime in South Carolina highlights installation of sidewalks, enhanced lighting, and public education as key strategies for mitigating midblock pedestrian crashes at night. The study also recommends expanding the range of roadway types that are considered for RRFB installation to include 3000 to 9000 AADT 2-lane roads with posted speeds of 35mph or less (Ogle et al., 2020). In addition, the study investigated the efficacy of camera technologies for detecting pedestrians at night. See Section 4.5.

2.2.3 Key Findings

The ITS treatments commonly referenced in the guidance documents reviewed include:

- Flashing beacons (mounted to static signs)
- RRFBs
- PHBs
- In-pavement lights

ITS Countermeasures in Existing Guidance

- Flashing beacons
- RRFBs
- PHBs
- In-pavement lights

These ITS treatments are installed as enhancements to marked crosswalks (i.e., marked crossings) and do not address uncontrolled approaches where a marked crossing does not exist.

Treatments for uncontrolled approaches where a marked crossing does not exist include installing a marked crossing (with additional treatments as needed) or in some cases installing a grade-separated crossing such as a pedestrian bridge or an underpass. Examples of other strategies include lighting, longitudinal pedestrian barrier (e.g., fencing), signage directing pedestrians to the nearest crossing, installing sidewalks with access to crossings, and roadway geometric improvements such road diets or other traffic calming measures.

Per the guidance documents reviewed, factors that agencies most commonly utilize to identify treatments at uncontrolled pedestrian crossings and uncontrolled approaches include:

- Distance to nearest crossing location
- Pedestrian volume
- Roadway configuration (e.g., number of traffic lanes, presence of raised median or curb ramps)
- Vehicle volume (i.e., AADT)
- Posted speed limit
- Pedestrian-vehicle crash history or known safety issues

Some guidance documents incorporate additional, emerging considerations such as:

- Pedestrian demand / pedestrian activity generators (i.e., directly serving schools, health centers, recreation centers, parks, trails, bicycle networks, shared use paths, housing complexes, commercial areas)
- Proximity to transit facilities (e.g., bus stops, bus stations, rail stations)
- Population income (e.g., location in low household income neighborhood)
- Sight distance

Overall, there is consistency in the types of ITS treatments that appear in existing guidance documents. However, the processes, criteria, considerations, and factors used to determine a wide range of pedestrian treatments vary in terms of agency-specific guidance.

Chapter 3: Input from Traffic Safety Professionals

After reviewing existing guidance specific to selecting pedestrian safety treatments at uncontrolled pedestrian crossing locations and uncontrolled approaches, the project convened traffic safety professionals from selected state DOTs to provide input for the research through an interactive meeting.

The 90-minute interactive meeting was conducted on July 23, 2024. Eight (8) representatives from the following five (5) state DOTs participated in the interactive meeting:

- Kansas DOT
- Michigan DOT
- Minnesota DOT
- Tennessee DOT
- Wisconsin DOT

3.1 Purpose and Format

The purpose of the interactive meeting was to engage traffic safety professionals in the research and to gather input regarding the selection of pedestrian safety countermeasures at uncontrolled pedestrian crossing locations and uncontrolled approaches. The meeting included an overview of the research conducted to date, followed by a facilitated state-by-state round robin and open discussion guided the following questions:

Round Robin:

- What guidance do you use to evaluate uncontrolled locations for possible pedestrian safety countermeasures?
- What ITS strategies has your DOT deployed at non-intersection locations (uncontrolled pedestrian crossings, uncontrolled locations)?
- What strategies are implemented where no marked crossing or intervention exists?
- What are some tradeoffs and considerations in determining safety treatments (e.g., impacts to traffic flow, laws requiring vehicles to yield to pedestrians, other)?
- What should DOTs be recommending to the automobile industry, in terms of improving pedestrian safety?

Open Discussion:

- What gaps exist (e.g., research, guidance)?
- What are some considerations with rural versus urban settings?

The interactive meeting was designed to facilitate the sharing of practices used by traffic safety professionals and to capture emerging issues and considerations for pedestrian safety. The following sections summarize input provided by each state DOT that participated in the interactive meeting.

3.2 Round Robin by State DOTs

To provide input for the research, each state first shared their perspectives in response to the research questions that were provided in advance of the meeting, in a round robin format. The round robin featured State DOTs sharing guidance they use for evaluating uncontrolled locations for pedestrian safety treatments, ITS strategies used, strategies used where no marked crossing exists, related tradeoffs and considerations, and possible recommendations for the automobile industry.

See the following tables for input provided by representatives from Kansas DOT (Table 3-1), Michigan DOT (Table 3-2), Minnesota DOT (Table 3-3), Tennessee DOT (Table 3-4), and Wisconsin DOT (Table 3-5.)

Table 3-1 Kansas DOT Input

Category	Kansas DOT Input*
Guidance Used	• Kansas DOT (KDOT) conducts a traffic study when there is a location with a possible pedestrian safety issue. • Considers posted speed, pedestrian counts, and where they are crossing. • Often looking at very small cities and towns, often near schools where stakeholders request a crosswalk and school zone signing. • Resource: Kansas DOT Crosswalk Guidance & Guide to Crosswalk Countermeasures
ITS Strategies	• Flashing beacons on signs are used to control speeds through a school zone. • RRFBs at mid-blocks are becoming popular. The agency is determining how to evaluate RRFBs especially for locations with low volumes and low speeds. • KDOT also considers road diets at crosswalks. • Small towns often have no sidewalks. Children often do not cross where they should (e.g., diagonally or at midblock, to access a convenience store), so it's a challenge when a crosswalk is requested. • KDOT's ITS section is currently not utilized, relative to pedestrian safety treatments. KDOT is determining how different groups within the agency will work together on pedestrian safety solutions. • A vulnerable road user (VRU) category is being created in the FHWA Highway Safety Improvement Program (HSIP), to help fund priority areas identified in VRU assessments.
Strategies for No Marked Crossings	• Find ways to consolidate multiple crosswalks into 1 or 2 crosswalks that are well signed. • Implement road diets to reduce 4 lanes down to 2 lanes, so pedestrians don't have a long distance to travel to cross the road. • KDOT's Traffic group sometimes works with the Multimodal Transportation group on crossings for cyclists. RRFBs or a Hawk may be considered for

Category	Kansas DOT Input*
	crossings in rural areas where traffic is traveling at 65 mph and can't slow all traffic for an occasional bicycle.
Recommendations for Automobile Industry	• Vehicles to detect pedestrians and assist with braking.

**Kansas DOT input was provided by Donna Lee and Thomas Northup during the interactive meeting.*

Table 3-2 Michigan DOT Input

Category	Michigan DOT Input*
Guidance Used	• Michigan DOT (MDOT) has its own published guidelines for pedestrian crosswalk treatments: MDOT Pedestrian/Bicyclist Guidance Documents. • MDOT first evaluates the need for an uncontrolled crossing and if there is a need then also identifies what types of treatments may be needed. • MDOT conducts an engineering study looking at traffic volumes, pedestrian volumes, speed, and number of lanes, then uses a flowchart and guidance to classify the type of treatment. Low volume, low speed situations could result in a marked crosswalk or nothing at all. Higher volumes and higher speeds might be a PHB or a full traffic signal. • MDOT often receives requests from locals for a new crosswalk. On higher speed, higher volume roadways, pedestrian counts are very low where no crossing exists. However, when a crosswalk is installed, pedestrians will likely cross there, which will increase the pedestrian volumes and may require a different type of treatment compared to the original analysis and design.
ITS Strategies	• RRFBs, pedestrian hybrid beacons, and full signals are used. • In Michigan there is no state law addressing pedestrian and driver responsibilities at unsignalized crosswalks. Michigan has a uniform traffic code that local municipalities can use to create local laws, but there are inconsistencies around the state for what drivers and pedestrians are required to do. • An apprehension with RRFBs is that when a pedestrian activates the flashing lights, they may interpret this as a protected phase and assume that oncoming traffic is required to stop. Near misses and observations drive this concern. Education is needed, both for drivers and pedestrians, regarding RRFBs, but no state law exists to drive consistency.
Strategies for No Marked Crossings	• Road diets are a good tool. This looks at the number of lanes for possible lane reductions to calm traffic in pedestrian crossing areas.

Category	Michigan DOT Input*
Recommendation for Automobile Industry	• Ensure vehicle technology can detect pedestrians in the dark, as the most significant pedestrian safety issues are at unsignalized, unmarked, midblock locations and during nighttime.

**Michigan DOT input was provided by Garrett Dawe, Michigan DOT during the interactive meeting.*

Table 3-3 Minnesota DOT Input

Category	Minnesota DOT Input*

Guidance Used	• Minnesota DOT (MnDOT) is developing related guidance and updating the "Non-motorized Facilities" chapter of its Traffic Engineering Manual.
	• MnDOT utilizes the following guidance and considerations:
	  ○ Implementing Complete Streets, with a focus on land use and transportation hierarchy. (See the MnDOT Complete Streets Transportation Hierarchy Tool.) This approach incorporates equity metrics, latent demand, land use context, and other proactive safety metrics to apply improvements at the highest need locations.
	  ○ Using the FHWA Safe Transportation for Every Pedestrian (STEP) chart.
	  ○ Trying to avoid the use of pedestrian counts as these counts change, especially when facilities are improved. Instead, MnDOT is moving toward considering land use, latent demand, and demand generators.
	  ○ Starting to integrate the Safe System Approach into pedestrian safety decisions.

ITS Strategies	• MnDOT has not implemented many ITS strategies. • MnDOT has investigated pedestrian detection technologies to inform whether a push button is always needed to activate traffic control devices. However, a push button is likely needed from an ADA perspective.
Strategies for No Marked Crossings	• Type of roadway matters (e.g., high-speed vs. low-speed, number of lanes). In some locations, road development has cut off pedestrian access. It's not a simple solution and very few tactics exist to address this. • Roadway design and Complete Streets considerations are important. Cass Lake in northern Minnesota example: tribal town, roadway 6000 ADT, entering town the road widens from 2 lane to 4 lane divided, and residents are more likely to walk compared to driving. A study is investigating whether the road is overbuilt.
Tradeoffs and Relevant Research	• Traffic flows and speeds versus safe pedestrian access. • RRFBs are not an ideal solution for low vision or blind individuals, as they need to listen to be sure a vehicle is stopping before crossing. • A challenge is cost and considering "percent conflict" between vehicles and pedestrians. For example, in a tribal area that is sparsely populated, 2000

Category	Minnesota DOT Input*

	ADT, with residences on one side of the highway and employment on the other side, MnDOT needs to consider when to apply a treatment and which treatment is best. RRFBs are intended to alert drivers at locations where pedestrians are not expected to be crossing, not where they are consistently crossing.
	• Notable MnDOT-sponsored Research:
	  ○ Guidelines for Safer Pedestrian Crossings: Understanding the Factors that Positively Influence Vehicle Yielding to Pedestrians at Unsignalized Intersections
	  ○ Pedestrian Crossings and Safety on Four Anishinaabe Reservations in Minnesota

Recommendations for Automobile Industry	• If vehicles can see road stripes, they should be able to detect pedestrians.

**Minnesota DOT input was provided by Sonja Piper during the interactive meeting.*

Table 3-4 Tennessee DOT Input

Category	Input from Tennessee DOT*

Guidance Used	• Resources used by Tennessee DOT (TDOT) for pedestrian crossing treatments:
	  ○ TDOT Standard Drawings
	  ○ TDOT Multimodal Design Guidelines – See section 3-405.10 for TDOT policy for uncontrolled locations.
	  ○ TDOT Multimodal Project Scoping Guide
	  ○ FHWA Guidance: Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations and FHWA STEP Resources
	• Traffic volume, crossing geometry, speed, and crash history are typically utilized to help make decisions on pedestrian crossing treatments.
	• TDOT has a program called Pedestrian Road Safety Initiative (PRSI) to assist with improving pedestrian safety. One of the biggest factors considered in this program is historical pedestrian crash data.

ITS Strategies	• RRFBs and PHBs have recently been deployed. Standards and guidance for these have recently been developed for TDOT in the standard drawings. • More specifically in terms of TDOT's ITS system, there has not been much consideration for uncontrolled pedestrian crossings. The current ITS system focuses heavily on freeway operations (e.g., cameras, DMS, radar, fiber). • TDOT is looking into acquiring video analytics software that can automatically detect and monitor vehicles. This software also has the

Category	Input from Tennessee DOT*
	capability to monitor vulnerable road users (VRUs), so that may be the best opportunity to incorporate the inclusion of pedestrians into its ITS system. • There are some situations in which ITS projects trigger ADA and when that is the case, crosswalks are added at signals. TDOT is not aware of any ITS strategies at non-intersection locations other than TDOT's PRSI.
Strategies for No Marked Crossings	• TDOT's Multimodal Access Grant (MMAG) is a state-funded competitive grant to support the transportation needs of pedestrians. These projects often add crossings where there were none before. PRSI often adds new crossings, and LiDAR will soon be used to help determine the best location to add a new crossing based on where people are crossing today. During paving projects, ADA is assessed, and curb ramps and crosswalks are often added where RRFB or PHB are not required as enhancements. Finally, during project reviews, the TDOT Local Programs & Community Investments Division contributes to the design as soon as a project begins and evaluates how safety and connectivity can be improved. • TDOT follows the Public Right-of-Way Accessibility Guidelines (PROWAG) and MUTCD definitions for a crosswalk. Crosswalks, whether marked or unmarked, must be made accessible which TDOT does and then evaluates if marking and enhancing is recommended.
Tradeoffs	• One big consideration is the preference of the local agency. This is especially true when installing a treatment like a PHB since the local agency would be responsible for maintaining it. In general, TDOT does not maintain any traffic signal or most of the installed traffic control devices within a city. If a city does not wish to maintain these systems, it could change what TDOT recommends. The local agencies may have concerns regarding the context of these pedestrian crossing treatments, for example, do their residents know how to interpret them. • Tradeoffs have included speed reduction and potential reduction of access. • In its PRSI planning reports, TDOT plans for the safest recommendations. Once the project moves into the design phase, if it is determined that the city is not willing to maintain a device such as a PHB, the agency looks to other alternatives. Only two PRSI projects have been constructed so far, so it remains to be seen how these treatments have changed driver traffic flow. The tradeoffs are often how to use funding effectively and the limited scope of the project that prevents safety features to be included.
Recommendations for Automobile Industry	• Connected and automated (CAV) technology is a significant consideration. For example, autonomous rideshare companies are utilizing various sensors, including LiDAR, to recognize pedestrians.

Category	Input from Tennessee DOT*
	• A culture change in the automobile industry (e.g., prioritizing safety over acceleration, agility, and speed of vehicles) is recommended. • Changes to vehicle size and configuration are recommended. Vehicles have become larger and offer more cameras to aid drivers in being aware of their surroundings. However, by keeping the front hood high, many children are at a higher risk of being hidden and if any person is hit, they are more likely to be moved beneath the vehicle instead of being hit and falling to one side. The new USPS mail carrier vehicles have been redesigned to reduce the severity of pedestrian collisions, a trend that if continued could improve vehicle safety.

**Tennessee DOT input was provided via email by Cam Morris and Will Rogers III after the interactive meeting. See also Section 3.3 and Section 3.4.*

Table 3-5 Wisconsin DOT Input

Category	Wisconsin DOT Input*

Guidance Used	• Wisconsin DOT (WisDOT) has the following guidance:
	  ○ Crosswalk Policy (WisDOT Traffic Engineering, Operations & Safety Manual (TEOpS) 3-2-3)
	  ○ Beacon Policy (WisDOT TEOpS 4-5-1)
	• WisDOT is working on a multimodal design guide that will be a chapter in the WisDOT Facilities Development Manual. This will be applicable for both state and local roads.
	• Crosswalks are typically installed at signals and school crossings. Crosswalks are not installed in urban areas where speeds are 45 mph or more unless an enhancement is included, such as additional signs or beacons. Non-intersection crosswalks are not allowed in rural areas with speeds of 45 mph or higher, but trail crossings can be an exception to this.
	• WisDOT does not install many high visibility markings (except for a safety issue, midblock, roundabouts) because of maintenance costs.

ITS Strategies	• The WisDOT beacon policy has a lot of data behind it. An uncontrolled crossing needs a minimum pedestrian volume of 20 or more during a single hour for a beacon treatment, which typically eliminates rural areas. Younger or elderly people count as two times toward the minimum volume. • Beacon types include blinker signs, standard flashing beacon, rapid flashing beacons (wig-wags), and RRFBs. • The WisDOT beacon policy favors RRFBs over PHBs, but PHBs can be considered for high traffic volumes or high pedestrian volumes. Very few PHBs are in place and some communities are removing them, as drivers are not familiar with them.

Category	Wisconsin DOT Input*
	• The WisDOT Pedestrian hybrid beacons web page information about PHBs, including videos that illustrate how a PHB operates. • There is a growing use of RRFBs. Wisconsin is a permit state and does not typically own the RRFBs. WisDOT has approval statewide to install RRFBs, and a memo was sent to all local agencies indicating they can install RRFBs if they agree to all MUTCD requirements. Not all communities are complying with this, therefore RRFBs are not being consistently implemented.
Strategies for No Marked Crossings	• Road diets are considered. • Wisconsin is a very rural state with several small communities and townships. If a safety issue exists, WisDOT will install a treatment but is not using risk-based metrics at this time. • WisDOT is starting to consider factors beyond reactive approaches such as setting safe speeds, pedestrian generators, land use, pedestrian types, and other proactive metrics. • The WisDOT ITS group tends to focus on freeway and expressway facilities compared to pedestrian facilities. • The WisDOT pavement marking budget has not increased in several years, which is a challenge with a desire to implement crosswalks and additional markings, but there is a lack of funding to maintain.

**Wisconsin DOT input was provided by Dan Brugman and Brian Porter during the interactive meeting.*

3.3 Gaps in Existing Guidance

After the round robin sharing by each State DOT, an open discussion focused on gaps in guidance for selecting pedestrian safety treatments at uncontrolled locations. Highlights from this discussion include:

- Not as much guidance exists for pedestrian traffic safety, compared to vehicle traffic. A lot of information is forthcoming (e.g., through National Cooperative Highway Research Program (NCHRP) project NCHRP 03-143: Framework and Toolkit for Selecting Pedestrian Crossing Treatments research) but there are still gaps in guidance. There is a need for guidance that reflects various land use types and population densities. There is also a need for guidance that is scalable, to deploy appropriate treatments in the appropriate locations. Proactive metrics are helpful, and this is a critical component to pedestrian safety.
- When a new technology or treatment comes out (e.g., RRFBs), WisDOT generally needs to know the impact on safety as the agency does not have a pilot program to deploy and test new technologies. The agency typically waits for other states to deploy and evaluate a new treatment and show the benefit before WisDOT deploys it. WisDOT has gone to more data-driven decisions (e.g., benefit/cost) with less use of engineering judgment. Therefore, if the supporting data doesn't exist, the improvement is harder to justify.

- It can be a challenge to coordinate pedestrian safety efforts with multiple groups across the agency. Every situation is unique and complex, therefore traffic safety professionals should be cautious of deploying a prescribed solution in every similar situation.

Input submitted by TDOT staff[1] pertaining to gaps in existing guidance includes:

- One gap is the consolidation of methods to select pedestrian crossing treatments. This was a topic from the panel for the NCHRP 03-143: Framework and Toolkit for Selecting Pedestrian Crossing Treatments research project. The NCHRP 03-143 project panel felt that it would be beneficial to develop a single framework and toolkit to assist with selecting appropriate pedestrian crossing treatments. The panel also felt that many of the methods did not consider factors such as pedestrian demand (rather than observed pedestrian volumes), demographics, land use context and other subjective factors -- the NCHRP 03-143 research aims to help provide this. This research also plans to recommend further MUTCD guidance for a future update.
- A gap is to determine if a full signal is safer for pedestrians at an intersection than a PHB. Pedestrian fatalities occur at mid-block locations and not at signals because there are not enough crossings, and signalized intersections have too many conflict points for a pedestrian to consider, especially if driver right-turn on red is allowed. The 20 Design Flags method is new, but this method only applies to intersections. An equivalent method for between intersections would be useful. See NCHRP Report 948: Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges (Kittelson & Associates, 2020) the 20 Design Flags method.
- An NCHRP research project that is exploring VRU crashes more thoroughly is NCHRP 07-35: Improving Crash Data for Active Transportation Users.

3.4 Urban Versus Rural Settings

Input provided by TDOT[1] regarding considerations for rural versus urban settings included:

- Urban applications seem to have the challenge of fitting into the context of their surroundings, coordinating with several other competing elements (business access, vehicle facilities, transit infrastructure, etc.), and having to adjust based on limited right of way and utility coordination. Rural settings often have the challenge of higher speeds, the lack of observed pedestrian volumes to support facilities, and the potential reluctance or inability of the local agency to maintain certain deployed treatments.
- TDOT recently developed a Project Scoping Guide which introduces five contexts: Urban Core, Urban, Suburban, Rural Town, and Rural. This will help TDOT improve safety for all road users based on what the community identifies as the design year context. For example, the context classification may be identified for 2050 and if this is different than the existing condition, the design year context is chosen which influences the facilities and roadway dimensions.

[1] *Input was provided via email by Cam Morris and Will Rogers III (both of TDOT) after the interactive meeting.*

- The TDOT PRSI program is data-driven, and the Multimodal Priority Tool uses four toolkits to determine where the hot spots are. These are typically in urban core, urban and suburban contexts. In rural areas, there are many opportunities to increase VRU safety like the TDOT MMAG grant program which often adds sidewalks. These grants are a huge help to rural areas where $1 Million goes a long way compared to their relatively smaller budgets.

3.5 Key Observations per Input from Traffic Safety Professionals

The interactive meeting with traffic safety professionals provided significant insight into the design practices, guidance used, challenges, and emerging considerations used by State DOTs when considering pedestrian safety treatments. Key observations from the interactive meeting are as follows:

State-specific guidance is common:

- Each state DOT indicated the use of state-specific guidance for selecting pedestrian treatments. Some agencies also use national guidance or noted that they are in the process of updating state guidance.
- Most guidance materials include common ITS treatments such as LED blinker signs, flashing beacons, RRFBs, and PHBs.

Key Observations

- State-specific guidance is common
- Deployment of ITS treatments is limited
- Selection considerations are changing
- Gaps in guidance exist
- Recommendations for the automobile industry include technology, vehicle design, and culture changes

Deployment of ITS treatments is limited:

- Participating agencies noted limited use of ITS treatments for improving pedestrian safety.
- The types of treatments installed can be influenced by the local agency's ability to maintain the treatment, at times making ITS treatments less likely to be deployed.
- When deploying ITS technologies that are "new" to a geographical area, it is important to educate drivers and pedestrians on their use. For example, some communities in Wisconsin are removing PHBs because drivers don't understand them. Pedestrians activating the flashing beacons on an RRFB may interpret this as a protected phase (similar to pedestrian crossing actuation at a traffic signal) and assume oncoming traffic is required to stop.
- Coordinating pedestrian safety efforts with multiple groups across the agency is a challenge. There is often limited interaction between the ITS group and other groups such as transportation planners, traffic engineering, traffic safety, and multi-modal functions.

Gaps in guidance exist:

- There is a need for guidance that reflects various land use types and population densities.
- A need exists for guidance that is scalable, to deploy appropriate treatments in the appropriate locations, reflecting multiple conditions and situations.

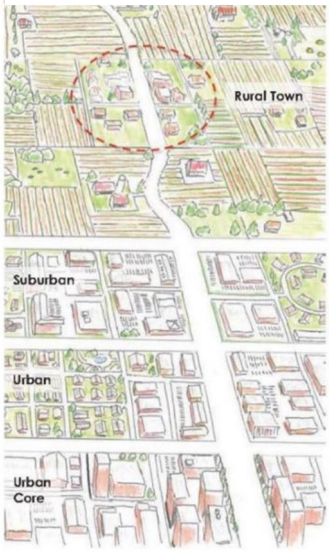
- There is a need for guidance that includes factors such as pedestrian demand (rather than observed pedestrian volumes), demographics, land use context, and other subjective factors.
- Additional design guidance specific to non-intersection locations is needed.
- Because every situation is unique and complex, traffic safety professionals should be cautious of deploying a prescribed solution for every similar situation.

Selection considerations are changing:

- When selecting pedestrian treatments, less emphasis is being placed on observed pedestrian volumes, as these can change over time especially when facilities are improved thereby generating additional pedestrian volumes.
- There is a trend toward considering multiple contexts to design and improve transportation facilities and consider pedestrians' needs in these contexts. The TDOT Project Scoping Guide introduces five contexts (Urban Core, Urban, Suburban, Rural Town, and Rural), and projects are scoped based on the community-identified design year context. The MnDOT Complete Streets approach incorporates a focus on land use and transportation hierarchy, incorporating equity metrics, latent demand, land use context, and other proactive safety metrics to apply improvements at the highest need locations. Figure 3.1 shows the five contexts included in the TDOT Project Scoping Guide. Figure 3.2 shows the context categories and baseline value for each user group by context in the MnDOT transportation hierarchy summary table.

- **Rural:** Areas with the lowest density, few houses or structures (widely dispersed or no residential, commercial, or industrial uses), and usually large setbacks.
- **Rural Town:** Areas with low density but diverse land uses with commercial main street character, potential for on-street parking and sidewalks, and small setbacks.
- **Suburban:** Areas with medium density, mixed land uses within and among structures (including mixed-use town centers, commercial corridors, and residential areas), and varied setbacks.
- **Urban:** Areas with high density, mixed land uses and prominent destinations, potential for some on-street parking and sidewalks, and mixed setbacks.
- **Urban Core:** Areas with highest density, mixed land uses within and among predominately high-rise structures, and small setbacks.

Figure 3-1 Context Classifications



Source: Figure 1-9, Highway System Access Manual. Originally from NCHRP Research Report 855 (1)

Figure 3.1 TDOT Context Classifications

Source: *TDOT Project Scoping Guide* (TDOT, 2024)

Context category	Walking	Bicycling	Transit	Autos	Trucks
Urban Core	High	High	High	Low	Medium
Urban Commercial	High	Medium	High	Low	Medium
Urban Residential	High	High	Medium	Low	Low
Suburban Commercial	High	High	Medium	Low	Low
Suburban Residential	High	High	Medium	Medium	Low
Industrial	Medium	Low	Low	High	High
Rural Crossroad	High	Medium	Low	High	Low
Rural	Medium	Low	Low	High	High
Natural	High	High	Low	Medium	High

Figure 3.2 MnDOT Transportation Hierarchy Summary Table

Source: *MnDOT Complete Streets Transportation Hierarchy Tool* (MnDOT, 2022)

- Overall, there is a movement toward consideration of land use contexts, pedestrian generators, demographics, and other subjective factors in selecting pedestrian crossing treatments, in addition to engineering factors (e.g., road configuration, traffic volumes, speed limit). The NCHRP 03-143: Framework and Toolkit for Selecting Pedestrian Crossing Treatments research project is underway to address this by developing a framework and toolkit for selecting pedestrian crossing treatments based on objective and subjective characteristics.

Recommendations for automobile industry include technology, vehicle design, and culture changes:

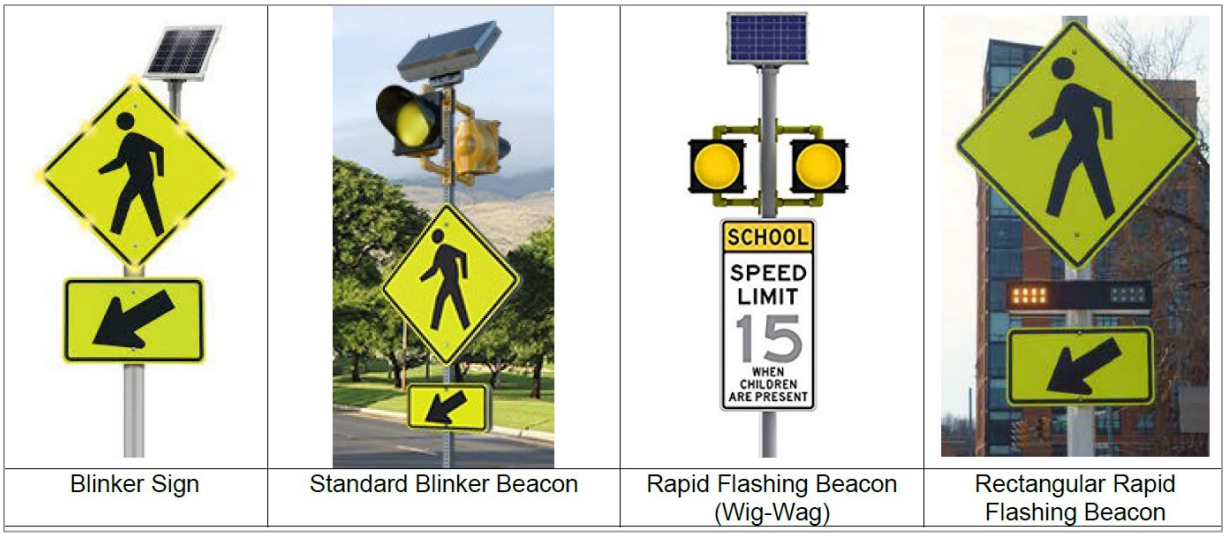
- Technology recommendations include vehicles with pedestrian detection and assistive braking, and detection that is effective in the dark since pedestrian fatalities are more prevalent at night.
- Changes to vehicle size and vehicle configuration are recommended to reduce the severity of vehicle-pedestrian collisions.
- A change in culture in the automobile industry was noted as a recommendation, to prioritize safety over acceleration, agility, and speed of vehicles.

Chapter 4: Potential Needs and Gaps in Guidance

After completing a review of guidance resources and the interactive meeting with traffic safety professionals, the information gathered was utilized to identify potential needs and gaps in existing guidance. Possible gaps and other needs (e.g., research, public education) are summarized in this section.

4.1 In-pavement Lights, Beacons, and Blinker Signs

While in-pavement lighting, flashing beacons on signs, and LED border/blinker signs are often included in state or local guidance resources, these ITS treatments are not included in leading national guidance (i.e., FHWA STEP resources). Furthermore, state and local guidance often includes design flexibility for applying these ITS treatments. For example, the WisDOT Beacon Policy provides four beacon types that may be used to enhance pedestrian and school warning signs: blinker sign, standard blinker beacon, rapid flashing beacons (wig-wags), and RRFBs. While the policy provides guidance for applying warning beacons based on pedestrian volumes, vehicular volumes, road lane configuration, distance to nearest crossing, and stopping distance, the policy provides some design flexibility in terms of which type of beacon is chosen. This design flexibility may not be a gap since it allows for engineering judgment and consideration of local contexts. See Figure 4.1 for the warning sign enhancement types included in WisDOT's Beacon Policy.



Blinker Sign	Standard Blinker Beacon	Rapid Flashing Beacon (Wig-Wag)	Rectangular Rapid Flashing Beacon

Figure 4.1 WisDOT Warning Sign Enhancement Options
Source: *WisDOT Beacon Policy* (WisDOT, 2018, TEOpS 4-5-1)

4.2 Comprehension of ITS Treatments and Public Education

The information gathered for this project suggests that additional research on driver and pedestrian comprehension of ITS strategies, especially when new to a geographical area, may be useful. Research and guidance on the use of public education strategies is also a possible gap. Though a comprehensive

review of literature was not conducted, the following recent studies provide insights on driver comprehension of ITS pedestrian treatments.

- An Evaluation of Driver Comprehension of the Pedestrian Hybrid Beacon (Caggiano et al., 2025): This study evaluated driver behavior and comprehension related to the use of PHBs in Massachusetts. Results indicated driver confusion and inconsistencies in comprehension across various PHB intervals. The research recommends additional and continued outreach and educational efforts to educate drivers about PHBs to improve driver comprehension.
- A MnDOT research study on Improving Pedestrian Safety on Reservations in Minnesota (Lindsey, 2024) found that pedestrian safety countermeasures (including ITS countermeasures) implemented on three Native American Reservations reduced risks and increased safety, but pedestrians and drivers did not always use the countermeasures as designed.
- Effectiveness of Rectangular Rapid Flashing Beacons (RRFBs) in Small and Rural Communities (Rowangould, Sullivan, & Pezeshknejad, 2023): This study utilized observational research design to evaluate RRFBs in small and rural communities in Vermont. Results suggest that RRFBs may improve the rate at which pedestrians step into the roadway before drivers yield, a possible indicator of pedestrian comprehension with RRFBs. See Figure 4.2 for a summary of findings from this research.

	RRFB effect on…	Prior literature	Difference-in-difference analysis	Multivariate modeling
Compliance outcomes	Driver yielding	Improve	Improve	Improve
	Pedestrian waiting time	No Data	Improve	Not significant
	Pedestrians crossing out of crosswalk	Improve	Improve	Improve
Safety-related outcomes	Driver stopping position	No Data	Unclear	Not significant
	Vehicles stopping suddenly	Improve (crashes)	Improve	Not significant
	Pedestrians stepping into the roadway before drivers yield	No Data	Unclear	May improve
Overall effectiveness	Outcomes in general contexts	Improve	No Data	No Data
	Outcomes in Vermont's small and rural communities	No Data	Improve	Improve
	Outcomes in both central and rural transition zones	No Data	Improve	Improve

Figure 4.2 Summary of Findings

Source: *Effectiveness of RRFBs in Small and Rural Communities* (Rowangould et al., 2023)

4.3 Guidance and ITS Treatments at Non-intersection Locations

Overall, there appears to be a lack of guidance for pedestrian design and safety treatments specific to uncontrolled non-intersection locations. There is also a lack of ITS treatments in guidance for uncontrolled approaches (i.e., locations not controlled by any sign, signal, marking, or other control devices).

Treatments that do exist for improving uncontrolled approaches may include adding a marked crossing (with additional non-ITS or ITS treatments), adding a grade-separated crossing, or directing pedestrians to the nearest crossing. In some cases, adding sidewalk(s) with a marked crossing may be appropriate.

Non-Intersection Locations

Non-intersection locations are inherently complex because of long distances spanning between intersections and the unpredictability of pedestrian crossing behavior.

Non-intersection locations are inherently complex because of long distances spanning between intersections and the unpredictability of pedestrian crossing behavior. Unique challenges exist at high-speed roadways and at locations that experience growth. When urban growth, land use changes, and roadway changes (e.g., higher traffic volumes, higher speeds) cuts off pedestrian access to activity generators, fewer options exist to accommodate pedestrian access. Higher speed road types are often not suitable for adding a marked crossing even with additional ITS treatments (e.g., beacons, RRFB, PHB) and the feasibility or cost of installing a grade-separated crossing may be prohibitive for an agency to implement.

Lastly, accommodating safe pedestrian access is based on many reactive and proactive metrics, and related guidance is not fully advanced though efforts are underway to address this. See Section 4.4 Scalable Guidance Using Multiple Contexts and Proactive Metrics.

4.4 Scalable Guidance Using Multiple Contexts and Proactive Metrics

A paradigm shift is occurring in the traffic safety community, relative to designing safe pedestrian access and determining pedestrian treatments at roadway crossings. Needs and gaps related to this shift include:

- There is a need for guidance that reflects a variety of land use types and population densities.
- A need exists for guidance that is scalable, reflecting multiple conditions and situations.
- There is a need for guidance that includes qualitative, proactive metrics such as pedestrian demand, land use context, demographics, latent demand, proximity to pedestrian generators, and other subjective safety metrics. NCHRP 03-143: Framework and Toolkit for Selecting Pedestrian Crossing Treatments research is underway to develop a framework and toolkit for selecting pedestrian crossing treatments based on objective and subjective characteristics and to propose new pedestrian warrants or guidance.

There is a need for scalable guidance that includes qualitative, proactive metrics such as pedestrian demand, land use context, demographics, latent demand, proximity to pedestrian generators, and other subjective safety metrics.

Though consistent guidance is useful, every situation is unique and complex. Therefore, traffic safety professionals are encouraged to assess each situation uniquely rather than applying a prescribed solution for every similar situation.

4.5 Emerging Technologies

There are numerous efforts to develop and research technologies to improve pedestrian safety with the use of vehicle-based technologies, mobile device applications, and infrastructure-based detection. These efforts have the potential to improve pedestrian safety, but gaps exist.

- Vehicle-based detection:
  - Pedestrian detection (e.g., camera sensors, radar, LiDAR) technologies are equipped on some vehicles to initiate warnings and automatic breaking. In 2024, the United States Department of Transportation's National Highway Traffic Safety Administration (NHTSA) finalized a Federal Motor Vehicle Safety Standard that will make automatic emergency braking (AEB), including pedestrian AEB, standard on all passenger cars and light trucks by September 2029. This safety standard is expected to significantly reduce rear-end and pedestrian crashes. (USDOT, 2024)
  - Though the 2024 NHTSA standard sets the stage for reducing pedestrian crashes, it will take additional time (beyond 2029) for pedestrian detection with AEB to be implemented on a majority of vehicles in operation in the United States.
- Mobile device applications:
  - In 2022, the ENTERPRISE PFS project Pedestrian Detection Systems for Improved Safety identified mobile device applications that communicate the presence of pedestrians to drivers, and vice versa. The TravelSafely™ mobile application and Visiblezone™ VRU safety solution product are examples of this technology. Figure 4.3 shows a screenshot of the Visiblezone™ application operating in a vehicle displaying the movement of a pedestrian toward the trajectory of the vehicle.

Figure 4.3 Viziblezone™ Safety Solution on Mobile Phone in the Vehicle
Source: *Detecting hidden pedestrian on a mobile phone* (Vizible Zone, n.d.)

  - These products appear to convey alerts to drivers and pedestrians. However, they require the pedestrian and the driver to simultaneously operate the same mobile application.

- Infrastructure-based detection:
  - Infrastructure-based pedestrian detection technologies can include detection-enabled cameras, infrared cameras, thermal imaging sensors, radar, or LiDAR. These technologies are increasingly being researched for their effectiveness in detecting pedestrians in light and dark conditions. Though current research is more commonly focused on at intersections, selected examples of research addressing pedestrian detection at midblock locations and other relevant studies.
  - Cameras: The study Assessment of Safety Benefits of Technologies to Reduce Pedestrian Crossing Fatalities at Midblock Locations tested the efficacy of camera technologies for detecting pedestrians at night. The test was conducted at unmarked, non-intersection locations and included two types of cameras (night vision PTZ camera and infrared camera). The test was conducted in a "dark not lit" condition and a "dark lit" condition that included a dark section of roadway that was lit with a vehicle headlight. The results indicated that for the "dark not lit" condition, the infrared camera outperformed the night vision PTZ camera. For the "dark lit with vehicle headlight" condition, the infrared camera and the night vision PTZ camera both performed well. (Ogle et al., 2020). See Figure 4.4 for a test result for a pedestrian in black clothes in a "dark not lit" condition.

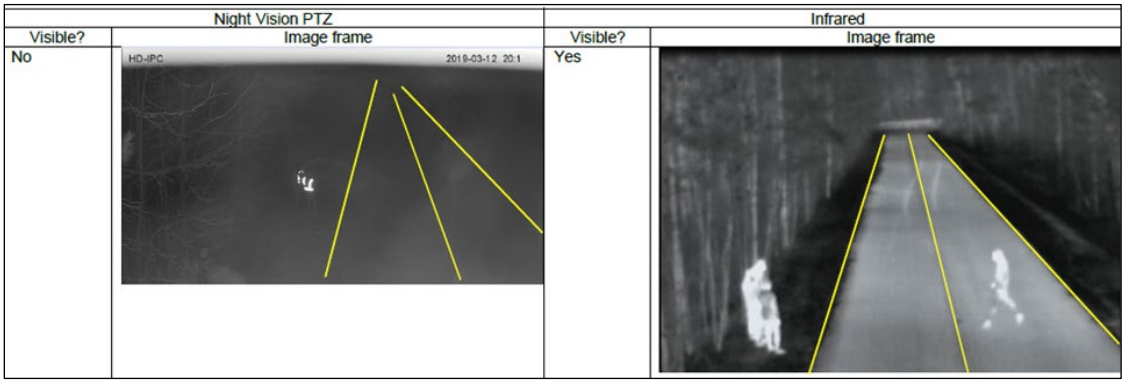


Figure 4.4 Test Result for Pedestrian in Black Clothes in "Dark Not Lit" Condition
Source: *Assessment of Safety Benefits of Technologies to Reduce Pedestrian Crossing Fatalities at Midblock Locations* (Ogle et al., 2020)

  - Cameras: A 2024 ITS America webinar Connectivity Solutions for Vulnerable Road Users: Let's have safer roads featured technologies for conveying VRU information to drivers. The webinar featured an effort at the University of Tennessee at Chattanooga that is utilizing mobile cameras for pedestrian detection with data collection for mobile safety analysis. The research utilizes mobile camera units to collect the number of pedestrian crossings and near misses at non-crosswalk locations. (Sartipi, 2024).
  - LiDAR: The study Enhancing Vulnerable Road User Detection and Volumetric Data Through Advanced Infrastructure Detection Technologies investigated infrared thermal imaging sensors and LiDAR sensors for VRU volumetric data collection at intersections and midblock crossings. The results indicated that while both sensors were able to detect VRUs at both midblock crossings and at intersections, positioning and placement of the

sensors may influence the performance of both types of sensors. (Calvo, Lee, Bowden, Jannat, & Eisert, 2025).

- LiDAR: A study on Pedestrian Detection with LiDAR Technology in Smart-City Deployments–Challenges and Recommendations concluded that when installing LiDAR sensors on poles, despite the advertising characteristics referring to the sensors having a range of up to 100 meters, great challenges exist for the automatic detection of objects at those distances. For an efficient detection in an outdoor scenario in an urban environment, as presented in this work, it is possible to detect pedestrians up to 15 meters away. Performance depends on sensor height and inclination, the vibration produced by the motor of the LiDAR, and wind conditions (due to pole movement). (Torres, Marques, & Marques, 2023) See Figure 4.5.

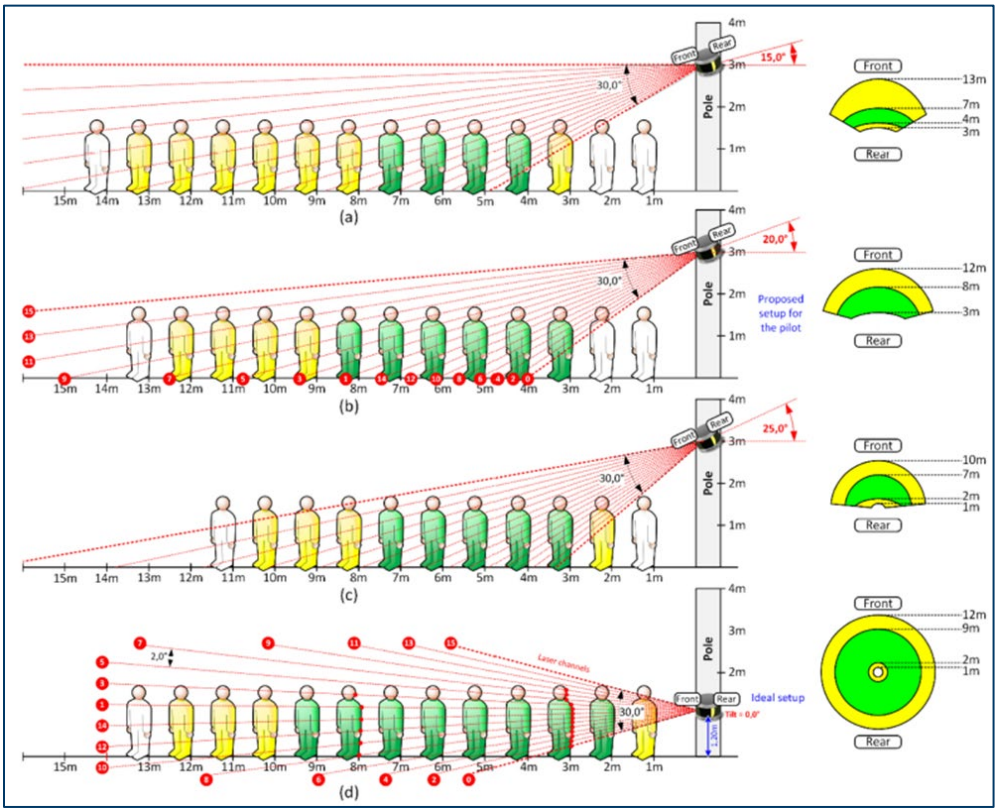


Figure 4.5 LiDAR Sensor Position and Impact on Pedestrian Classification and Area of Detection
Source: *Pedestrian Detection with LiDAR Technology in Smart-City Deployments–Challenges and Recommendations* (Torres et al., 2023)

- LiDAR: A study published by the Utah DOT, Utilizing LiDAR Sensors to Detect Pedestrian Movements at Signalized Intersections, explored state-of-the-art LiDAR technology to detect and track vehicles and pedestrians in real time at signalized intersections. The study used four LiDAR sensors mounted on traffic signal poles 20 feet above the ground, with fields of view as shown in Figure 4.6. The study recommended deploying up to four LiDAR sensors to cover typical intersections. (Li, Yang, & Liu, 2022)

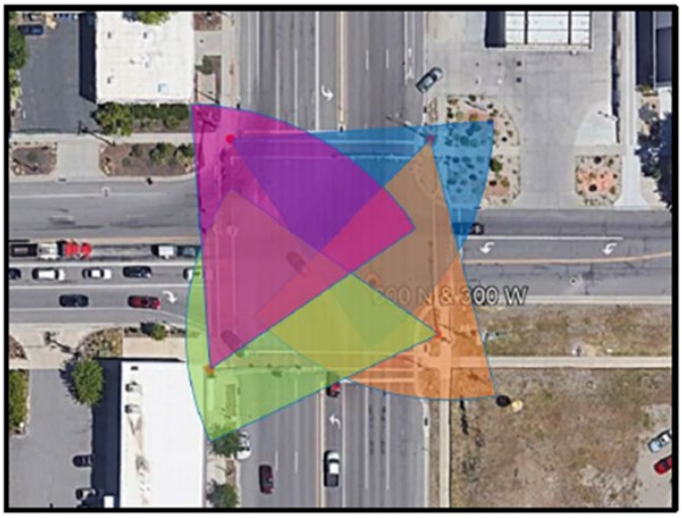


Figure 4.6 Fields of View for LiDAR Sensors Mounted on Traffic Signal Poles
Source: *Utilizing LiDAR Sensors to Detect Pedestrian Movements at Signalized Intersections* (Li et al., 2022)

- In reviewing these selected examples, there may be an opportunity to further deploy and test infrastructure-based pedestrian detection technologies, especially at locations with known safety issues.

Overall, there appears to be a gap in the development of technologies appropriate for non-intersection locations. Research and industry product development tends to be more focused on detection at signalized intersections, perhaps because these locations have infrastructure in place to accommodate equipment (e.g., detection-equipped cameras) installations. Because a majority of pedestrian fatalities occur at non-intersection locations, a case could be made for additional research and development of pedestrian safety technologies at non-intersection locations.

Chapter 5: Summary and Implementation

A significant increase in traffic-related pedestrian fatalities has occurred in the United States since 2010. Of particular concern are uncontrolled pedestrian crossings and uncontrolled approaches at non-intersection locations, as a majority of pedestrian fatalities occur at non-intersection locations. Several on-road ITS countermeasures are available to help address pedestrian safety. The objective of this research was to review existing guidance for deploying ITS countermeasures at uncontrolled pedestrian crossings and uncontrolled approaches, and to identify gaps and needs beyond the available guidance. The project completed a review of existing guidance, conducted an interactive meeting with state DOT traffic safety professionals, and identified potential gaps and needs.

5.1 Key Findings

Key findings include observations related to existing guidance and ITS countermeasures, potential needs and gaps, and a paradigm shift in pedestrian traffic safety considerations.

Existing Guidance and ITS Countermeasures: Many agencies utilize their own state or local guidance for selecting pedestrian treatments, along with national guidance such as the FHWA Safe Transportation for Every Pedestrian (STEP) resources. The guidance reviewed commonly includes ITS treatments such as blinker signs, flashing beacons, RRFBs, and PHBs. However, the interactive meeting with state DOT traffic safety professionals revealed limited deployment of ITS pedestrian safety treatments, inconsistency in application of ITS treatments, and hesitancy with the use of some ITS technologies (e.g., RRFBs and PHBs) because drivers and pedestrians may not be familiar with these treatments.

Potential Needs and Gaps: Though there are multiple national, state, and local guidance resources for selecting pedestrian countermeasures, gaps in guidance exist. Table 5-1 provides a summary of potential needs and gaps, including gaps in existing guidance, possible research, and public education needs. See Chapter 4: Potential Needs and Gaps in Guidance for detail regarding potential needs and gaps.

Table 5-1 Potential Needs and Gaps

Gap Area	Possible Gap
In-pavement Lighting, Flashing Beacons, and Blinker Signs	In-pavement lighting, flashing beacons on signs, and LED border/blinker signs are often included in state or local guidance resources, however these ITS treatments are not included in leading national guidance (e.g., FHWA STEP resources.) State and local guidance often includes design flexibility for applying these ITS treatments, and this may not be a gap since it allows for engineering judgment and consideration of local contexts.
Comprehension of ITS Treatments and Public Education	Additional research on driver and pedestrian comprehension of ITS treatments, particularly RRFBs, PHBs, and future technologies may be useful. Research and guidance on the use of public education strategies to improve comprehension is also a possible gap.

Gap Area	Possible Gap
Guidance and ITS Treatments at Non-intersection Locations	Overall, there appears to be a lack of guidance for pedestrian safety improvements specific to non-intersection locations. There is also a lack of on-road ITS pedestrian treatments for uncontrolled approaches (i.e., locations not controlled by any sign, signal, marking, or other control devices.) Non-intersection locations are inherently complex because of long distances between intersections and the unpredictability of pedestrian crossing behavior. Unique challenges exist at high-speed roadways and at locations that experience growth that cuts off pedestrian access to activity generators.
Scalable Guidance Using Multiple Contexts and Proactive Metrics	There is a need for guidance that is scalable, reflecting multiple conditions and situations. There is also a need for guidance that utilizes qualitative, proactive metrics such as pedestrian demand, demographics, land use context, latent demand, proximity to pedestrian generators, and other subjective characteristics to select pedestrian safety treatments. The NCHRP 03-143: Framework and Toolkit for Selecting Pedestrian Crossing Treatments research is developing a framework and toolkit for selecting pedestrian crossing treatments based on objective and subjective characteristics.
Emerging Technologies	Emerging technologies such as vehicle-based detection and mobile applications hold potential to improve pedestrian safety. However, these approaches often depend upon vehicles equipped with detection and CAV technology, or pedestrians and drivers simultaneously operating mobile applications. There may be an opportunity to further develop infrastructure-based pedestrian detection approaches such as cameras, radar, and LiDAR, especially at locations with known safety issues.
Interactions Among ITS, Traffic Safety, Transportation Planners, and Multimodal Groups	A gap was noted regarding interactions among ITS, traffic safety, and multimodal groups within transportation agencies. The interactive meeting with traffic safety professionals revealed that ITS groups tend to focus more on freeway deployments compared to pedestrian-related technologies. It would therefore be beneficial for transportation planners, traffic safety, multimodal, and ITS groups to increase interactions to learn from one another and explore pedestrian safety technologies.
Automobile Industry	Recommendations for the automobile industry from traffic safety professionals engaged in this project included additional vehicles with pedestrian detection and assistive braking, detection that is effective in dark conditions, changes to vehicle size and configuration to reduce the severity to pedestrians when a collision occurs, and an improved culture to prioritize vehicle safety.

Paradigm Shift in Pedestrian Safety: Numerous factors influence pedestrian traffic safety. The design of roadways with safe, pedestrian access is a highly specialized discipline performed by traffic safety professionals with expertise in traffic engineering and pedestrian safety. The considerations typically used

to select pedestrian crossing treatments include reactive measures such as distance to nearest crossing, vehicle and pedestrian volumes, roadway configuration, crash history, known safety issues, and even public requests. A paradigm shift is occurring toward the use of proactive metrics such as pedestrian demand (e.g., proximity to parks, schools, transit facilities, commercial areas or other activity generators), land use context, and population income or other demographics when designing roadways and selecting pedestrian safety treatments.

5.2 Implementation Plan

Transportation agencies can implement the results of this research in several ways. Recommended implementation steps for ENTERPRISE agencies could include the following:

1. Distribute this report to agency staff who are responsible for planning and designing pedestrian facilities and applying pedestrian safety treatments. Agency staff and groups who may benefit from the information in this report could include:
    - ITS managers and designers
    - Traffic engineers / traffic safety professionals
    - Multimodal groups (e.g., pedestrian, bicycle, transit)
    - Roadway designers
    - Transportation planners
    - District or region engineers who interact with local government agencies (e.g., cities, counties, municipalities) to plan and design roadway and pedestrian facilities
2. ITS groups within transportation agencies are encouraged to seek out and increase interactions with groups responsible for planning and designing pedestrian facilities and considering pedestrian safety treatments, for example transportation planners, traffic safety engineers, and multimodal groups, with the following in mind:
    - These interactions will allow these groups to exchange information, share expertise, and explore how ITS strategies may be utilized to improve pedestrian safety.
    - These interactions should be conducted regularly and become institutionalized in ongoing activities to foster continued progress as practices change and as staff turnover occurs.
    - These interactions should place an emphasis on considering ITS approaches, exploring solutions at mid-block locations, and understanding when public outreach is needed as new ITS technologies are deployed.
3. ITS professionals and traffic safety experts in State DOTs are encouraged to participate in national committees, groups, and research studies (e.g., NCHRP research) that focus on pedestrian safety, including connected and automated vehicle efforts. This integration of ITS with traditional traffic safety is an important aspect of research and knowledge transfer.
4. The ENTERPRISE Pooled Fund Study members and member agencies are encouraged to follow current research that is exploring emerging trends in pedestrian safety, for example:
    - NCHRP 03-143: Framework and Toolkit for Selecting Pedestrian Crossing Treatments
    - NCHRP 07-35: Improving Crash Data for Active Transportation Users

References

Alluri, P., Kadeha, C., Wu, W., and Kitali, A. 2020. Guidelines for Installing Pedestrian Treatments at Midblock Locations. Florida Department of Transportation. https://rosap.ntl.bts.gov/view/dot/59918.

Blackburn, L., Zegeer, C., and Brookshire, K. 2018. Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations. 2018. Federal Highway Administration Report FHWA-SA-17-072. https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-07/STEP_Guide_for_Improving_Ped_Safety_at_Unsig_Loc_3-2018_07_17-508compliant.pdf.

Caggiano, A., Pamarthi, J., Zafian, T.M., Deng, M.Y., Johnson, K., Tainter, F., and Knodler, M. 2025. An Evaluation of Driver Comprehension of the Pedestrian Hybrid Beacon. Journal of Safety Research. https://www.sciencedirect.com/science/article/pii/S0022437524001506.

Calvo, J., Lee, Y., Bowden, E., Jannat, M., and Eisert, J. 2025. Enhancing Vulnerable Road User Detection and Volumetric Data Through Advanced Infrastructure Detection Technologies. Federal Highway Administration FHWA-HRT-24-175. https://highways.dot.gov/media/58566.

City and County of Denver. 2022. Uncontrolled Pedestrian Crossing Guidelines. https://www.denvergov.org/files/assets/public/v/2/doti/documents/standards/doties-015.2-uncontrolled_pedestrian_crossing_guidelines.pdf.

East Central Wisconsin Regional Plan Commission. 2021. Action Plan for Implementing Pedestrian Crossing Countermeasures. Federal Highway Administration. https://www.ecwrpc.org/wp-content/uploads/2021/10/STEP-Action-Plan.pdf.

Federal Highway Administration (FHWA). 2018a. Pedestrian Hybrid Beacon (PHB). FHWA Countermeasure Tech Sheet SA-18-064. https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa18064.pdf.

Federal Highway Administration (FHWA). 2018b. Rectangular Rapid Flashing Beacon (RRFB). FHWA Countermeasure Tech Sheet SA-18-0695. https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-08/techSheet_RRFB_2018.pdf.

Federal Highway Administration (FHWA). 2023. Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) – 11th Edition. https://mutcd.fhwa.dot.gov/pdfs/11th_Edition/mutcd11thedition.pdf.

Florida Department of Transportation (FDOT). 2025. Traffic Engineering Manual. https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/traffic/trafficservices/studies/tem/tem-2025/2025-fdot-traffic-engineering-manual.pdf?sfvrsn=a7778316_1.

Kittleson & Associates. 2020. Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges. National Cooperative Highway Research Program (NCHRP) Report 948.

Accessed January 2025 from https://nap.nationalacademies.org/catalog/26072/guide-for-pedestrian-and-bicyclist-safety-at-alternative-and-other-intersections-and-interchanges.

Li, P., Yang, X., and Liu, C. 2022. Utilizing LiDAR Sensors to Detect Pedestrian Movements at Signalized Intersections. Utah Department of Transportation Report No. UT-22.26. https://rosap.ntl.bts.gov/view/dot/74624.

Lindsey, G. 2024. Improving Pedestrian Safety on Reservations in Minnesota. Minnesota Department of Transportation Research Summary. https://mdl.mndot.gov/items/202418rs.

Michigan Department of Transportation. 2022a. Best Design Practices for Walking and Bicycling in Michigan. Accessed in January 2025 from https://mdotjboss.state.mi.us/TSSD/getCategoryDocuments.htm?categoryPrjNumbers=1403862&category=Pedestrian/Bicyclist.

Michigan Department of Transportation. 2022b. Tools for the Planning and Design of Pedestrian Crossing Enhancements. Accessed January 2025 from https://mdotjboss.state.mi.us/TSSD/getCategoryDocuments.htm?categoryPrjNumbers=1403862&category=Pedestrian/Bicyclist.

Miner, K. and Arvidson, T. 2020a. Pedestrian Crosswalk Policy Development Guidelines. Minnesota Department of Transportation. https://mdl.mndot.gov/_flysystem/fedora/2023-02/2020ric01.pdf.

Miner, K. and Arvidson, T. 2020b. Uncontrolled Pedestrian Crosswalk Quick Reference Guide. Minnesota Local Road Research Board. https://mdl.mndot.gov/items/2020RIC01G.

Minnesota Department of Transportation (MnDOT). 2022. Complete Streets Transportation Hierarchy Tool. Accessed March 2025 from https://www.dot.state.mn.us/complete-streets/transportation-hierarchy-tool.html.

Montana Department of Transportation (MDT). 2019. Guidance for Determining Pedestrian Crossing Treatment at Uncontrolled Locations. Memorandum. https://www.mdt.mt.gov/other/webdata/external/cadd/design_memos/2019-11-01_Pedesterian_Crossing_Treatment_Guidance.pdf.

North Carolina Department of Transportation. 2018. Action Plan for Implementing Pedestrian Crossing Countermeasures at Uncontrolled Locations. Federal Highway Administration. https://connect.ncdot.gov/projects/BikePed/Documents/ncdot-step-action-plan.pdf.

Ogle, J.H., Islam, S., Brown, K.T., Mwakalonge, J., Michalaka, D., and Chowdhury, M. 2020. Assessment of Safety Benefits of Technologies to Reduce Pedestrian Crossing Fatalities at Midblock Locations. Center for Connected Multimodal Mobility (C^2M^2). https://rosap.ntl.bts.gov/view/dot/53588/dot_53588_DS1.pdf.

Petraglia, E. and Macek, K. 2023. Pedestrian Traffic Fatalities by State: 2022 Preliminary Data (January – December). Governors Highway Safety Association. https://www.ghsa.org/sites/default/files/2024-12/2022-ped-report.pdf.

Qi, Y., Fries, R.N., Zhou, H., Rab, A., and Baireddy, R. 2017. Establishing Procedures and Guidelines for Pedestrian Treatments at Uncontrolled Locations. Illinois Center for Transportation. https://www.eng.auburn.edu/files/centers/hrc/siu-fang-establishingprocedures-pedestrian.pdf.

Rowangould, D., Sullivan, J., and Pezeshknejad, P. 2023. Effectiveness of Rectangular Rapid Flashing Beacons (RRFBs) in Small and Rural Communities. Vermont Agency of Transportation. https://vtrans.vermont.gov/sites/aot/files/Research/Final_RRFB_Evaluation_March21_2023_0.pdf.

Sartipi, M. 2024, October 8. Connectivity Solutions for Vulnerable Road Users: Let's have safer roads. ITS America webinar. YouTube video at https://itsa.org/event/connectivity-solutions-for-vulnerable-road-users-lets-have-safer-roads/.

Schroeder, B. n.d. Framework and Toolkit for Selecting Pedestrian Crossing Treatments. NCHRP 03-143 [Active]. Accessible at: https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5125.

Tennessee Department of Transportation (TDOT). 2024. TDOT Project Scoping Guide. https://www.tn.gov/content/dam/tn/tdot/engineering-production-support/documents/project-scoping-guide/TDOT%20Project%20Scoping%20Guide%20September%202024.pdf.

Torres, P., Marques, H., and Marques, P. 2023. Pedestrian Detection with LiDAR Technology in Smart-City Deployments–Challenges and Recommendations. https://www.mdpi.com/2073-431X/12/3/65.

United States Department of Transportation (USDOT). 2024. NHTSA Finalizes Key Safety Rule to Reduce Crashes and Save Lives. https://www.transportation.gov/briefing-room/nhtsa-finalizes-key-safety-rule-reduce-crashes-and-save-lives.

Vermont Agency of Transportation (VTrans). 2019. Guidelines for Pedestrian Crossing Treatments. https://vtrans.vermont.gov/sites/aot/files/highway/documents/ltf/VTrans%20Ped%20Crossing%20Guide%20August%202019%20Update.pdf.

Virginia Department of Transportation. 2022. Pedestrian Crossing Accommodations at Unsignalized Approaches. https://www.vdot.virginia.gov/media/vdotvirginiagov/doing-business/technical-guidance-and-support/technical-guidance-documents/traffic-operations/TE-384.1_Pedestrian_Crossing_Accommodations_at_Unsignalized_Approaches_acc081622.pdf.

Vizible Zone. n.d. Detecting hidden pedestrian on a mobile phone. Accessed February 2025 from https://www.vizible.zone/automotive-viziblezone-protectingvehicles.

Washington State Department of Transportation. 2018. Action Plan for Implementing Pedestrian Crossing Countermeasures at Uncontrolled Locations. Federal Highway Administration. https://wsdot.wa.gov/sites/default/files/2021-11/WSDOT-STEP-ActionPlan_FINAL-Dec2018.pdf.

Wisconsin Department of Transportation (WisDOT). 2018. Traffic Engineering, Operations & Safety Manual (TEOpS) (Chapter 4-5). https://wisconsindot.gov/dtsdManuals/traffic-ops/manuals-and-standards/teops/04-05.pdf.

Wisconsin Department of Transportation (WisDOT). 2023. Traffic Engineering, Operations & Safety Manual (TEOpS) (Chapter 3, Section 2-3). https://wisconsindot.gov/dtsdManuals/traffic-ops/manuals-and-standards/teops/03-02.pdf#3-2-3.