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Selection of Pedestrian Crossing Treatments at Controlled and Uncontrolled Locations

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16. Abstract

Designers and traffic engineers have to make decisions on selecting a pedestrian treatment whenever designing a new pedestrian facility or retrofitting an existing one. The goal is either to provide or improve pedestrian safety at pedestrian crossing facilities, including controlled locations of signalized intersections and approaches with stop and yield signs, and uncontrolled locations of intersections and midblock sites. Currently, the Indiana Department of Transportation (INDOT) has limited resources on pedestrian treatment selection that does not take into consideration key elements such as number of lanes and the existence of a raised median. Therefore, there is a need to find a more detailed and comprehensive approach to providing guidelines when deciding on a pedestrian crossing treatment. The approach has to be practical and can be easily utilized by traffic and design engineers, planners, and other constituents.

Most of the State DOTs developed their guidelines on pedestrian crossing treatment based on several resources. However, the 2002 FHWA-RD-01-075 study titled "*Safety Effects of Marked Vs. Unmarked Crosswalks at Uncontrolled Locations*" was adopted by several states either "as is," with some modifications, or referenced as a source on pedestrian crosswalk selection. State DOTs mainly use standards and guidelines from the National MUTCD, Part 3 and NCHRP Report 672 for roundabout crosswalk markings. In general, there are no clear warrants for grade separation treatment. In addition, there is a need for a national and comprehensive study to develop practical guidelines on pedestrian crossing treatments, especially on multilane roadways, complex intersections, and when the speed is 45 mph or more.

This study proposed guidelines on crosswalk markings and treatment selection of pedestrian crossings based on a synthesis of federal and state reports, guidelines, design manuals, polices, and other relevant publications. It is recommended to adopt these guidelines as a reference for pedestrian treatment selection at INDOT.

The results of a survey on pedestrian crossing treatments indicate that the most effective and most frequently used treatments by the different states represented in the survey are advanced signs, crosswalk signs and pavement markings, countdown displays at signalized intersections, curb extensions, high-visibility signs and markings, and median refuge islands. The least effective and least frequently used treatments are automated detection, in-roadway warning lights, overhead flashing beacons (passive), pedestrian crossing flags, pedestrian railings, and split midblock signals. In addition, the main recommendation on high-speed divided highway pedestrian crossings is to provide enough time for pedestrian to cross the entire width of the intersection without a median whenever there is a demand.

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EXECUTIVE SUMMARY

SELECTION OF PEDESTRIAN CROSSING TREATMENTS AT CONTROLLED AND UNCONTROLLED LOCATIONS

Introduction

Designers and traffic engineers have to make decisions on selecting a pedestrian treatment whenever designing a new pedestrian facility or retrofitting an existing one. The goal is either to provide or improve pedestrian safety at pedestrian crossing facilities, including controlled locations of signalized intersections and approaches with stop and yield signs, and uncontrolled locations of intersections and midblock sites. Currently, the only source of pedestrian treatment selection for Indiana Department of Transportation (INDOT) is 51–7 O in the INDOT (2013) Design Manual. The information in the current is general, limited, and does not take into consideration key elements such as the number of lanes and the existence of a raised median. Therefore, there is a need to find a more detailed and comprehensive approach to providing guidelines when deciding on a pedestrian crossing treatment. The approach has to be practical and can be easily utilized by traffic and design engineers, planners, and other constituents.

Findings

Guidelines for the selection of pedestrian crossing treatments at controlled and uncontrolled locations have been recommended in this final report based on a review of the most updated federal and state reports, guidelines, design manuals, polices, and other relevant documents and resources on pedestrian crossing treatment selection.

The following is a summary of the findings:

- The National MUTCD and State MUTCD along with the corresponding state supplement(s) are the main sources of standards and guidelines on pedestrian treatment selection for all state DOTs.
- Some state DOTs have established standalone guidelines on pedestrian treatment selection; some have the guidelines as part of their traffic or design manual; and the rest either have limited information or information could not be found.
- Most of the State DOTs developed their guidelines based mainly on several FHWA, AASHTO, and ITE published studies and reports. However, the study by Zegeer, Stewart, Huang, and Lagerwey (2002) was adopted by several states either "as is," or with modifications, or referenced as a source on pedestrian crosswalk selection.
- Several cities in the US have developed their own guidelines on pedestrian crossing treatment selection.
- State DOTs use mainly standards and guidelines from the National MUTCD, Part 3, and a study by FHWA (2000) for roundabout crosswalk markings.
- There are no clear warrants for grade separation treatment. However, several states used the general guidelines in the AASHTO (2004) design guide or have established criteria for grade separation of path crossings for roadways. Arizona DOT, however, has established comprehensive criteria that must be satisfied to consider construction of a pedestrian grade-separated structure (ADOT, 2012).
- There is no unique or common procedure for selecting pedestrian crossing treatments at controlled and uncontrolled locations in the US.
- There is a need for a national and comprehensive study to develop practical guidelines on pedestrian crossing treatments, especially on multilane roadways, complex intersections, and when the speed is 45 mph or more.
- A survey was conducted online on pedestrian crossing treatments and high-speed divided highways and a total of 21 subjects completed the survey fully. The results of the survey indicate that the treatments most frequently used by the different states represented in the survey are advanced signs, crosswalk signs and pavement markings, countdown displays at signalized intersection, high-visibility signs and markings, curb extensions, and median refuge islands. The least frequently used treatments include in-roadway warning lights, pedestrian railings, overhead flashing beacons (passive), split midblock signals, and pedestrian crossing flags.
- The top choices among all subjects for future treatments were countdown displays at signalized intersection, crosswalk signs and pavement markings, high-visibility signs and markings, and median refuge islands. The least frequently selected treatments for future projects were in-roadway warning lights and pedestrian crossing flags.
- The top five most effective pedestrian treatments ranked by subjects are countdown displays at signalized intersections, crosswalk signs and pavement markings, median refuge islands, high-visibility signs and markings, and curb extensions. The bottom five pedestrian treatments are overhead flashing beacons (continuous), overhead flashing beacons (passive), split midblock signals, in-roadway warning lights, and pedestrian crossing flags.
- In the case of high-speed divided highways, the majority of subjects (82%) reported that they will consider providing adequate pedestrian timings to cross the entire highway length. In addition, 73% of the subjects do not believe the delays caused by providing the pedestrian timing is a major concern.
- The main recommendations on providing pedestrian timings to cross the entire high-speed divided highway length were to provide enough time to cross the entire width of the intersection without a median whenever there is a demand. The feedback on the concern of creating considerable vehicular traffic delay when treating high-speed divided highways with adequate pedestrian timings indicates that safety trumps reasonable delay where pedestrian demand is not high.
- On the issue of having a refuge island built with curbs, which are not typically used on high-speed roadways with speeds equal to or greater than 50 mph, the results of the survey showed a split vote on the recommendation of a refuge island in the median: 6 out of 10 (60%) said yes and 4 (40%) said no. The results suggested that a maximum speed limit, where a refuge island is not feasible, should be site specific and in the range of 40–45 mph. In addition, it is recommended either to let pedestrians cross the entire length at one time or, if possible, to provide grade separation for pedestrian crossings.

Implementation

The recommended Guidelines for Marking Crosswalks and Treatments Selection of Pedestrian Crossings in this study provide information on the installation of marked crosswalks at controlled and uncontrolled locations. INDOT engineers can use the proposed guidelines as a source for selecting appropriate treatment for existing and new pedestrian crosswalks. A workshop will be arranged in the near future and after the approval of the final report to disseminate the findings of the project to INDOT engineers, planners, and other constituents.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY

AADT	Average Annual Daily Traffic: the average number of vehicles during a 24-hour period collected every day of a certain year, expressed in vehicles per day (vpd)
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
ADAAG	Americans with Disabilities Act Accessibility Guidelines
ADT	Average Daily Traffic: the total volume of traffic collected over a given period of time that is greater than one day and less than a year divided by the number of days in the time period
Controlled Location	Intersection or midblock crossing location with a traffic signal or stop sign
FHWA	Federal Highway Administration
ITE	Institute of Transportation Engineers
Midblock Crossing	A pedestrian crossing located between two intersections
MUTCD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
Uncontrolled Location	Intersection or midblock crossing without a traffic signal

1. INTRODUCTION

1.1 Background

Designers and traffic engineers have to make decisions on selecting a pedestrian treatment option to improve pedestrian safety at all pedestrian crossings at signalized and unsignalized intersections, midblock, roundabouts, trails and/or bikeway crossing roadways on a regular basis. Adding to the challenge are the safety requirements set by the Americans with Disabilities Act (ADA) for pedestrians who are visually impaired. This safety issue is of a particular concern at roundabout crossings. Currently, the only source of recommended treatment used by INDOT is Figure 51-7 O in the Indiana Department of Transportation (INDOT) Design Manual shown in Figure 1.1 (INDOT, 2013).

The current table provides limited information for traffic and design engineers. Therefore, there is a need to find a more detailed and comprehensive approach to provide guidelines when deciding on a pedestrian crossing treatment. The approach has to be practical and one that can be easily utilized by traffic and design engineers, planners and other constituents.

1.2 Methods of Crossing Treatments

Treatment methods are many and include, in addition to traditional traffic and pedestrian signals, marked crosswalks, signing, raised median islands, road diets or lane reductions, Pedestrian Hybrid Beacons, High-intensity Activated cross-Walk (HAWK) signals, etc. Some factors impacting the decision of selecting a treatment option include, but are not limited to, type (controlled or uncontrolled), pedestrian and traffic volumes, speed, number of lanes, crossing length, location (intersection, midblock, roundabout), demographic characteristics, cost, and expected behavior, including the understanding of the intended behavior of pedestrians and drivers. In addition, design elements at crossings vary and include elements such as signing, type of crosswalk markings, illumination, signage, use of raised medians or pedestrian islands, one-stage or two-stage crossing, traffic signals with different pedestrian options if warranted, overpasses, and underpasses.

Motor-Vehicle Speed	AADT	Intersection Treatment
50 mph	Any	Grade Separation (Good)
		Traffic Signal and 40-mph Speed Zone (Satisfactory)
45 mph	Any	Grade Separation (Good)
		Traffic Signals (Satisfactory)
40 mph	≥7,000	Grade Separation (Good)
		Traffic Signals (Satisfactory)
	<7,000	Traffic Signals (Good)
		Crosswalk and Median Refuge Island (Satisfactory)
30 mph	≥9,000	Grade Separation (Good)
		Traffic Signals (Satisfactory)
	5,000 ≤ AADT <9,000	Traffic Signals (Good)
		Crosswalk and Median Refuge Island (Satisfactory)
	<5,000	Crosswalk and Median Refuge Island (Good)
		Crosswalk (Satisfactory)

Figure 1.1 Recommended treatment of shared-use path and roadway intersection (INDOT Design Manual Figure 51-7 O).

TABLE 1.1
Pedestrian, Bicyclists, and Other Cyclists Fatalities in Indiana, 2007–2012

		Pedestrian		Bicyclist & Other Cyclist		Total	
Year	All	Number	%	Number	%	Number	%
2007	898	60	7%	13	1%	73	8%
2008	815	60	7%	16	2%	76	9%
2009	692	55	8%	7	1%	62	9%
2010	754	62	8%	14	2%	76	10%
2011	749	63	8%	13	2%	76	10%
2012	779	64	8%	14	2%	78	10%

1.3 Pedestrian Safety at Crossings

Most pedestrian crashes and some bicyclist crashes occur at pedestrian crossings. As shown in Table 1.1, pedestrian fatalities in Indiana have been consistent and constitute around 8% of the total traffic fatalities between 2007 and 2012. Bicyclist and other cyclist fatalities make up around 2% of the total traffic fatalities during the same period (INDOT, 2012).

Figure 1.2 shows a comparison of individual county pedestrian and pedalcyclist fatality rates in Indiana to the rates of fatalities in all US counties in 2011 (NHTSA, 2012). The rates are based on the number of fatalities per 100,000 population. There are 24 counties that have pedestrian fatalities of which five counties are ranked among the highest third in the US, seven in the middle third, and eleven in the lower third. Similarly, there are nine counties with pedalcyclist fatalities of which two are ranked in the top third, five in the middle third, and two in the lower third when compared to fatalities in all US counties.

1.4 Problem Statement

Traffic engineers face a challenge when making decisions on selecting a pedestrian treatment plan to improve safety at pedestrian crossings. There are several elements to consider when selecting treatment that may include: type, pedestrian and traffic volumes, speed, number of lanes, crossing length, location, demographic characteristics, cost, and expected behavior, and federal and state policies and standards such as the Americans with Disabilities Act of 1990 (ADA) and the national Manual on Uniform Traffic Control Devices of 2009 (MUTCD). INDOT designers and engineers refer mainly to the Indiana Design Manual (IDM) and the 2011 Indiana MUTCD for guidance. However, these publications do not provide answers to all cases. Therefore, there is a need to develop guidelines to help in selecting a pedestrian crossing treatment. The guidelines will be based on synthesis of the federal and state reports, guidelines, design manuals, polices, and other relevant documents and resources.

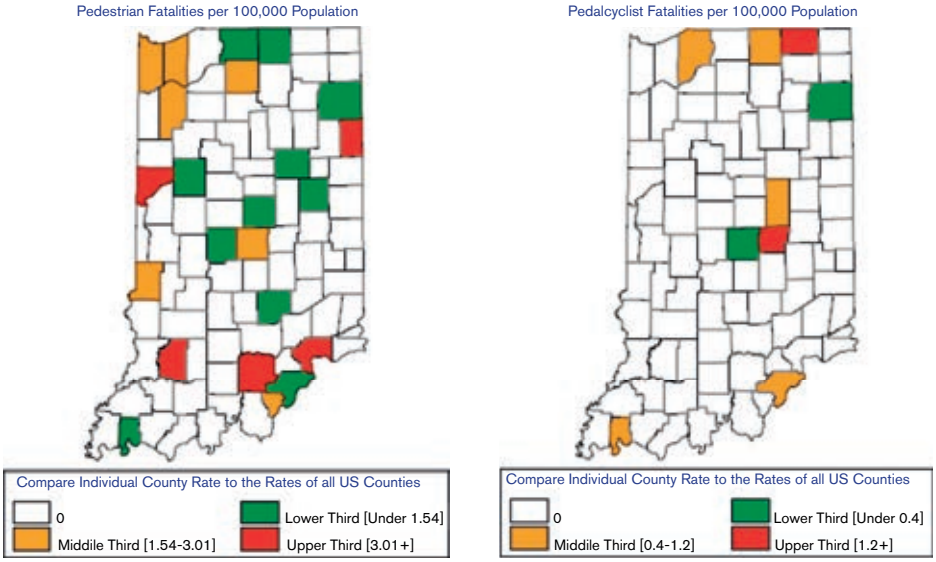


Figure 1.2 Pedestrian and pedalcyclist fatalities per 100,000 population in Indiana 2011.

1.5 Research Objective

The objective of the research is to recommend guidelines for pedestrian treatments selection to provide INDOT designers and traffic engineers with practical tool when considering pedestrian crossing treatment options. The guidelines are developed based on a synthesis of federal and state reports, guidelines, design manuals, polices and the results of a questionnaire answered mainly by State DOT traffic and design engineers.

1.6 Research Methodology

The study approach was based on the following two steps in order to achieve the goals of the project:

1. Review the most updated federal and state reports, guidelines, design manuals, polices, and other relevant documents and resources on pedestrian crossing treatments selection.
2. A questionnaire developed and sent to State DOT's and other transportation agencies on their practice and guidelines on selecting pedestrian crossing treatments.

1.7 Organization of the Report

The first chapter introduces the background of the research, methods of crossing treatments, pedestrian safety at crossings, problem statement, and research objectives and methodology. The second chapter summarizes the results of the literature search conducted in this research. The third chapter presents the proposed Guidelines for Marking Crosswalks and Treatments of Pedestrian Crossing. The fourth chapter presents the survey results on pedestrian crossing treatments and on high-speed divided highway. The fifth chapter has the conclusions and recommendations of the study.

2. LITERATURE REVIEW

The literature review was conducted on federal and state reports, guidelines, design manuals, and policies. In addition, the review included manuals and guidelines of selected cities in the US. The following is the summary of the findings that are unique or worth highlighting and usually beyond the information found in the National MUTCD (2009) edition which is referred to as the National MUTCD in this report. The researcher attempted to review all relevant documents pertaining to this research; however, some relevant information may have been unintentionally overlooked due to the massive amount of material reviewed in this research.

2.1 US State Departments of Transportation Manuals

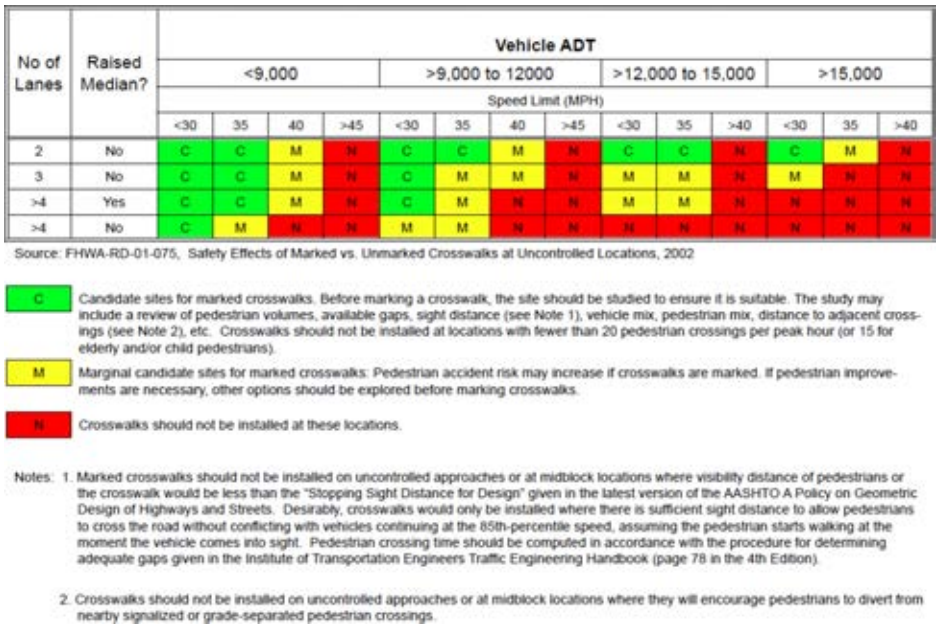
2.1.1 Alabama

The Alabama Department of Transportation (ALDOT) has adopted the National MUTCD along with the *Traffic Signal Design Guide & Timing Manual* (Sullivan & Jones, 2007) as the primary sources for guidelines and standards on pedestrian crossing treatment selection. The traffic manual states that a pedestrian crosswalk should be considered at signalized intersections where pedestrian facilities such as sidewalks exist, locations with 20 or more pedestrians crossing per hour regardless of sidewalk presence, and may be installed at locations with or without pedestrian signal heads. A crosswalk, however, may not be installed, in order to discourage pedestrian crossing, at locations where pedestrian volumes are low or pedestrian crossing conditions are not safe (Sullivan & Jones, 2007).

2.1.2 Alaska

The Alaska Department of Transportation and Public Facilities (AKDOT, 2012) has adopted the National MUTCD along with the State supplement as the primary sources for standards and guidelines on pedestrian crossing treatment selection.

The selection of crosswalk marking at uncontrolled approaches or at midblock locations is based on four elements: number of lanes, median type, average daily traffic



No of Lanes	Raised Median?	Vehicle ADT													
		<9,000				>9,000 to 12000				>12,000 to 15,000			>15,000		
		Speed Limit (MPH)													
		<30	35	40	>45	<30	35	40	>45	<30	35	>40	<30	35	>40
2	No	C	C	M	N	C	C	M	N	C	C	N	C	M	N
3	No	C	C	M	N	C	M	M	N	M	M	N	M	N	N
>4	Yes	C	C	M	N	C	M	N	N	M	M	N	N	N	N
>4	No	C	M	N	N	M	M	N	N	N	N	N	N	N	N

Source: FHWA-RD-01-075, Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations, 2002

C — Candidate sites for marked crosswalks. Before marking a crosswalk, the site should be studied to ensure it is suitable. The study may include a review of pedestrian volumes, available gaps, sight distance (see Note 1), vehicle mix, pedestrian mix, distance to adjacent crossings (see Note 2), etc. Crosswalks should not be installed at locations with fewer than 20 pedestrian crossings per peak hour (or 15 for elderly and/or child pedestrians).

M — Marginal candidate sites for marked crosswalks: Pedestrian accident risk may increase if crosswalks are marked. If pedestrian improvements are necessary, other options should be explored before marking crosswalks.

N — Crosswalks should not be installed at these locations.

Notes: 1. Marked crosswalks should not be installed on uncontrolled approaches or at midblock locations where visibility distance of pedestrians or the crosswalk would be less than the "Stopping Sight Distance for Design" given in the latest version of the AASHTO A Policy on Geometric Design of Highways and Streets. Desirably, crosswalks would only be installed where there is sufficient sight distance to allow pedestrians to cross the road without conflicting with vehicles continuing at the 85th-percentile speed, assuming the pedestrian starts walking at the moment the vehicle comes into sight. Pedestrian crossing time should be computed in accordance with the procedure for determining adequate gaps given in the Institute of Transportation Engineers Traffic Engineering Handbook (page 78 in the 4th Edition).

2. Crosswalks should not be installed on uncontrolled approaches or at midblock locations where they will encourage pedestrians to divert from nearby signalized or grade-separated pedestrian crossings.

Figure 2.1 ADOT&PF recommendations for crossing treatment selection at uncontrolled locations (AKDOT, 2012).

(ADT), and speed limit as shown in Figure 2.1 (AKDOT, 2012). This table is part of a study by Zegeer et al. (2002b) and its final report (Zegeer et al., 2005).

ADOT&PF has slightly modified the original table presented in the report by adding recommendations for speed limit of 45 mph or more. In addition, the table has M (Marginal) to replace P (Possible) in the original report which stands for *"P = Possible increase in pedestrian crash risk may occur if crosswalks are added without other pedestrian facility enhancements."* This procedure has been used by other states and cities and will be presented later in this report; and will be referred to as the Zegeer et al. (2002b) study.

2.1.3 Arizona

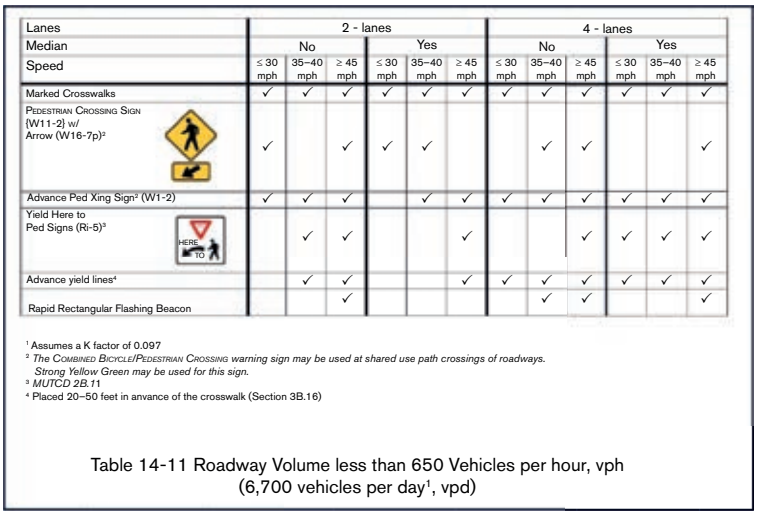
The Arizona Department of Transportation (ADOT) has adopted the National MUTCD along with the State supplement, the AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities (2004), and Roadway Design Guidelines* (ADOT, 2012) as the primary sources for standards and guidelines on pedestrian crossing treatment selection. The ADOT manual has the specific requirements for grade separation structures. The *Roadway Design Guidelines* states:

- *"Established pedestrian patterns should be maintained across highway routes. If adjacent vehicular crossings are inadequate for the type and age of pedestrians, then grade separation structures should be considered.*
- *To warrant construction of a pedestrian grade structure, all six of the following criteria must be satisfied:*
  a. *High vehicular volumes conflict with high pedestrian volumes, constituting an extreme hazard; and*
  b. *Modification of school routes, busing policies, campus procedures, or attendance boundaries to eliminate the need for a crossing is not feasible; and*
  c. *Physical conditions make a grade separation structure feasible from an engineering standpoint, including pedestrian channelization to insure usage of the structure; and*
  d. *Pedestrian movements can be restricted for at least 600 ft on each side of the proposed overpass; and*
  e. *A demonstrated problem exists that simpler, more economic solutions have failed to remedy; and*
  f. *The anticipated benefits to be derived from the overpass clearly outweigh the costs.*
- *Pedestrian overcrossings are the preferred type of grade separation structure. If conditions are unfavorable for an overcrossing, undercrossings may be provided with special attention given to safety issues including width, lighting, visibility, drainage and entrance/exit conditions."*

2.1.4 Colorado

The Colorado Department of Transportation (CDOT) has adopted the National MUTCD with the State MUTCD supplement and the *CDOT Roadway Design Guide* (2005) as the primary sources for standards and guidelines on pedestrian crossing treatment selection. Chapter in this guide has statutes for signalized, unsignalized, midblock, and roundabout crossings (CDOT, 2005).

The *CDOT Roadway Design Guide* (2005) states that marked crosswalks should be installed at signalized intersections that have sidewalks. In addition, the pedestrian crossing at uncontrolled crossings should be treated as midblock crossings. The manual provides a comprehensive guide for traffic control treatment at uncontrolled and midblock crossings. The guidelines are based on vehicle volume, number of lanes, presence of median, and speed. This approach is based in part on the recommendations in the Zegeer et al. (2002b) study. The treatment selection is based on the ADT, number of lanes, presence of median, and speed. The ADT is classified into three tiers: low (<6,700 vpd), medium (6,700–12,000 vpd), and high



Lanes	2 - lanes						4 - lanes					
Median	No			Yes			No			Yes		
Speed	≤ 30 mph	35–40 mph	≥ 45 mph	≤ 30 mph	35–40 mph	≥ 45 mph	≤ 30 mph	35–40 mph	≥ 45 mph	≤ 30 mph	35–40 mph	≥ 45 mph
Marked Crosswalks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pedestrian Crossing Sign (W11-2) w/ Arrow (W16-7p)[2]	✓		✓	✓	✓			✓	✓			✓
Advance Ped Xing Sign[2] (W1-2)	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Yield Here to Ped Signs (Ri-5)[3]		✓	✓			✓			✓	✓	✓	✓
Advance yield lines[4]		✓	✓			✓	✓	✓	✓	✓	✓	✓
Rapid Rectangular Flashing Beacon			✓					✓	✓			✓

[1] Assumes a K factor of 0.097
[2] *The Combined Bicycle/Pedestrian Crossing warning sign may be used at shared use path crossings of roadways. Strong Yellow Green may be used for this sign.*
[3] *MUTCD 2B.11*
[4] Placed 20–50 feet in anvance of the crosswalk (Section 3B.16)

Table 14-11 Roadway Volume less than 650 Vehicles per hour, vph
(6,700 vehicles per day[1], vpd)

Figure 2.2 CDOT recommendations for crossing treatments for low volume of vehicles at uncontrolled locations (FDOT, 2007).

(>12,000 vpd). There are guidelines for each tier. Figure 2.2 shows the guidelines for treatment selection for low-traffic volume. The complete guidelines are presented in Appendix A.

2.1.5 Florida

The Florida Department of Transportation (FDOT) has adopted the National MUTCD, *Florida Department of Transportation Plans Preparation Manual* (2014a), *Florida Intersection Design Guide* (2007), and *Traffic Engineering Manual* (2014b) as the primary sources for the design and treatment selection of their pedestrian facilities.

The FDOT Traffic manual lists the following factors that should be taken into account when considering a midblock crosswalk installation (FDOT, 2014a, 2014b):

1. The existence of pedestrian generators and attractors that create a minimum pedestrian demand of 20 pedestrians during any hour of four consecutive 15-minute periods; or 60 pedestrians during any consecutive or non-consecutive 4 hours of the day. However, minimum pedestrian volume should not be considered at school crossings.
2. The roadway should have a minimum ADT of 2,000 vpd.
3. Spacing between adjacent intersections shall be at least 660 feet and spacing between the midblock crosswalk and the nearest intersection or crossing location shall be at least 300 feet. In addition, there should be no influence of adjacent signalized intersections on the proposed location.
4. The stopping sight distance shall be adequate and meet the requirement of the MUTCD Table 6C-2.
5. The midblock crosswalks shall meet the ADA requirement for cross slope and grade criteria along the crosswalk.
6. The midblock crosswalks shall be supplemented with a median or crossing island where the crossing distance is more than 60 feet.
7. The crosswalk should be illuminated.

An engineering study should be conducted at uncontrolled locations before installing a midblock crosswalk. The Traffic Engineering Manual section on midblock pedestrian crossing treatments is present in Appendix B (FDOT, 2014b).

FDOT has developed Figure 2.3 and Figure 2.4 to provide guidelines for installing pedestrian treatments on low-speed and high-speed roadways. The figures were developed based on Figure 4C-7, Figure 4F-1, and Figure 4F-2 in the MUTCD (FDOT, 2014b).

2.1.6 Georgia

The Georgia Department of Transportation (GDOT) has adopted the National MUTCD, and the GDOT *Guidance on Marking Crosswalks* (2007) to provide guidelines for controlled and uncontrolled intersections. For controlled intersections, the following guidelines are listed:

a. At signalized intersections, marked crosswalks should be placed across all approaches that have adequate ADA and pedestrian accommodations/displays. Limited right-of-way and other limiting factors may not allow adequate pedestrian access.
b. At all-way stops, marked crosswalks should be placed across all roads where there is sidewalk, or any evidence of pedestrian movement (such as worn paths on the roadside, transit stops, adjacent land uses that generate pedestrian trips—schools, parks, retail, dense residential development, etc.).

For uncontrolled intersections, the guidelines recommend installing crosswalks, and any enhancement that may be required in accordance with the recommendations of the Zegeer et al. (2002b) study. At uncontrolled midblock locations, installing crosswalks or any enhancement should be considered based on the particulars of each case and engineering study.

The GDOT *Design Policy Manual* (2014) states that installing signals at all existing unsignalized or new intersections should be in accordance with MUTCD warrants. GDOT adopted NCHRP Report 672 section 6.8.1 for its statutes on roundabout crossings (TRB, 2010).

2.1.7 Hawaii

The Hawaii Department of Transportation (HDOT) has adopted the National MUTCD and the *Hawaii Pedestrian*

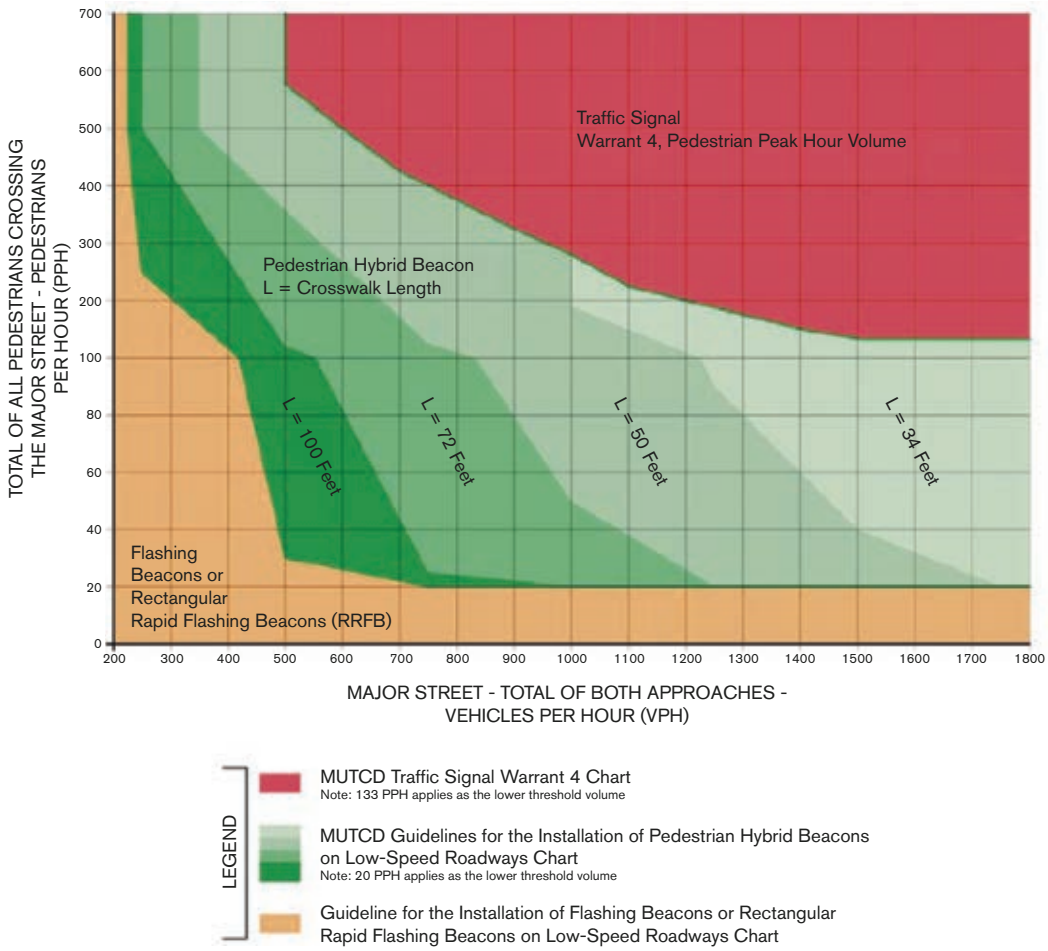


Figure 2.3 Guidelines for the installation of pedestrian treatments on low-speed roadways of 35 mph or less (Figure 2.8.4 in FDOT, 2014b).

Toolbox (2013) as the primary sources for standards and guidelines on pedestrian crossing treatment selection. The HDOT preference is to use the ladder-style crosswalk at stop-controlled or signalized intersections. However, the guidelines recommends the use of marked crosswalks with other pedestrian safety measures on multi-lane roadways with an average daily traffic (ADT) of 12,000 or more in accordance with the Zegeer et al. (2002b) study. Safety measures may include the installation of stop or yield signs, signals, or raised medians (HIDOT, 2013). Signalization should be based on an engineering study and in accordance with the MUTCD. Pedestrian signals should be installed at all locations where a traffic signal is installed except at locations where pedestrian crossing is not allowed. For unsignalized crossing, the manual recommends the use of Pedestrian Hybrid Beacons (HAWK Signal) in accordance with the MUTCD. Other treatments presented in the Toolbox include Pedestrian Actuated Signals, Audible Devices, Curb Bulb-Outs and Extensions, Medians and Center Refuge Islands, and Right-Turn Lanes/Slip Lanes.

The installation of midblock crossings should be based on a detailed engineering study if it is at a location other than an existing stop/yield sign or traffic signals. The HDOT Toolbox adopts the guidelines in the ITE (1998) manual for installing a midblock crossing. These guidelines are summarized in Figure 2.5.

In general, the Toolbox recommends the use of marked crosswalks and signs. Markings, stop or yield signs, signalization, pedestrian hybrid beacons, pedestrian actuated buttons, refuge islands, curb extensions, and/or signs with or without flashing lights should be considered at marked midblock crosswalks with four-lane roadways and an ADT of 12,000 or more.

Figure 2.6 shows the recommendations of HDOT Toolbox on using traffic control treatments for pedestrian crossing of four or more lanes. The use of midblock pedestrian actuated signals, warning beacons, and advance warning signs should be in accordance with the MUTCD (HIDOT, 2013).

Roundabouts are addressed with reference to study by FHWA (2000). In summary, it is recommended to have the sidewalks installed on the entire outer edge of the intersection. The crossings should be installed on all approaches and be located no less than 20 ft from the outside edge of the roundabout roadway and use splitter islands.

2.1.8 Idaho

Section 800 of the Idaho Department of Transportation Traffic Manual covers pedestrian protection (ITD, 2012b).

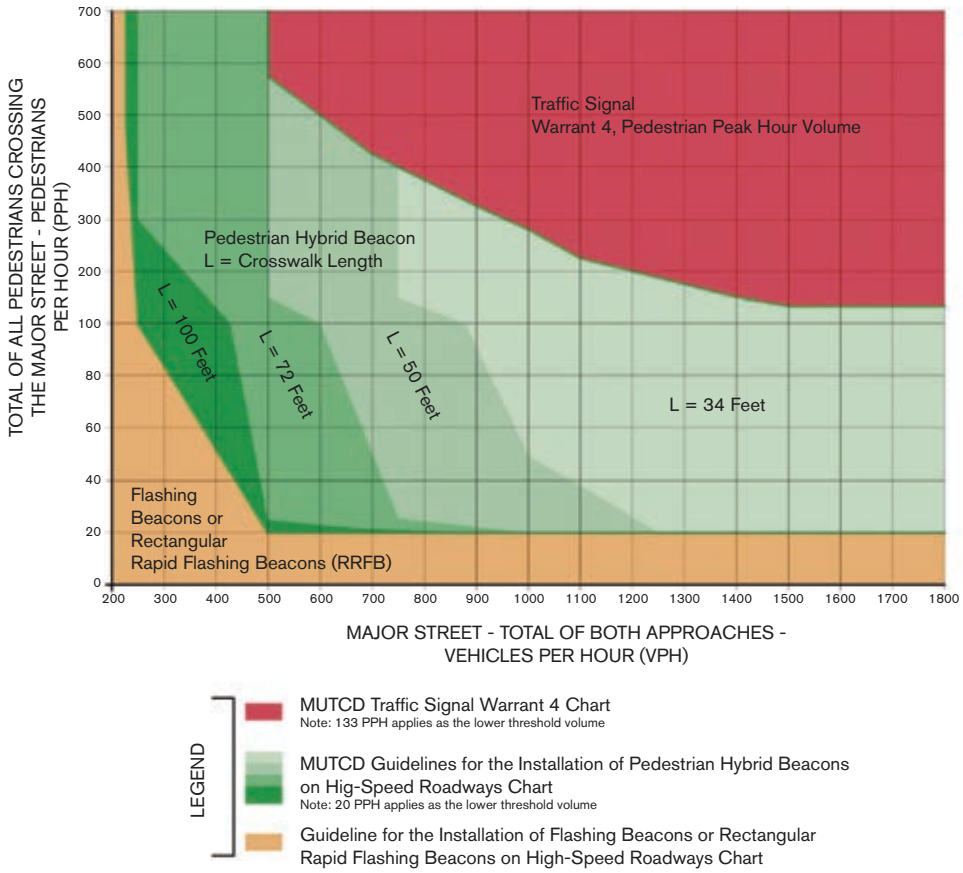


Figure 2.4 Guidelines for the installation of pedestrian treatments on low-speed roadways of 40 mph or more (Figure 2.8.5 in FDOT, 2014b).

The manual states that pedestrian crosswalks are not always necessary at all intersections in urban residential areas with frequent intersections. The manual does not recommend the use of midblock crosswalks in urban areas due to disruption of traffic and increasing conflict between traffic and pedestrians (ITD, 2012a).

School crossings should be warranted according to the MUTCD signal warrants. The manual recommends using a pedestrian gap study following the ITE handbook or similar methods to test the warrant. The manual has placed restrictions on the use of intersection-type flashing beacons at school crossings. However, it is recommended as an

EXHIBIT 5.28 Where and Where Not to Locate Mid-Block Crossings

LOCATE MID-BLOCK CROSSINGS	AVOID LOCATING MID-BLOCK CROSSINGS
• Where significant pedestrian crossings and substantial pedestrian/vehicle conflicts exist; should not be used indiscriminately.	• Mid-block crosswalks should generally be avoided under the following circumstances (unless they are stop controlled):
• Where the crossing can serve to concentrate or channelize multiple pedestrian crossings to a single location.	— Immediately downstream (less than 300 feet) from a traffic signal or bus stop where motorists are not expecting pedestrians to cross (Knoblauch et. al.);
• At approved school crossings or crossings on recommended safe routes to schools.	— Within 600 feet of another crossing point (Knoblauch et. al.), except in central business districts or other locations where there is a well-defined need. The recommended minimun separation is 300 feet;
• Where land uses create high concentrations of pedestrians needing to cross (such as residential areas across from retail or recreation, and transit stops across from residential or employment).	— On multi-lane streets with no refuge; and
• Where pedestrians could not otherwise recognize the proper place to cross or there is a need to delineate the optimal location to cross.	— On streets with speed limits above 45 mph.

Figure 2.5 HDOT recommendations for identifying midblock locations (HIDOT, 2013).

EXHIBIT 5.36 Suggested Traffic Control Treatments on Four (or More) Lane Road Crossings

SPEED OF AVG DAILY TRAFFIC ON ROADWAY (85%)	<10,000 ADT	10,000–19,999 ADT	20,000+ ADT
<=35 mph (60 kph)	Refuge area, preferably protected	Protected Refuge or Signal	Signal or grade separated
>=40 mph (60 kph)	Protected Refuge or Signal	Signal	Signal or grade separated

Source: Florida Pedestrian Planning and Design Handbook

Figure 2.6 Traffic control treatments at midblock locations of four lanes or more (ITD, 2012a).

effective advanced warning sign when the school crossing is difficult to recognize and where heavy pedestrian traffic exists (ITD, 2012a).

2.1.9 Illinois

The Illinois Department of Transportation (IDOT) has adopted the National MUTCD and the Illinois supplement to the MUTCD in reference to pedestrian treatments (IDOT, 2014). The *Illinois Bureau of Design & Environment Manual* (IDOT, 2013) has recommended the use of an engineering study to determine the need for and proper location of crosswalks at signalized and unsignalized locations. Examples of locations where crosswalks should be used are points of significant pedestrian concentration, signalized and unsignalized intersection approaches, and traffic stops that channelize pedestrians into identified corridors. The chapter has a lengthy discussion of bike path intersections. It is recommended to have a bicycle path crossing at a highway far away from the highway intersection with other streets. However, the bike pathway can utilize the existing intersection for dual use as shown in Figure 2.7.

2.1.10 Indiana

The guidelines and standards on pedestrian crossing treatment selection by the Indiana Department of Transportation (INDOT) are derived from the Indiana MUTCD with Revision 1 and the Indiana Design Manual (INDOT, 2013). The manual has recommendations on the treatment of shared-use path and roadway intersection as shown in Figure 1.1 (INDOT, 2013).

2.1.11 Louisiana

The manuals used in reference to pedestrian treatments by the Louisiana Department of Transportation and Development (LADOTD) are the National MUTCD and *Traffic Engineering Manual* (LaDOT, 2012). The traffic manual addresses in detail the installation of marked crosswalks at controlled and uncontrolled approaches at an intersection, a midblock and a school. The manual requires a traffic engineering study to make sure that the criteria and warrants are met at the approach under consideration. The LADOTD requirements for installing and not installing crosswalks are listed in Appendix C.

2.1.12 Maine

The State of Maine Department of Transportation (MaineDOT) has adopted the National MUTCD and the *Highway Design Guide, Volume I* (2004) to address pedestrian treatment issues. The manual states that all crosswalks shall meet the latest standards and ADA criteria. The design guide has 12 restrictions on installing the crosswalks including: (1) crosswalks should not be installed where the speed limit is higher than 35 mph; and (2) the minimum distance of 500 feet should exist between crosswalks.

2.1.13 Maryland

The Maryland Department of Transportation (MDOT) has adopted the Maryland MUTCD and ADA guidelines for pedestrian treatments as stated in the *Accessibility Policy & Guidelines for Pedestrian Facilities along State Highways* manual (Maryland SHA, 2010) as the primary sources for standards and guidelines on pedestrian crossing treatment selection. At the beginning of this research MDOT used to have a report titled *Maryland SHA Bicycle and Pedestrian Design Guidelines* (Maryland SHA, n.d.). Currently, this report is no longer published on the MDOT website. Chapter 10 of this

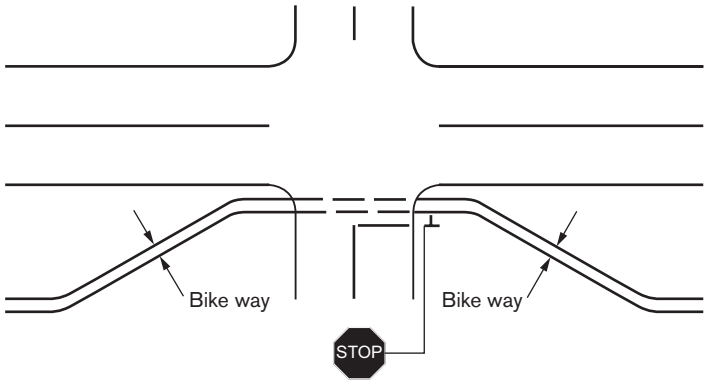


Figure 2.7 Shared bicycle/pedestrian crossing (IDOT, 2013, Fig. 17-2.II).

Table 6-1. Mid-Block Crossing Treatment Design Criteria (*Charlotte DOT, 2005*).
**Note: MUTCD recommends pedestrian volumes of at least 400 for a four-hour period. **A HAWK (High-Intensity Activated Crosswalk) signal is a pedestrian-activated system used for high-volume crossings found to be useful in increasing the rate of driver responses to pedestrian crossings, especially in Tucson, AZ where they have been utilized extensively."*

Pedestrian Mid-block Crossing Treatment	AADT	Operating Speed	Approx. Cost
Signs	5,000 – 35,000	Less than 45 mph	$250 – 350
High-Visibility Markings	5,000 – 12,000	Less than 35 mph	$500 – 1,500
Colored and Textured Markings	5,000 – 12,000	Less than 35 mph	$5,000+
Curb Extensions	5,000 – 12,000	Less than 35 mph	$5,000 – 25,000
Raised Crosswalks	5,000 – 15,000	Less than 30 mph	$2,000 – 15,000
Refuge Island	12,000 – 30,000	Less than 40 mph	$10,000 – 40,000
Median	15,000 – 35,000	35 – 45 mph	Varies greatly
In-Pavement Illumination	5,000 – 15,000	Less than 35 mph	$40,000
Pedestrian-Only Signal*	15,000 – 35,000	35 – 45 mph	$40,000 – 75,000
HAWK Signal**	15,000 – 35,000	35 – 45 mph	$35,000 – 60,000

Figure 2.8 Design criteria for midblock pedestrian crossing treatment (NCDOT, 2007).

report addresses roadway crossing design and it recommends treatment in accordance with the Zegeer et al. (2002b) study.

2.1.14 Massachusetts

The Massachusetts Department of Transportation (MassDOT) has adopted the National MUTCD, the State supplement *Massachusetts Amendments to the 2009 MUTCD,* and the *Highway Design Guide, Volume I* (2006) to address pedestrian treatment issues. The design guide has a provision on grade and interchange separation.

2.1.15 Michigan

The primary sources of standards and guidelines on pedestrian crossing treatment selection at the Michigan Department of Transportation (MDOT) are *Michigan Manual on Uniform Traffic Control Devices*, *Traffic and Safety Note 401D* (MDOT, 2012) for the evaluation of uncontrolled non-motorized crosswalks, the *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities* (AASHTO, 2004), *PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System* (Zegeer et al., 2013), and *Pedestrian Facilities User Guide–Providing Safety and Mobility* (Zegeer et al., 2002a).

2.1.16 New York

The New York Department of Transportation (NYSDOT) has adopted the National MUTCD along with the New York State Supplement NYS MUTCD, and the *Highway Design Manual (HDM)* (2014) as the primary sources for standards and guidelines on pedestrian crossing treatment selection.

For uncontrolled locations, the manual adopts the procedure listed in the Zegeer et al. (2002b) study. However, the speeds are listed in km/hr and rounded up to the nearest number. The HDM lists the following factors when deciding on the location and design details of the midblock crossing:

> *distance between signalized crossings, vehicle operating speeds, frequency and duration of crossable gaps at adjacent intersections with concurrent phasing, availability of pedestrian refuge islands, the locations of pedestrian trip generators (including transit stops), and the percentage of pedestrians who are elderly, disabled, and/or children. (NYSDOT, 2014)*

2.1.17 North Carolina

The primary sources of standards and guidelines on pedestrian crossing treatment selection at the North Carolina Department of Transportation (NCDOT) are the National MUTCD, the *North Carolina Supplement to the MUTCD*, the most updated NCDOT Roadway Standard Drawings, and specific standards set by the department such as the Standard Practice for Crosswalk-Midblock (Unsignalized).

The NCDOT has started the Bicycle and Pedestrian Planning Grant Initiative in order to help local municipalities create a comprehensive bicycle and pedestrian plan. NCDOT provides access to samples of well-prepared bicycle and pedestrian plans (NCDOT, n.d.). Section 6 in the *Hertford Comprehensive Pedestrian Plan* provides details on the best practices of pedestrian design standards and guidelines (NCDOT, 2007). The report adopted the City of Charlotte guidelines shown in Figure 2.8.

2.1.18 Oregon

The Oregon Department of Transportation (ODOT) has adopted the National MUTCD along with the *Oregon Supplement to the Manual on Uniform Traffic Control Devices*, *ODOT Highway Design Manual* (HDM) (2012),

and *ODOT Traffic Manual* (2013) as the primary sources for standards and guidelines on pedestrian crossing treatment selection.

The ODOT general criteria for establishing marked crosswalks on State highways include the following provisions: all school crossings and signalized approaches at intersections must have marked crosswalks; urban roundabouts shall have marked crosswalks at all approaches, and marked crosswalks may be installed at intersection approaches which have a stop sign, at channelized right-turn lanes, or at rural roundabouts (Oregon DOT, 2013). The manual has criteria for several treatments including marking school crossing at uncontrolled locations, in-street pedestrian crossing sings, pedestrian activated warning lights, textured/colored crosswalks, and others. The manual calls for an engineering study to make sure installing marked crosswalks are warranted.

However, the manual recommends that marked crosswalks should be avoided at uncontrolled approaches unless additional safety measures are included in the installation. The manual requires that the approach meets the following criteria before installing a marked crosswalk: speed limit should be 40 mph or less, ADT should be 10,000 or less unless a raised median is included, and curb extensions and/or pedestrian refuge areas should be considered on multilane highways. Similar criteria are set for marked crosswalks at midblock locations. The manual established polices on additional treatments including Flashing Beacons (warning, speed limit sign, and stop beacons), Rectangular Rapid Flashing Beacons (RRFB) and Textured Crosswalks. The HDM recommends installing pedestrian median refuges especially when crossing length is more than 6 lanes (Oregon DOT, 2012). ODOT has adopted the NCRHP Report 672 for roundabouts (TRB, 2010).

2.1.19 Pennsylvania

The primary sources of standards and guidelines on pedestrian crossing treatment selection at the Pennsylvania Department of Transportation (PennDOT) are the National MUTCD, the Pennsylvania supplement to the MUTCD, and the *Traffic Engineering Manual* (PennDOT, 2014).

PennDOT has eleven warrants for traffic signals. The first nine warrants are exactly as defined in Part 4 of the MUTCD. PennDOT requires a gap acceptance study in order to justify installing a signal under Warrant 5. The study should be in accordance with the ITE publication titled *School Trip Safety Zone Guidelines* (1985). PennDOT's additional two warrants are called Warrant PA-1 Volume Warrant and Warrant PA-2 Optional Traffic Signal Warrant for Midblock Crossings and Trail Crossings. Both warrants are presented in Appendix D (PennDOT, 2014).

The traffic manual is cautious on the use of the crosswalks at unsignalized midblock locations. The manual refers to an uncited recent survey of state traffic engineers where it is stated that "midblock crosswalks are highly discouraged in their state and are rarely installed. Currently, only a few states have any warrants or guidance for midblock crosswalks." The manual lists a set of minimum requirements for new midblock installations. The PennDOT additional signal warrants and the minimum requirements for new midblock installations are shown in Appendix D (PennDOT, 2014).

2.1.20 Utah

The Utah Department of Transportation (UDOT) criteria for pedestrian crossing treatments can be found in the *Utah Manual on Uniform Traffic Control Devices for Streets and Highways* (UDOT, 2009), *UDOT Roadway Design Manual of Instruction* (UDOT, 2011), and the *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities* (AASHTO, 2004), and other documents such as traffic standard drawings. The considerations for sidewalks and signalized intersections at UDOT are: crosswalks are at least 10' wide and prominently marked using appropriate style markings for location, pedestrian signals pushbuttons are provided, pushbuttons should be accessible, maximize pedestrian visibility at crossings from the motorist's point of view, and proper selection of lighting type and placement.

The *UDOT Roadway Design Manual of Instruction* (2011) lists the following conditions to warrant grade-separated pedestrian crossings:

1. *Heavy pedestrian movements such as at central business districts, factories, schools, or athletic fields*
2. *Moderate to high pedestrian demand to cross a highway, or freeway*
3. *A large number of young children, particularly on school routes who regularly cross a high-speed or high-volume roadway*
4. *Streets with high vehicular volumes and high pedestrian crossing volumes and crossings are extremely hazardous for pedestrians.*

2.1.21 Vermont

The primary sources of standards and guidelines on pedestrian crossing treatment selection at the Vermont Agency of Transportation (VTrans) are the National MUTCD (2009 edition), *Guideline for the Installation of Crosswalk Markings and Pedestrian Signing at Marked and Unmarked Crossings* (VTrans, 2002), and *Vermont Pedestrian and Bicycle Facility Planning and Design Manual* (VTrans, 2004).

VTrans *Guidelines* has details on marked crosswalks at controlled intersections, including signalized intersection and stop and yield sign intersection controls. VTrans recommends the use of Zegeer et al. (2002b) study for appropriate crossing treatments of uncontrolled crossings at intersections and midblock locations. The manual recommends the use of treatments at midblock crossings based on a set of criteria listed in the design manual. These treatments are: curb extensions; marked with highly visible crosswalks such as block, ladder, or diagonal markings; angling the crossing in the refuge islands and medians; midblock pedestrian-actuated signals as needed based on the number of available adequate gaps on high speed/volume and/or roadways with four lanes or more; raised midblock crossings; flashing beacons, advance warning signs and pedestrian crossing signs; and illumination.

2.1.22 Virginia

The Virginia Department of Transportation (VDOT) main sources for pedestrian crossing treatments include the National

MUTCD along with the state supplement, and *Guidelines for the Installation of Marked Crosswalks* (VDOT, 2005). The guidelines manual is comprehensive and has recommendations for crosswalk markings at controlled, uncontrolled, and unconventional intersection locations including T and offset intersections and intersections at hills and curves. The following sections summarize the key points in the manual (VDOT, 2005).

In general, pedestrian crosswalks should be installed at locations and approaches with significant pedestrian activity. In addition, crosswalks should not be used extensively so pedestrians utilize them fully and pedestrians stay alert to their presence. A marked crosswalk may be installed when the following conditions exist:

1. At controlled locations with a stop sign or signal in order to prevent vehicles from blocking pedestrian traffic.
2. At uncontrolled locations where an engineering study recommends installing a pedestrian crosswalk in order to keep traffic and pedestrians safe and mobile.
3. On recommended school routes or at approved locations of school crossings.

However, pedestrian crossings may not be considered at all approaches of controlled locations when conflict exists between pedestrians and right- and/or left-turn movement especially on multilane suburban arterials with wide, high speed and traffic volume. This issue could be addressed by adding extra measures such as pedestrian signals, protected pedestrian phasing, refuge medians, and/or slip lane refuge islands to make pedestrian crossing safe at these locations. Details on special treatments at controlled intersections can be found in the manual (VDOT, 2005).

Pedestrian crossing should be prohibited under limited conditions including locations where crossing is very dangerous due to an obstruction that limits feasibility and cannot be removed; the existence of many installed crosswalks in the area has no major adverse impact on pedestrian mobility.

Installation of marked crosswalks at uncontrolled approaches of intersections and midblock locations should be only considered after conducting an engineering study that takes into consideration posted speed limit, ADT, pedestrian visibility, number of lanes and the geometry of the location (VDOT, 2005). The following conditions should exist before installing a marked crosswalk:

1. Sufficient demand exists when either of the following conditions exists:
   a. Pedestrian demand is at least 20 pedestrians per hour during the peak hour, 15 elderly and/or children per hour, or a total of 60 pedestrians total for any consecutive 4-hour period; or
   b. The crossing exists on the route to or from a major pedestrian generator such as school, shopping center, hospital, and other similar facilities.
2. The distances should be at least 300 feet from nearby controlled or uncontrolled crossing locations.
3. Sufficient sight distance exists or has improved before installing the crosswalk marking.
4. In case a safety issue is a concern, a procedure based on the Zegeer et al. (2005) study should be used to identify possible treatments required to ensure safe crossing at controlled intersections. The Zegeer et al. (2002b) and VDOT (2005) procedures are presented in Appendix E.

2.1.23 Washington

The Washington State Department of Transportation (WSDOT) main sources for pedestrian crossing treatments include the National MUTCD and the supplement of *Washington Modification,* WSDOT *Design Manual* (2013), and *Traffic Manual* (2011).

The design manual states that "*all Washington State highways are distinguished as being either limited access or managed access highways*." Pedestrian crossing is allowed either when grades are separated or at-grade when the following conditions exist:

1. Meet the design criteria for crossing facilities listed in the manual including but not limited to shortening crossing distance and minimizing running radii to maintain low speeds.
2. On two-lane highways:
   a. at mailbox locations.
   b. at a distance of at least 100 feet from a school bus loading zone, if stopping in the traveled lane is dangerous.
   c. On two-lane highways where the school bus is stopped on the traveled lane to load or unload passengers and the required sign and signal lights are displayed.

Figure 2.9 lists the WSDOT recommendations for crosswalk marking and enhancement guidelines.

The WSDOT design manual recommends pedestrian-grade separations where (WSDOT, 2013):

- *There is moderate-to-high pedestrian demand to cross a freeway or expressway.*
- *There are large numbers of young children, particularly on school routes, who regularly cross high-speed or high-volume roadways.*
- *The traffic conflicts that would be encountered by pedestrians are considered unacceptable (such as on wide streets with high pedestrian volumes combined with high-speed traffic).*
- *There are documented collisions or close calls involving pedestrians and vehicles.*
- *One or more of the conditions stated above exists in conjunction with a well-defined pedestrian origin and destination (such as a residential neighborhood across a busy street from a school).*

2.1.24 Wisconsin

The Wisconsin Department of Transportation (WisDOT) main sources for pedestrian crossing treatments include the National MUTCD along with the *Wisconsin Supplement to the Manual on Uniform Traffic Control Devices, Wisconsin Bicycle Facility Design Manual* (WisDOT, 2004b), *Traffic Guidelines Manual* (WisDOT, 2004a), and *Wisconsin Guide to Pedestrian Best Practice* (WisDOT, 2010).

In general, an engineering traffic study and/or engineering judgment should be considered before installing crosswalk markings. The site-specific elements that should be considered when making a study/judgment are pedestrian volumes; pedestrian types; pedestrian delay; traffic volumes; existing traffic control—signal, stop, yield or none; posted speed limit; geometrics characteristics such as number of lanes and width of crossing; and visibility.

WisDOT policy limits installing marked crosswalks on state highway streets to roadways with speeds of 40 mph or less. In addition, the manual states that "crosswalk markings are warranted, but not required, at signalized intersections where pedestrian indications are present" (WisDOT, 2010).

In urban areas with speed limits of 45 mph or more, crosswalk markings may be installed with a traffic signal, an all-way stop sign, or crossing enhancements of adding curb pullouts and pedestrian refuge islands. In general, crosswalk markings at rural areas, isolated locations, and midblock crosswalks are prohibited when speed limit is 45 mph or more. Exceptions may be considered at trail crossings where advance warning signs are placed (WisDOT, 2010). The manual suggests grade-separated crossings may be considered:

- At locations where moderate to high pedestrian demand exists to cross facilities with topographic displacement such as freeways, arterials, railroads, and other similar facilities;
- In urban areas if the locations meet signal warrants but a signal cannot be installed for technical reasons.
- On "*rural roadways and trails if the roadway speed is 40 mph or higher and ADT is 3,500 or higher*" (WisDOT, 2010).
- In some locations such as parking structures across from hospitals, hotels, or colleges.

In order to access the overpass, stairs and ramps shall be accessible and meet Americans with Disabilities Act Accessibility Guidelines (ADAAG) ramp criteria of a grade of maximum 5 percent. If the ramp has a level landing for every 30 feet, then a grade of 8.33 percent or less can be used. In addition to the ramps, stairs can supplement the ramp.

2.1.25 Other States

Standards and guidelines information on pedestrian treatment selection in the rest of the states were found mainly in the National MUTCD, the State MUTCD, or in the National MUTCD along with the corresponding State supplement(s). A list of the states along with the type of the MUTCD used and other references on State policies, practices, guidelines and manuals, are compiled and posted on the FHWA MUTCD website (FHWA, 2014).

In this research, information on pedestrian treatment selection in the design manuals, traffic manuals, safety manuals, and other references were found to be either similar to the information in the National MUTCD, limited, or could not be located. The following is a list of the states with references that were found and reviewed: DOTs of Arkansas (AHTD, n.d., 2014); California (Caltrans, 2014a, 2014b); Connecticut (CTDOT, 2009); Delaware (DelDOT, 2011); Iowa (2010); Kansas, which requires creating a free account to access their manual (KDOT, 2014); Kentucky (KYTC, 2002, 2006); Minnesota (MnDOT, 2012); Mississippi (2012); Missouri (MoDOT, 2012); Montana (MDT, 2006, 2009); Nebraska (NDOR, 2012); Nevada (NDOT, 2010); New Hampshire (NHDOT, 1999); New Jersey (NJDOT, 2014); New Mexico (NMDOT, 2010–2014); North Dakota (NDDOT, 2013); Ohio (ODOT, 2014); Oklahoma (2009); Rhode Island (RIDOT, 2004); South Carolina (Highway Design Manual is not available online and can be obtained for a fee); South Dakota (SDDOT, n.d.); Tennessee (TDOT, 2003); Texas (TXDOT, 2011, 2013); West Virginia (WVDOT, 2011); and Wyoming (WYDOT, 2014).

2.2 Relevant Studies on Pedestrian Crossing Treatments

In order to achieve the goals of this project, several additional resources were reviewed during this study including a list of documents posted on the FHWA's Bicycle & Pedestrian publications websites (FHWA, n.d.a, n.d.b). The following sections include a summary of selected and most relevant documents to this research.

2.2.1 Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines (Zegeer et al., 2002b)

This study found that having a marked crosswalk alone on multilane roads with an average daily traffic of more than 12,000 vehicles per day was related to a higher pedestrian crash rate when compared to a similar unmarked crosswalk. The study found that raised medians improved pedestrian safety significantly on multilane roads as compared to roadways with no raised median. The recommendations developed in this study for installing marked crosswalks at uncontrolled locations were used with or without modification by several states as presented earlier in this report. The recommendations of this study are presented in Figure 2.10.

2.2.2 Improving Pedestrian Safety at Unsignalized Crossings—NCHRP Report 562

The objective of this report is to provide recommendations on pedestrian crossing treatments to improve pedestrian safety at unsignalized intersections with high-speed and high-traffic volume. However, this study excludes school crossings. The procedure developed in this study for pedestrian crossing treatments is based on two worksheets and consists of five steps as shown in the chart presented in Figure 2.11 (City of Stockton Public Works Department, 2003). The first step is to select either Worksheet 1 or Worksheet 2 for analysis. Worksheet 1 is based on MUTCD Warrant 3, Peak-Hour for roadways with a posted speed limit of 35 mph or less, and Worksheet 2 is based on Warrant 3, Peak Hour (70% Factor) for roadways with a posted speed limit of more than 35 mph, communities with a population of less than 10,000 or where a major transit stop exists.

The second step is to check on the minimum pedestrian volume in order to decide if it is necessary to consider a traffic control device for treatment. This can be achieved by checking if the peak-hour pedestrian volume is at least 20 pedestrians per hour (ped/hr) for Worksheet 1, or 14 ped/hr for Worksheet 2. This 20 ped/hr threshold is recommended in the Zegeer et al. (2002b) study and shown in Figure 2.10. If the intersection does not meet this requirement, then treatments such as median refuge island and curb extensions are appropriate, and traffic control devices are not recommended at this location.

Traffic Volume (ADT)	Posted Speed	Roadway Type			
		2 lanes	2 lanes, raised median[1]	4 lanes, raised median[1]	6 lanes, raised median[1]
Less than or equal to 9,000	30 mph and lower	Marked crosswalk	Marked crosswalk	Additional enhancement	
	35 mph to 40 mph	Marked crosswalk	Marked crosswalk	Additional enhancement	
	45 mph and higher	Additional enhancement	Additional enhancement	Active enhancement	
9,000 to 15,000	30 mph and lower	Marked crosswalk	Marked crosswalk	Additional enhancement	
	35 mph to 40 mph	Marked crosswalk	Marked crosswalk	Additional enhancement	
	45 mph and higher	Additional enhancement	Additional enhancement	Active enhancement	
15,000 to 30,000	30 mph and lower	Additional[2] enhancement	Additional enhancement	Additional[2] enhancement	Active[4] enhancement
	35 mph to 40 mph	Additional[2] enhancement	Additional enhancement	Active enhancement	Active[4] enhancement
	45 mph and higher	Active[5] enhancement	Active enhancement	See note[3]	See note[3]
Gteater than 30,000	45 mph and lower	Active[5] enhancement	Active enhancement	Pedestrian[6] traffic signal	Pedestrian[6] traffic signal

Inside city limits where the population exceeds 25,000, coordinate the decision to mark crosswalks with the city. Provide documentation for all marked crosswalks.

For additional consideration that may be appropriate based on site-specific engineering analyses, see 1510.10.

Notes:

[1] Raised madian/traffic island with a cut-through path minimum width of 5 feet and a median width of 6 feet.

[2] Consider active enhancement treatment for roadways exceeding 20,000 ADT.

[3] Provide alternate routes for pedestrian crossings, or construct a grade-separated facility.

[4] Location may be approaching the need for a controlled crossing. A pedestrian signal may be appropriate, based on engineering analysis.

[5] Raised median/traffic island required.

[6] Refer to the region Traffic Engineer for approval and design of a pedestrian traffic signal. Midblock pedestrian crossing are deviations that require ASDE approval.

Minimum Guidelines (additive for each level):

" Marked crosswalk"

- Marked/signed inaccordance w/MUTCD (signed @ crossing only)
- Pedestrian-view warning signs
- Illumination

"Additional enhancement"

- Minimum guidelines listed under "Marked crosswalk"
- Stop line in accordance w/MUTCD
- Advance signing in accordance w/MUTCD

"Active enhancement"

- Minimum guidelines listed under "Addition enhancement"
- Pedestrian-actuated flashing beacons for roadway with 4 or more lanes

Crosswalk Marking and Enhancement Guidelines

Exhibit 1510-28

Figure 2.9 WSDOT recommendations for crosswalk marking and enhancement guidelines (WSDOT, 2013).

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

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

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

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

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

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

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

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

Figure 2.10 Recommendations for installing marked crosswalks and other pedestrian crossing improvements at uncontrolled locations (Zegeer et al., 2002b).

If the intersection meets the minimum peak-hour pedestrian requirements, then move to step 3 and check if the intersection meets the traffic signal warrant. If it does, then consider installing a traffic signal if the distance between this crossing and the nearest signal is more than 300 feet. If the traffic signal is not warranted, then move to step 4 and calculate an estimate of the crossing total pedestrian delay (TPD). Step 5 provides four possible treatments based on the TPD and level of motorist compliance (low or high). The motorist compliance and TPD are shown in Table 2.1. Worksheets 1 and 2 are shown in Appendix F.

The study developed several plots that are equivalent to the worksheets and based on MUTCD Figure 4C-7 on Warrant 4, Pedestrian Peak Hours. Each plot is unique to a specific speed limit, crossing distance, and pedestrian walking speed on major-roadway. These plots can be used as a quick tool to identify the potential treatment based on the total vehicle volume on a major road in both directions and pedestrian volume crossing the same road. A sample of these plots is shown in Figure 2.12. The worksheets should be used in case none of the plots matches the input data.

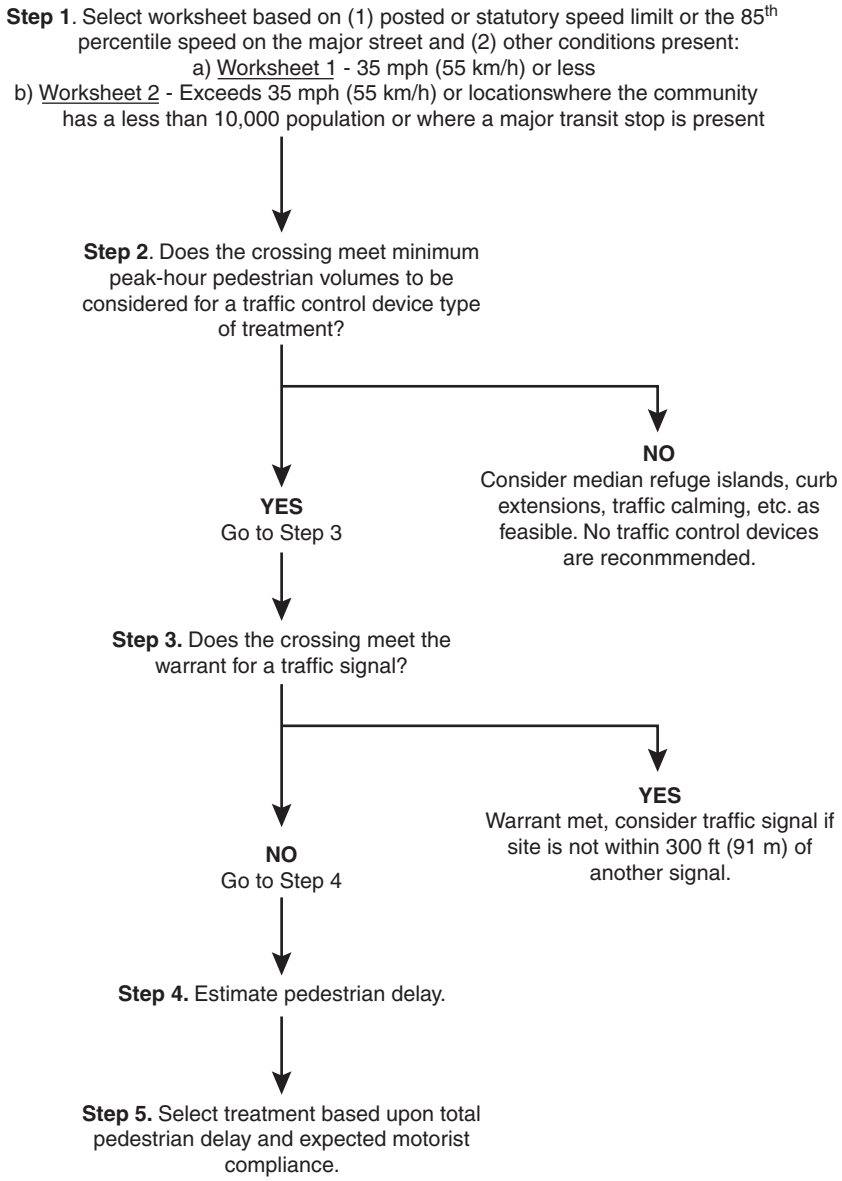


Figure 2.11 Flowchart for guidelines for pedestrian crossing treatments—NCHRP Report 562 (Fitzpatrick et al., 2006).

TABLE 2.1
Recommendations for Pedestrian Crossing Improvement at Uncontrolled Locations Based on *NCHRP Report 562* Guidelines (Fitzpatrick et al., 2006)

Peak-Hour Speed (mph)	Treatment Category	Total Pedestrian Delay (TPD) (hours)	Motorist Compliance	Sample Treatments
35 mph or less	Crosswalk	<1.3	Low or High	Crosswalk markings and pedestrian crossing signs
35 mph or less	Active when Present	$1.3 \leq TPD < 5.3$	Low or High	Devices that are activated to warn motorist when pedestrian are present or crossing the intersection such as Rectangular Rapid Flash Beacon
More than 35 mph Any	Enhanced Devices	$TPD < 5.3$ $5.3 \leq TPD < 21.3$	High	Devices that increase visibility of the crossing and to warn motorist of pedestrian presence such as signal or beacon
Any	Red Indication Devices	$5.3 \leq TPD < 21.3$ ≥ 21.3	Low Low or High	Devices such as signal or beacon that display a circular red indication to warn motorists of pedestrian crossing.

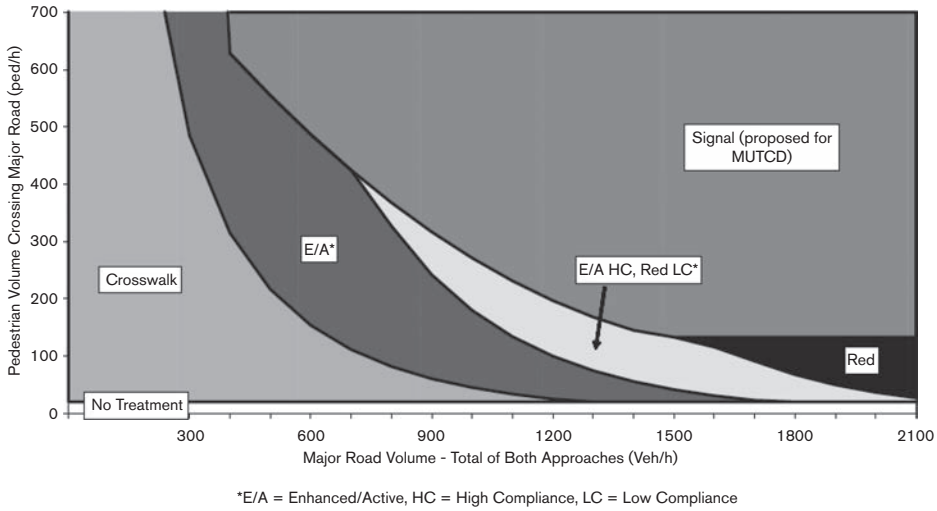


Figure 2.12 Sample of guidelines plot for pedestrian crossing treatment options at unsignalized locations—NCHRP Report 562 (Fitzpatrick et al., 2006).

3. GUIDELINES FOR MARKING CROSSWALKS AND TREATMENTS OF PEDESTRIAN CROSSING

3.1 Introduction

The following sections are proposed guidelines for the installation of marked crosswalks and pedestrian treatment selection at controlled locations of signalized intersections and approaches with stop and yield signs, and uncontrolled locations of intersections and midblock sites. These guidelines are based on several FHWA, US DOTs, NCHRP, and other relevant publications. Using engineering judgment and/or performing an engineering study, if needed, should be considered before installing crosswalk markings. A definition of the engineering judgment and engineering study can be found in section 1A-13 of the MUTCD.

3.2 Guideline for the Installation of Marked Crosswalks and Other Treatments at Controlled Locations

Crosswalk markings are installed at signalized intersections and approaches controlled by stop or yield signs in order to increase the safety and mobility of pedestrians and to prevent motorists from blocking pedestrian traffic.

In general, crosswalk markings should be considered at all controlled approaches that meet pedestrian needs, ADA requirements, and are located directly near a facility that generates or attracts pedestrian trips such as schools, hospitals, and shopping centers. In addition, for signalized intersections, the following factors should be considered for installing marked crosswalks (GDOT, 2007; VDOT, 2005):

1. Locations where pedestrians do not have adequate access to cross the roadway due to site restrictions such as limited right-of-way.

2. Crossing locations with high right-turn or left-turn traffic volumes in direct conflict with pedestrian movement.

For all-way stop intersections, marked crosswalks should be considered at all approaches that have a sidewalk (GDOT, 2007).

Crosswalk markings should not be used extensively and only used at locations with significant pedestrian traffic. Installing crosswalk markings are not recommended at all controlled approaches with conflict between pedestrians and left-turn or right-turn vehicular movements. This occurs frequently on high-speed, high-volume multilane suburban arterials. Crosswalk markings, however, may be considered when additional measures are installed to ensure the safety of pedestrians at these locations. These measures may include but are not limited to installing a pedestrian signal, refuge medians, and fully protected pedestrian phasing (VDOT, 2005).

However, there are locations where pedestrian crossing should be prohibited. Some locations may even need the installation of barrier treatments to eliminate pedestrian crossing at these locations. This prohibition should be limited to places where visibility is poor due to an obstruction that cannot be removed; where an arterial with multiple offset or T-intersections is crowded with legal crosswalks; and where special consideration exists and prohibiting pedestrian crossing does not severely impact pedestrian mobility (VDOT, 2005).

In order to improve safety at pedestrian crossings with high pedestrian-vehicle conflicts, the following potential treatments can be considered in the following cases (City of Stockton Public Works Department, 2003; VDOT, 2005):

Case I: Locations with high numbers of turning vehicles.
Treatments:

1. Installing animated eyes symbol to a pedestrian signal head to make pedestrians pay attention to turning vehicles.
2. Installing special pavement stencils such as "Pedestrians Look Left" and "Watch for Turning Vehicles" onto the pavement to make pedestrians more alert to turning vehicles.
3. Add "Yield to Pedestrians" signs and retrofit intersections with reduced corner radii.

Case II: Locations with high numbers of pedestrians in the vicinity of an intersection.
Treatments:

1. Add pedestrian "scramble" phases to signal timing so pedestrians have a walk signal in all directions and vehicles have an all-red phase at appropriate locations such as CBD's and universities.
2. Install "No Right Turn on Red" signs especially in central business district areas.
3. Installing stop lines or yield lines according to the MUTCD guidelines.

Case III: Locations with wide intersections.
Treatments:

1. Installing additional pedestrian signal heads (if possible) in a median where the crossing distance is more than 60 feet. This should also include pedestrian push buttons where necessary.
2. Installing pedestrian refuge islands
3. Adding bulb-outs especially at intersections of three or more lanes.

3.3 Guideline for the Installation of Marked Crosswalks and Other Treatments at Uncontrolled Locations

Research has found that a marked crosswalk alone (i.e., without any additional treatment) was associated with a higher pedestrian crash rate when compared to a comparable unmarked crosswalk on multilane roadways with an ADT of 12,000 vehicles per day or more (Zegeer et al., 2002b). In addition, having raised medians at pedestrian crossings has significantly lowered pedestrian crash rates when compared to roadways with no raised median. The following guidelines are recommended for adoption by INDOT and based on the Zegeer et al. (2002b) study, VDOT guidelines for the installation of marked crosswalks, and other relevant documents. The current procedure is proposed because the Zegeer et al. (2002b) study has been adopted "as is" or with some modification by several State DOTs and cities in the US, including Alaska; Florida; Colorado; Georgia; Maryland; New York; Vermont; Virginia; City of Boulder, Colorado; and City of Stockton, California.

In general, an engineering traffic study and/or engineering judgment should be considered before installing crosswalk markings. The site-specific elements that should be considered when making a study/judgment are pedestrian volumes; pedestrian types; pedestrian delay; traffic volumes; existing traffic control-signal, stop, yield or none; posted speed limits; geometrics characteristics such as number of lanes and width of crossing; and visibility (FDOT, 2014b).

The following are basic justifications for installing a marked crosswalk based on the most common elements found in the literature:

1. *Pedestrian Demand:*
   a. A minimum of 20 pedestrians crossing (or 15 or more elderly and/or child pedestrians) during any hour of four consecutive 15-minute periods (FDOT, 2014b; Zegeer et al., 2002b); or
   b. A minimum of 60 pedestrians crossing during any consecutive 4-hour period of the day (FDOT, 2014b; VDOT, 2005).
   c. The crossing is located directly on a pedestrian route to/from a pedestrian generator such as school, hospital, and shopping center (VDOT, 2005).
2. *Location:* The nearest marked crosswalk or controlled crossing should be at least 300 feet from the proposed crossing site (City of Stockton, 2003; FDOT, 2014b; PennDOT, 2014; VDOT, 2005).
3. *Sight Distance:* The available stopping sight distance between a motorist and the proposed crosswalk must satisfy the requirement of the MUTCD Table 6C-2 (FDOT, 2014b; PennDOT, 2014; VDOT, 2005).
4. *Speed:* The MUTCD recommends that new marked crosswalks should not be installed alone at uncontrolled approaches where the posted speed limit is more than 40 mph and one of the following conditions exists:
   a. The number of lanes of the roadway is four or more with an ADT of at least 12,000 vpd and without a pedestrian refuge island or raised median; or

b. The number of lanes of the roadway is four or more with an ADT of at least 15,000 vpd and with a pedestrian refuge island or raised median.

3.3.1 Recommended Treatment at Uncontrolled Locations

Table 3.1 provides recommendations on the appropriate treatment devices for pedestrian crosswalks at uncontrolled locations. The recommendations are based on posted speed, number of lanes, ADT, and presence of a raised median. The table should be used to check if there is a need for special treatments and to provide safe measures for pedestrian crossing at uncontrolled locations.

Table 3.2 shows a different way of presenting the table, similar in the format to the table in the original study.

1. These guidelines are not applicable to school crossings.
2. Marked crosswalks should not be used alone at unsignalized locations where the speed limit exceeds 40 mi/h.
3. The raised median or crossing island must be at least 4 ft wide and 6 ft long to meet the requirements of MUTCD and AASHTO guidelines.
4. The following are a list of treatments recommended. More information on each treatment can be found in VDOT guidelines (VDOT, 2005):

Level 1
- a. Standard Crosswalk
- b. Raised Midblock Crosswalk
- c. Rumble Strips

Level 2
- a. White and Retroreflective High-Visibility Crosswalks including:
  - i. textured pavement crosswalks
  - ii. "zebra" and "continental" crosswalks
  - iii. "triple-four" crosswalks

Level 3
- a. Refuge Islands
- b. Split Pedestrian Crossover (SPXO)
- c. Intersections Bulbouts
- d. Midblock Locations Bulbouts

Level 4
- a. Overhead Signs and Flashing Beacons
- b. In-Roadway Warning Lights (IRWLs)

Level 5
- a. Pedestrian-Actuated Signals
- b. Grade-Separated Crossings

An engineering judgment or study is needed before deciding if the site is suitable for installing marked crosswalk. Note that Level 1 and Level 2 treatment devices are installed at locations that are considered *candidate sites (C)* for marked crosswalks; Level 3 and Level 4 treatment devices are considered at sites that are *probable candidate sites (P)* for marked crosswalks; and Level 5 treatment devices are used at sites where installing marked crosswalks alone are *not sufficient (N)*. In case installing Level 5 devices is not feasible, then a combination of treatment

TABLE 3.1
Recommended Treatment at Uncontrolled Locations[1] (FDOT, 2014b; VDOT, 2005)

Speed Limit[2]	Roadway Type	ADT	Proposed Treatments Levels[3]
≤30 mph	2 Lanes	Any	**1** or **2**
	3 Lanes	≤12,000	**1** or **2**
		> 12,000	Add **3** or **4** if feasible
	≥ 4 Lanes with Raised Median[3]	≤12,000	**1** or **2**
		12,000 < ADT ≤ 15,000	Add **3** or **4** if feasible
		> 15,000	**5** or multiple treatments from **2**, **3** and **4**
	≥ 4 Lanes without Raised Median	≤ 9,000	**1** or **2**
		9,000 < ADT ≤ 12,000	Add **3** or **4** if feasible
		> 12,000	**5** or multiple treatments from **2**, **3** and **4**
35 mph	2 Lanes	≤15,000	**2**
		> 15,000	**3** or **4**
	3 Lanes	≤ 9,000	**2**
		9,000 < ADT ≤ 15,000	Add **3** or **4** if feasible
		> 15,000	**5** or multiple treatments from **2**, **3** and **4**
	≥ 4 Lanes with Raised Median[3]	≤ 9,000	**2**
		9,000 < ADT ≤ 15,000	Add **3** or **4** if feasible
		> 15,000	**5** or multiple treatments from **2**, **3** and **4**
	≥ 4 Lanes without Raised Median	≤12,000	Add **3** or **4** if feasible
		> 12,000	**5** or multiple treatments from **2**, **3** and **4**
≥40 mph[5]	2 Lanes	≤12,000	Add **3** or **4** if feasible
		> 12,000	**5** or multiple treatments from **2**, **3** and **4**
	3 Lanes	≤12,000	Add **3** or **4** if feasible
		> 12,000	**5** or multiple treatments from **2**, **3** and **4**
	≥ 4 Lanes with Raised Median[3]	≤ 9,000	Add **3** or **4** if feasible
		> 9,000	**5** or multiple treatments from **2**, **3** and **4**
	≥ 4 Lanes without Raised Median	Any	**5** or multiple treatments from **2**, **3** and **4**

NOTE: Superscripted numbers in parentheses [1–6] pertain to Section 3.3.1 numbered list. Boldface numbers **1–5** pertain to levels within the Section 3.3.1 numbered list.

TABLE 3.2
Recommended Treatments at Uncontrolled Locations: As Presented by VDOT [1,2,4] (VDOT, 2005; Zegeer et al., 2002b)

Roadway Type (Number of Travel Lanes and Median Type)	≤9,000 ADT			>9,000 ADT to ≤12,000 ADT			>12,000 ADT to ≤15,000 ADT			>15,000 ADT		
	≤30 mi/h	35 mi/h	≥40 mi/h	≤30 mi/h	35 mi/h	≥40 mi/h	≤30 mi/h	35 mi/h	≥40 mi/h	≤30 mi/h	35 mi/h	≥40 mi/h
Two lanes	**1** or **2**	**2**	**3** or **4**[6]	**1** or **2**	**2**	**3** or **4**[6]	**1** or **2**	**1** or **2**	**5** or **2**, **3**, **4**	**1** or **2**	**3** or **4**[6]	**5** or **2**, **3**, **4**
Three lanes	**1** or **2**	**2**	**3** or **4**[6]	**1** or **2**	**3** or **4**[6]	**3** or **4**[6]	**3** or **4**[6]	**3** or **4**[6]	**5** or **2**, **3**, **4**	**3** or **4**[6]	**5** or **2**, **3**, **4**	**5** or **2**, **3**, **4**
≥4 lanes with raised median[3]	**1** or **2**	**2**	**3** or **4**[6]	**1** or **2**	**3** or **4**[6]	**5** or **2**, **3**, **4**	**3** or **4**[6]	**3** or **4**[6]	**5** or **2**, **3**, **4**	**5** or **2**, **3**, **4**	**5** or **2**, **3**, **4**	**5** or **2**, **3**, **4**
≥4 lanes without raised median	**1** or **2**	**3** or **4**[6]	**5** or **2**, **3**, **4**	**3** or **4**[6]	**3** or **4**[6]	**5** or **2**, **3**, **4**	**5** or **2**, **3**, **4**	**5** or **2**, **3**, **4**	**5** or **2**, **3**, **4**	**5** or **2**, **3**, **4**	**5** or **2**, **3**, **4**	**5** or **2**, **3**, **4**

Source: Adapted from VDOT (2005).
NOTE: Superscripted numbers in parentheses [1–6] pertain to Section 3.3.1 numbered list. Boldface numbers **1–5** pertain to Levels 1–5 within the Section 3.3.1 numbered list.

devices from Levels 2, 3, or 4 should be considered. The following are detailed guidelines for each site as listed in the Zegeer et al. (2002b) study:

- ***C = Candidate sites for marked crosswalks****. Marked crosswalks must be installed carefully and selectively. Before installing new marked crosswalks, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review may be sufficient at some locations, while a more in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, etc. may be needed at other sites. It is recommended that a minimum of 20 pedestrian crossings per peak hour (or 15 or more elderly and/or child pedestrians) exist at a location before placing a high priority on the installation of a marked crosswalk alone.*
- *P = Possible increase in pedestrian crash risk may occur if crosswalks are added without other pedestrian facility enhancements. These locations should be closely monitored and enhanced with other pedestrian crossing improvements, if necessary, before adding a marked crosswalk.*
- *N = Marked crosswalks alone are insufficient, since pedestrian crash risk may be increased due to providing marked crosswalks alone. Consider using other treatments, such as traffic-calming treatments, traffic signals with pedestrian signals where warranted, or other substantial crossing improvement to improve crossing safety for pedestrians.*

5. One of the criteria in the Zegeer et al. (2002b) study limits the speed to 40 mph. However, the speed of more than 40 mph is recommended based on the VDOT guidelines (2005) and the current proposed procedure of INDOT shown in Figure 1.1.
6. Add 3 or 4 if feasible.

3.4 Roundabout

Roundabout crosswalk markings should adhere to the standards and guidelines in the National MUTCD, Part 3 and NCHRP Report 672, *Roundabouts: An Informational Guide*, Second Edition (TRB, 2010).

3.5 Grade Separation

There are no clear warrants for grade separation treatment. However, several states have established criteria for grade separation as presented earlier in this report. The Arizona DOT guidelines on grade separation are comprehensive and recommended for this section.

The following criteria must be satisfied in order to consider a construction of a pedestrian grade separated structure (ADOT, 2012):

a. *High vehicular volumes conflict with high pedestrian volumes, constituting an extreme hazard; and*
b. *Modification of school routes, busing policies, campus procedures, or attendance boundaries to eliminate the need for a crossing is not feasible; and*
c. *Physical conditions make a grade separation structure feasible from an engineering standpoint, including pedestrian channelization to insure usage of the structure; and*
d. *Pedestrian movements can be restricted for at least 600 ft on each side of the proposed overpass; and*
e. *A demonstrated problem exists that simpler, more economic solutions have failed to remedy; and*
f. *The anticipated benefits to be derived from the overpass clearly outweigh the costs.*

ADOT recommends that school crossings should have special considerations and a pedestrian structure may be warranted regardless of the volume of pedestrians at these locations.

3.6 ADAAG and PROWAG Requirements

All pedestrian facilities should be designed in accordance with the Americans with Disabilities Act Accessibility Guidelines (ADAAG) and the future adopted version of the Public Right-of-Way Accessibility Guidelines (PROWAG) to accommodate pedestrians with special needs and depend on special devices for mobility such as wheelchairs and others.

The ADAAG and the current proposed PROWAG are both available on the United States Access Board website. The link to the ADAAG is http://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-ada-standards/background/adaag and the link to the PROWAG is http://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way/proposed-rights-of-way-guidelines.

4. SURVEY ON PEDESTRIAN CROSSING TREATMENTS AND HIGH-SPEED DIVIDED HIGHWAYS

4.1 Introduction

The survey was conducted online and a link to the survey was emailed to the AASHTO Standing Committee on Highway Traffic Safety. The committee members were asked to take the survey and/or pass it to traffic engineers and other engineers and planners who are experts on traffic safety. A total of 21 subjects completed the survey fully. The specialty and/or title of the respondents is shown in Table 4.1. The majority of the subjects (HIDOT, 2013) who filled out the survey are engineers/planners from the State DOTs.

4.2 Pedestrian Crossing Treatments—Resources

The results of the survey indicate that most of the subjects use the MUTCD and the State Design Manual when selecting a pedestrian crossing treatment as shown in Table 4.2. The resources listed in the table starting from three and up were not listed in the survey and were added by respondents. This explains why some of these resources were ranked low. It is anticipated that the frequency for these resources could have been different if they were listed in the survey and subjects had the chance to evaluate them as the first two.

TABLE 4.1
Specialty of Subjects Completed the Survey

No.	Title/Specialty	Response	%
1	Traffic Engineer	12	57%
2	Design Engineer	1	5%
3	Planner	1	5%
4	Highway Safety Engineer	3	14%
5	City Engineer	1	5%
6	Others	3	14%
	Total	**21**	**100%**

4.3 Pedestrian Crossing Treatments—Frequency of Usage

Table 4.3 lists the frequency of pedestrian crossing treatments currently used in each city or state of the subjects. The list of treatments is sorted in descending order from the highest to the lowest usages. The results indicate that the most frequently used treatments by the different states represented in the survey are advanced signings, crosswalk signs and pavement markings, countdown display at signalized intersection, high-visibility signs and markings, curb extension, and median refuge island. The least frequently selected treatments for future projects include in-roadway warning lights, pedestrian railings, overhead flashing beacon (passive), split midblock signal, and pedestrian crossing flags.

It is worth mentioning that the least used treatments listed in the table, starting from treatment 25 (i.e., bollard based pedestrian crosswalk lighting), were ignored in this analysis because they were not listed in the survey and were added by respondents. This explains why these treatments ranked the least and will be dropped to maintain consistency. It is anticipated that the frequency for these treatments could have been different if they were listed in the survey and subjects had the chance to evaluate them as the rest of the treatments.

Similarly, Table 4.4 lists the frequency of pedestrian crossing treatments that will be used by subjects in future projects. The subjects chose different treatment options for future projects but the change of order of each treatment selection was within a small range. The top choices among all subjects for future treatments were countdown display at signalized intersection, crosswalk signs and pavement markings, high-visibility signs and markings, and median refuge island. The future treatments that were least likely selected are in-roadway warning lights and pedestrian crossing flags. It is important to mention, as stated by one of the subjects, that future treatments are dependent on the specifics of each case and the goals needed to be achieved by a selected treatment.

Table 4.5 summarizes the current and the future rankings and the change between the two. For example, a change of 2 indicates that this treatment will have more priority in the future and has moved two places up from the current usage. The maximum change was of ± 5 levels (Roadway

TABLE 4.2
Manuals/References Used When Selecting a Pedestrian Crossing Treatment

No.	Manual/Reference	All the Time	Sometimes	Not at All
1	MUTCD	14	3	–
2	State Design Manual	6	7	1
3	Transportation Association of Canada (TAC) Pedestrian Crossing Control Guide 2012	2	–	–
4	State MUTCD	1	–	–
5	State Guidelines for the Installation of Marked Crosswalks	1	–	–
6	District Highway Safety Guidance Manual	1	–	–
7	Centre for Research and Contract Standardization in Civil and Traffic Engineering (CROW) Publications	1	–	–
8	AASHTO Guides	–	1	–
9	Experienced Engineering Judgment/Familiar with Location/Region	1	–	
10	ITE resources	–	1	–
11	Multiple FHWA, NCHRP, Pedestrian Facility and Accessibility References/Tools	–	1	–
12	National Association of City Transportation Officials (NACTO) Guides	–	1	–
13	Published research (e.g., TRB Human Factors Guidelines)	–	1	–

TABLE 4.3
Frequency of Currently Used Pedestrian Crossing Treatment in Cities/States

		Responses				
		Yes		No.		
	Pedestrian Crossing Treatment	No.	%	No.	%	Total
1	Advance Signing	19	100%	0	0%	19
2	Crosswalk Signs and Pavement Markings	19	100%	0	0%	19
3	Countdown Display at Signalized Intersection	18	95%	1	5%	19
4	High-Visibility Signs and Markings	18	95%	1	5%	19
5	Curb Extension	17	89%	1	5%	18
6	Median Refuge Island	17	89%	2	11%	19
7	Traffic Calming	16	84%	2	11%	18
8	Overhead Signs	15	79%	4	21%	19
9	Pedestrian Crosswalk Signal	15	79%	2	11%	17
10	HAWK Beacon Signal	14	74%	5	26%	19
11	In-Street Pedestrian Crossing Sign	14	74%	4	21%	18
12	Pedestrian Beacon	14	74%	4	21%	18
13	Roadway Narrowing	14	74%	4	21%	18
14	Advance Placement of Stop Line and Sign	13	68%	5	26%	18
15	Midblock Traffic Signal	12	63%	6	32%	18
16	Overhead Flashing Beacon (Continuous)	12	63%	7	37%	19
17	Overhead Flashing Beacon (Pushbutton)	11	58%	8	42%	19
18	Intersection Pedestrian Signals (Half Signals)	9	47%	9	47%	18
19	Automated Detection	6	32%	11	58%	17
20	In-Roadway Warning Lights	6	32%	12	63%	18
21	Pedestrian Railings	6	32%	11	58%	17
22	Overhead Flashing Beacon (Passive)	4	21%	12	63%	16
23	Split Midblock Signal	4	21%	13	68%	17
24	Pedestrian Crossing Flags	3	16%	14	74%	17
25	Bollard based pedestrian crosswalk lighting	1	5%	0	0%	1
26	Rectangular Rapid Flashing Beacon, pedestrian activated	1	5%	0	0%	1
27	Roundabouts	1	5%	0	0%	1
28	Raised crosswalks	1	5%	0	0%	1

Narrowing increased by five levels and Overhead Signs dropped five levels) which indicates that there is no substantial change between the current and the recommended future use of treatments.

4.4 Pedestrian Crossing Treatments—Selection Criteria

4.4.1 General Criteria

The survey asked subjects to select the criteria they use when selecting a pedestrian treatment. The survey listed three criteria: speed, ADT, and number of lanes. The results indicate that all subjects are using all three criteria whenever they make decisions. In addition, subjects added additional criteria as shown in Table 4.6. The top three criteria added to the list are pedestrian volume, stopping sight distance, and geometrics/sidewalk/curb ramps/grade. These additional criteria are consistent with the MUTCD recommendations and typically considered in any safety traffic study.

4.4.2 Details of the General Criteria

The subjects were asked to identify, based on their experience, the criteria they use when selecting treatments for a range of speeds, ADT, and number of lanes. For example, speed was presented with four values: 30 mi/hr or less, 35 mi/hr, 40 mi/hr, 45 mi/hr or more and number of lanes were two lanes, three lanes, four or more lanes with raised median, and four or more lanes without raised median. An additional option of "not used" will not be utilized in the analyses. Table 4.7 shows a summary of the findings and the details of the responses for all criteria are shown in Appendix G.

Table 4.7 lists the number of subjects that selected each criteria (speed, ADT, Lanes) and their percentage out of the total responses. The number of responses is larger than the number of subjects because each subject can choose several values under each criteria. The number of lanes was used more frequently than other criteria when selecting most of the treatments. For example, 51% of the respondents who answered this question used number of lanes for advance signing, 26% used ADT, and 23% of chose speed. However, the dominant criteria for automated detection and median refuge island was the ADT.

The top three treatments that were most selected by the subjects and has the well-established criteria are Crosswalk Signs and Pavement Markings (156 responses), Advance Signing (136 responses), and high-visibility signs and markings (136 responses); and the three least selected treatments are pedestrian crossing flags (0 responses), split

TABLE 4.4
Frequency of Using Pedestrian Crossing Treatment in Future Projects

		Responses				
		Yes		No		
	Treatment	No.	%	No.	%	Total
1	Countdown Display at Signalized Intersection	18	100%	0	0%	18
2	Crosswalk Signs and Pavement Markings	18	100%	0	0%	18
3	High-Visibility Signs and Markings	18	100%	0	0%	18
4	Median Refuge Island	18	100%	0	0%	18
5	Advance Signing	17	94%	0	0%	17
6	Curb Extension	17	94%	0	0%	17
7	HAWK Beacon Signal	16	89%	2	11%	18
8	Roadway Narrowing	16	89%	1	6%	17
9	Traffic Calming	16	89%	1	6%	17
10	Advance Placement of Stop Line and Sign	15	83%	2	11%	17
11	Pedestrian Beacon	15	83%	2	11%	17
12	Pedestrian Crosswalk Signal	15	83%	1	6%	16
13	Overhead Signs	14	78%	4	22%	18
14	In-Street Pedestrian Crossing Sign	13	72%	4	22%	17
15	Overhead Flashing Beacon (Pushbutton)	13	72%	5	28%	18
16	Midblock Traffic Signal	11	61%	6	33%	17
17	Overhead Flashing Beacon (Continuous)	10	56%	8	44%	18
18	Pedestrian Railings	9	50%	7	39%	16
19	Automated Detection	8	44%	6	33%	14
20	Intersection Pedestrian Signals (Half Signals)	7	39%	10	56%	17
21	Overhead Flashing Beacon (Passive)	7	39%	8	44%	15
22	Split Midblock Signal	7	39%	9	50%	16
23	In-Roadway Warning Lights	4	22%	13	72%	17
24	Pedestrian Crossing Flags	3	17%	13	72%	16

TABLE 4.5
Ranking of Current and Future Usage of Pedestrian Crossing Treatment

	Usage of Treatment		
Treatment	Future	Current	Change
Countdown Display at Signalized Intersection	1	3	2
Crosswalk Signs and Pavement Markings	2	2	0
High-Visibility Signs and Markings	3	4	1
Median Refuge Island	4	6	2
Advance Signing	5	1	−4
Curb Extension	6	5	−1
HAWK Beacon Signal	7	10	3
Roadway Narrowing	8	13	5
Traffic Calming	9	7	−2
Advance Placement of Stop Line and Sign	10	14	4
Pedestrian Beacon	11	12	1
Pedestrian Crosswalk Signal	12	9	−3
Overhead Signs	13	8	−5
In-Street Pedestrian Crossing Sign	14	11	−3
Overhead Flashing Beacon (Pushbutton)	15	17	2
Midblock Traffic Signal	16	15	−1
Overhead Flashing Beacon (Continuous)	17	16	−1
Pedestrian Railings	18	21	3
Automated Detection	19	19	0
Intersection Pedestrian Signals (Half Signals)	20	18	−2
Overhead Flashing Beacon (Passive)	21	22	1
Split Midblock Signal	22	23	1
In-Roadway Warning Lights	23	20	−3
Pedestrian Crossing Flags	24	24	0

TABLE 4.6
Pedestrian Crossing Treatments Selection Criteria

	Treatment Selection Criteria	Responses
1	Speed (mi/hr)	17
2	Average Daily Traffic (ADT) Vehicle per Day	17
3	Number of Lanes	16
4	Pedestrian Volume	11
5	Stopping Sight Distance	5
6	Geometrics/Sidewalk/Curb Ramps/Grade	4
7	Type of Pedestrian Activity/Demand	2
8	Crash History	2
9	Distance to Nearest Traffic Signal/ Crosswalk/School	2
10	Land Use	2
11	Pedestrian Crashes	2
12	Age of Pedestrians	1
14	Case by case, No Formal Criteria	1
15	Consistency of Adjacent Intersection and Crossing Treatments	1
16	Length of Crossing	1
17	PROWAG	1
18	Public Complaints	1
19	Requests	1
20	Safety Performance of the Location	1
21	Type of Pedestrian Generators	1

midblock signal (13 responses), and in-roadway warning lights (15 responses).

4.5 Pedestrian Crossing Treatments—Advantages and Disadvantages

A list of advantages, disadvantages, and recommendations for each treatments as stated by the subjects are summarized in Appendix H.

4.6 Effectiveness of Pedestrian Crossing Treatments

The subjects were asked to evaluate the effectiveness of pedestrian crossing treatments based on their professional experience. The results are shown in Table 4.8. The surveys asked the subjects to use a scale of 1 = Not Effective, 2 = Somewhat Not Effective, 3 = Neutral, 4 = Somewhat Effective, and 5 = Effective, to rate a treatment as being effective or not. An index is based on the last two scales of rating: 4 and 5. The index is equal to the sum of the product of the responses and their scales. The treatments were sorted from the highest score (i.e., effective) to lowest (i.e., least effective) as shown in Table 4.9. The results indicates that the top five pedestrian treatments are countdown display at signalized intersection, crosswalk signs and pavement markings, median refuge island, high-visibility signs and markings, and curb extension. The bottom five pedestrian treatments are overhead flashing beacon (continuous), overhead flashing beacon (passive), split midblock signal, in-roadway warning lights, and pedestrian crossing flags.

4.7 High-Speed Divided Highway Pedestrian Crossing Treatments

The following is a summary of the survey questions on high-speed divided highway pedestrian crossing treatment. The details of the results are shown in Appendix I.

4.7.1 Pedestrian Crossing Treatments on High-Speed Divided Highways

In the case of treatments for pedestrian crossing at high-speed divided highways, the majority of subjects (82%) reported that they will consider providing adequate pedestrian timings to cross the entire highway length. In addition, 73% of the subjects do not believe the delays caused by providing the pedestrian timing is a major concern.

The main recommendation was to provide enough time to cross the entire width of the intersection without a median whenever there is a demand. The argument is that the cycle length is long and pedestrians will experience a long delay on these types of roadways. Therefore, some impatient pedestrian may attempt to cross the entire length and create safety issues. However, a second opinion suggested having two-phase crossing if the median was sufficient.

TABLE 4.7
Summary of Pedestrian Crossing Treatments Criteria Selection—Speed, ADT, and Number of Lanes

		Responses						
		Speed		ADT		No. of Lanes		
	Treatment	No.	%	No.	%	No.	%	Total
1	Advance Placement of Stop Line and Sign	17	29%	19	33%	22	38%	58
2	Advance Signing	31	23%	35	26%	70	51%	136
3	Automated Detection	6	29%	8	38%	7	33%	21
4	Curb Extension	25	25%	30	30%	44	44%	99
5	HAWK Beacon Signal	32	32%	27	27%	42	42%	101
6	High-Visibility Signs and Markings	33	25%	37	28%	60	46%	130
7	In-Roadway Warning Lights	4	27%	4	27%	7	47%	15
8	In-Street Pedestrian Crossing Sign	19	32%	19	32%	22	37%	60
9	Intersection Pedestrian Signals (Half Signals)	7	29%	8	33%	9	38%	24
10	Median Refuge Island	33	32%	37	36%	32	31%	102
11	Overhead Flashing Beacon (Continuous)	22	29%	19	25%	35	46%	76
12	Overhead Flashing Beacon (Pushbutton)	17	26%	17	26%	31	48%	65
13	Overhead Flashing Beacon (Passive)	8	27%	8	27%	14	47%	30
14	Overhead Signs	30	28%	27	25%	49	46%	106
15	Pedestrian Beacon	15	24%	18	29%	29	47%	62
16	Pedestrian Crossing Flags	0	—	0	—	0	—	0
17	Pedestrian Crosswalk Signal	18	26%	19	28%	31	46%	68
18	Pedestrian Railings	9	31%	8	28%	12	41%	29
19	Roadway Narrowing	16	25%	23	35%	26	40%	65
20	Split Midblock Signal	4	31%	4	31%	5	38%	13
21	Traffic Calming	16	24%	20	30%	30	45%	66
22	Countdown Display at Signalized Intersection	36	28%	35	28%	56	44%	127
23	Crosswalk Signs and Pavement Markings	40	26%	43	28%	73	47%	156
24	Midblock Traffic Signal	22	27%	26	32%	34	41%	82

TABLE 4.8
Input on Effectives of Pedestrian Crossing Treatments

	Treatment	(1) Not Effective	(2) Somewhat Not Effective	(3) Neutral	(4) Somewhat Effective	(5) Effective	Total Responses
1	Advance Placement of Stop Line and Sign	0	0	3	6	4	**13**
2	Advance Signing	0	1	2	10	4	**17**
3	Automated Detection	0	0	1	4	2	**7**
4	Countdown Display at Signalized Intersection	0	0	1	5	11	**17**
5	Crosswalk Signs and Pavement Markings	0	0	2	8	8	**18**
6	Curb Extension	0	0	1	7	7	**15**
7	HAWK Beacon Signal	0	0	1	5	6	**12**
8	High-Visibility Signs and Markings	0	1	2	6	8	**17**
9	In-Roadway Warning Lights	1	1	1	2	1	**6**
10	In-Street Pedestrian Crossing Sign	0	0	1	9	4	**14**
11	Intersection Pedestrian Signals (Half Signals)	0	1	2	2	5	**10**
12	Median Refuge Island	0	1	1	5	10	**17**
13	Midblock Traffic Signal	0	1	2	7	3	**13**
14	Overhead Flashing Beacon (Continuous)	1	3	3	2	2	**11**
15	Overhead Flashing Beacon (Pushbutton)	0	2	3	4	5	**14**
16	Overhead Flashing Beacon (Passive)	0	1	1	2	2	**6**
17	Overhead Signs	0	1	2	10	2	**15**
18	Pedestrian Beacon	0	0	0	7	6	**13**
19	Pedestrian Crossing Flags	0	0	0	2	0	**2**
20	Pedestrian Crosswalk Signal	0	1	1	5	7	**14**
21	Pedestrian Railings	0	0	0	3	2	**5**
22	Roadway Narrowing	0	0	0	6	5	**11**
23	Split Midblock Signal	0	0	1	3	1	**5**
24	Traffic Calming	0	0	0	7	5	**12**

TABLE 4.9
Evaluation of Effectives of Pedestrian Crossing Treatments

	Treatment	Index
1	Countdown Display at Signalized Intersection	75
2	Crosswalk Signs and Pavement Markings	72
3	Median Refuge Island	70
4	High-Visibility Signs and Markings	64
5	Curb Extension	63
6	Advance Signing	60
7	Pedestrian Beacon	58
8	In-Street Pedestrian Crossing Sign	56
9	Pedestrian Crosswalk Signal	55
10	Traffic Calming	53
11	Overhead Signs	50
12	HAWK Beacon Signal	50
13	Roadway Narrowing	49
14	Advance Placement of Stop Line and Sign	44
15	Midblock Traffic Signal	43
16	Overhead Flashing Beacon (Pushbutton)	41
17	Intersection Pedestrian Signals (Half Signals)	33
18	Automated Detection	26
19	Pedestrian Railings	22
20	Overhead Flashing Beacon (Continuous)	18
21	Overhead Flashing Beacon (Passive)	18
22	Split Midblock Signal	17
23	In-Roadway Warning Lights	13
24	Pedestrian Crossing Flags	8

The feedback on the concern of creating considerable vehicular traffic delay when treating high-speed divided highways with adequate pedestrian timings indicates that safety trumps reasonable delay when pedestrian demand is not high.

4.7.2 Refuge Island on High-Speed Divided Highways

Having a refuge island built with curbs is not typically used on high-speed roadways with speeds equal to or greater than 50 mph. The following is a summary of recommendations on providing a refuge island in the median.

There was a split vote on recommending the provision of a refuge island in the median: 6 out of 10 (60%) subjects answered the question said yes and 4 (40%) said no. The group who supported the island recommended having additional measures to ensure pedestrian safety such as two-phase crossing. Two types of islands were recommended: either to have a "*Grass Island with mountable curbing around the nose, paved cut through, pedestrian pushbutton provided*," or a raised island with ADA pedestrian ramps. The suggested maximum speed limit where a refuge island is not feasible should be site specific and in the range of 40–45 mph.

However, several have safety concerns about keeping pedestrians waiting in the median at high-speed highways.

They recommended either to let pedestrians cross the entire length at one time or, if possible, provide grade separation for pedestrian crossings. Typical installations of a selected pedestrian treatment devices are shown in Appendix J.

5. CONCLUSIONS AND RECOMMENDATIONS

Selecting treatments for pedestrian crossings is a challenge that design and traffic engineers encounter on a regular basis. Adding to this challenge is the lack of a unique or common acceptable national procedure for selecting pedestrian crossing treatments at controlled and uncontrolled locations in the US. In some cases, the guidelines presented are general and descriptive in nature. Therefore, there is a need for a national and comprehensive study to develop practical guidelines on pedestrian crossing treatments, especially on multilane roadways, complex intersections, and when the speed is 45 mph or more.

The current source of pedestrian treatment selection for INDOT provides limited guidelines and does not take into consideration key elements such as number of lanes and the existence of a raised median. The proposed guidelines presented in the study on crosswalk markings and treatment selection of pedestrian crossings is based on a synthesis of federal and state reports, guidelines, design manuals, polices, and other relevant publications. It is recommended to adopt these guidelines as a reference for pedestrian treatment selection at INDOT.

The results of the survey indicate that the most frequently used treatments by the different states represented in the survey are advanced signings, crosswalk signs and pavement markings, countdown displays at signalized intersections, curb extensions, high-visibility signs and markings, and median refuge islands. The least frequently used treatments include in-roadway warning lights, pedestrian railings, overhead flashing beacons (passive), split midblock signals, and pedestrian crossing flags.

The results on the effectiveness of treatments indicate that the top five pedestrian treatments are countdown displays at signalized intersection, crosswalk signs and pavement markings, median refuge islands, high-visibility signs and markings, and curb extension. The bottom five pedestrian treatments are overhead flashing beacons (continuous), overhead flashing beacons (passive), split midblock signals, in-roadway warning lights, and pedestrian crossing flags.

In the case of high-speed divided highways, the majority of subjects (82%) reported that they will consider providing adequate pedestrian timings to cross the entire highway length. In addition, 73% of the subjects do not believe the delays caused by providing the pedestrian timing is a major concern.

The main recommendations on pedestrian timings to cross the entire highway length were to provide enough time to cross the entire width of the intersection without a median whenever there is a demand. The feedback on the concern of creating considerable vehicular traffic delay when treating high-speed divided highways with adequate pedestrian timings indicates that safety trumps reasonable delay when pedestrian demand is not high.

Having a refuge island built with curbs is not typically used on high-speed roadways with speeds equal to or greater than 50 mph. The results of the survey showed a split vote on the recommendation of a refuge island in the median: 6 out of 10 (60%) said yes and 4 (40%) said no. The results of the survey suggested that a maximum speed limit, where a refuge island is not feasible, should be site specific and in the range of 40–50 mph. In addition, it is recommended either to let pedestrians cross the entire length at one time or, if possible, to provide grade separation for pedestrian crossings.

REFERENCES

AASHTO. (2004). *Guide for the planning, design, and operation of pedestrian facilities*. Washington, DC: American Association of State and Highway Transportation.

ADOT. (2012). *Roadway Design Guidelines*. Phoenix, AZ: Arizona Department of Transportation. Retrieved June 2, 2014, from www.azdot.gov/docs/business/roadway-design-guidelines.pdf

AHTD. (n.d.). *Manuals*. Little Rock, AR: Arkansas State Highways and Transportation Department. Retrieved June 26, 2014, from http://www.arkansashighways.com/manuals/manuals.aspx

AHTD. (2014). *Safety Manual*. Little Rock, AR: Arkansas State Highways and Transportation Department. Retrieved June 26, 2014, from http://www.arkansashighways.com/human_resources_division/SafetyManual50.pdf

AKDOT. (2012). *Alaska Traffic Manual Supplement to the 2009 Edition of the MUTCD, Part 3: Markings*. Juneau, AK: Alaska Department of Transportation and Public Facilities. Retrieved June 2, 2014, from http://www.dot.state.ak.us/stwddes/dcstraffic/assets/pdf/atm/current/part3_markings.pdf

Caltrans. (2014a). *California MUTCD*. Sacramento, CA: California Department of Transportation. Retrieved June 26, 2014, from http://www.dot.ca.gov/hq/traffops/engineering/mutcd/ca_mutcd2014.htm

Caltrans. (2014b). *Highway Design Manual, Chapter 400: Intersections at Grade*. Sacramento, CA: California Department of Transportation. Retrieved June 26, 2014, from www.caltrans.ca.gov/hq/oppd/hdm/pdf/english/chp0400.pdf

CDOT. (2005). *CDOT Roadway Design Guide*. Denver, CO: Colorado Department of Transportation. Retrieved June 2, 2014, from www.coloradodot.info/business/designsupport/bulletins_manuals/roadway-design-guide

City of Stockton. (2003). *Pedestrian safety and crosswalk installation guidelines*. Stockton, CA: City of Stockton Public Works Department. Retrieved June 29, 2014, from http://www.stocktongov.com/files/PedestrianSafetyAndCrosswalkInstallationGuidelines.pdf

CTDOT. (2009). *Traffic Control Signal Design Manual*. Newington, CT: Connecticut Department of Transportation. Retrieved June 26, 2014, from http://www.ct.gov/dot/lib/dot/documents/dtrafficdesign/sigmanapproved2009.pdf

DelDOT. (2011). *Road Design Manual*. Dover, DE: Delaware Department of Transportation. Retrieved June 28, 2014, from http://www.deldot.gov/information/pubs_forms/manuals/road_design/index.shtml

FDOT. (2007). *Florida Intersection Design Guide*. Tallahassee, FL: Florida Department of Transportation. Retrieved June 4, 2014, from www.dot.state.fl.us/rddesign/PPMManual/2014PPM.shtm

FDOT. (2014a). *Plans Preparation Manual, Vol. 1*. Tallahassee, FL: Florida Department of Transportation. Retrieved June 4, 2014, from www.dot.state.fl.us/rddesign/PPMManual/2014PPM.shtm

FDOT. (2014b). *Traffic Engineering Manual*. Tallahassee, FL: Florida Department of Transportation. Retrieved June 4, 2014, from www.dot.state.fl.us/trafficoperations/Operations/Studies/TEM/FDOT_Traffic_Engineering_Manual_revised_May_2014.pdf

FHWA. (n.d.a). *Bicycle & Pedestrian Publications*. Washington, DC: Federal Highway Administration. Retrieved July 11, 2014, from http://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/

FHWA. (n.d.b). *Pedestrian and Bicycle Related Research Reports*. Retrieved July 14, 2014, from http://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/web_pub.cfm

FHWA. (2000). *Roundabouts: An information guide* (Publication No. FHWA-RD-00-068). Washington, DC: Federal Highway Transportation. Retrieved June 10, 2014, from www.fhwa.dot.gov/publications/research/safety/00068/

FHWA. (2014). *MUTCDs & Traffic Control Devices Information by State*. Retrieved June 25, 2014, from http://mutcd.fhwa.dot.gov/resources/state_info/index.htm

Fitzpatrick, K., Turner, S., Brewer, M., Carlson, P., Ullman, B., Trout, N., & Lord, D. (2006). *Improving Pedestrian Safety at Unsignalized Crossings* (NCHRP Report 562). Washington, DC: Transportation Research Board. Retrieved June 29, 2014, from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_562.pdf

GDOT. (2007). *Guidance on marking crosswalks*. Atlanta, GA: Georgia Department of Transportation. Retrieved June 5, 2014, from www.dot.ga.gov/doingbusiness/PoliciesManuals/roads/smguide/Draft_Crosswalk_Guidance.pdf

GDOT. (2014). *Design Policy Manual*. Atlanta, GA: Georgia Department of Transportation. Retrieved June 7, 2014, from www.dot.ga.gov/doingbusiness/PoliciesManuals/roads/DesignPolicy/GDOT-DPM.pdf

HIDOT. (2013). *Hawaii Pedestrian Toolbox: A Guide for Planning, Design, Operations, and Education to Enhance Pedestrian Travel in Hawaii*. Honolulu, HI: Hawaii Department of Transportation. Retrieved June 7, 2014, from http://hidot.hawaii.gov/highways/statewide-pedestrian-master-plan-and-hawaii-pedestrian-toolbox/

IDOT. (2010). *Bureau of Design & Environment Manual*. Springfield, IL: Illinois Department of Transportation. Retrieved June 13, 2014, from www.dot.state.il.us/desenv/bdemanual.html

IDOT. (2014). *Illinois Supplement to the National Manual on Uniform Traffic Control Devices*. Springfield, IL: Illinois Department of Transportation. Retrieved June 10, 2014, from http://idot.illinois.gov/Assets/uploads/files/Transportation-System/Manuals-Guides-&-Handbooks/Highways/Operations/2009%20ILMUTCD%20-%202014%20update.pdf

INDOT. (2012). *Indiana crash facts*. Retrieved June 1, 2014, from www.in.gov/cji/files/T_Fact_Book_2012.pdf

INDOT. (2013). *Indiana Design Manual*. Retrieved June 25, 2014, from www.in.gov/indot/design_manual/

Iowa DOT. (2010). *Design Manual*. Ames, IA: Iowa Department of Transportation. Retrieved June 26, 2014, from http://www.iowadot.gov/design/dmanual/manual.html

ITD. (2012a). *Roadway Design Manual*. Boise, ID: Idaho Department of Transportation. Retrieved June 10, 2014, from http://itd.idaho.gov/manuals/Manual%20Production/RoadwayDesign/files/Roadwaydesignprintable.pdf

ITD. (2012b). *Traffic Manual*. Boise, ID: Idaho Department of Transportation. Retrieved June 10, 2014, from http://itd.idaho.gov/manuals/Manual%20Production/Traffic/800Ped.pdf

ITE. (1985). *School trip safety program guidelines*. Washington, DC: Institute of Transportation Engineers. Retrieved June 21, 2014, from www.ite.org/membersonly/itejournal/pdf/JAA85A12.pdf

ITE. (1998). *Design and safety of pedestrian facilities for identifying locations*. Washington, DC: Institute of Transportation Engineers. Retrieved June 10, 2014, from www.ite.org/decade/pubs/RP-026A-E.pdf

KDOT. (2014). *Road Design Manual*. Topeka, KS: Kansas Department of Transportation. Retrieved June 20, 2014, from http://kart.ksdot.org/

KYTC. (2002). *Pedestrian and Bicycle Travel Policy*. Frankfort, KY: Kentucky Transportation Cabinet. Retrieved July 1, 2014, from http://transportation.ky.gov/Bike-Walk/Documents/Task%20Force%20FINAL%20June%2018_02%20policy%20rec%20to%20Sec%20Codell.pdf

KYTC. (2006). *Highway Design Manual*. Frankfort, KY: Kentucky Transportation Cabinet. Retrieved June 1, 2014, from http://transportation.ky.gov/highway-design/pages/highway-design-manual.aspx

LaDOT. (2012). *Traffic Engineering Manual*. Baton Rouge, LA: Louisiana Department of Transportation and Development. Retrieved June 13, 2014, from wwwsp.dotd.la.gov/Inside_LaDOTD/Divisions/Engineering/Traffic_Engineering/Misc%20Documents/Traffic%20Engineering%20Manual.pdf

MaineDOT. (2004). *Volume one: National standards highway design guide, 2004*. Augusta, ME: Maine Department of Transportation. Retrieved June 13, 2014, from http://digitalmaine.com/mdot_docs/32/

Maryland SHA. (2010). *Accessibility policy & guidelines for pedestrian facilities along state highways*. Baltimore, MD: Maryland Department of Transportation, State Highway Administration. Retrieved June 13, from http://roads.maryland.gov/Index.aspx?PageId=80

Maryland SHA. (n.d.). *Maryland SHA Bicycle and Pedestrian Design Guidelines, Chapter 10: Roadway Crossing Design*. Baltimore, MD: Maryland State Highway Administration. Retrieved June 15, 2014, from http://actfortransit.org/archives/reports_and_other/IntersectionDesign.pdf

MassDOT. (2006). *Project Development and Design Guide*. Boston, MA: Massachusetts Department of Transportation. Retrieved June 16, 2014, from www.massdot.state.ma.us/highway/DoingBusinessWithUs/ManualsPublicationsForms/ProjectDevelopmentDesignGuide.aspx

MDOT. (2012). *Traffic and Safety Note 401D*. Lansing, MI: Michigan Department of Transportation. Retrieved June 16, 2014, from http://mdotcf.state.mi.us/public/tands/Details_Web/mdot_note401d.pdf

MDT. (2006). *Road Design Manual*. Helena, MT: Montana Department of Transportation. Retrieved July 2, 2014, from http://www.mdt.mt.gov/publications/manuals.shtml

MDT. (2009). *Traffic Engineering Manual*. Helena, MT: Montana Department of Transportation. Retrieved July 2, 2014, from http://www.mdt.mt.gov/publications/manuals.shtml

Mississippi DOT. (2012). *Roadway Design Manual*. Jackson, MS: Mississippi Department of Transportation. Retrieved July 1, 2014, from http://sp.mdot.ms.gov/RoadwayDesign/Pages/Roadway-Design-Manual.aspx

MnDOT. (2012). *Road Design Manual*. St. Paul, MN: Minnesota Department of Transportation. Retrieved July 1, 2014, from http://roaddesign.dot.state.mn.us/

MoDOT. (2012). *Traffic Practices: A Guidebook for City and County Agencies*. The Missouri Department of Transportation. Retrieved July 1, 2014, from http://contribute.modot.mo.gov/safety/documents/TrafficPracticesaGuidebookforcitycountyagencies.pdf

NCDOT. (2007). *Hertford comprehensive pedestrian plan, Section 6: Design standards and guidelines*. Raleigh, NC: North Carolina Department of Transportation. Retrieved June 19, 2014, from http://connect.ncdot.gov/municipalities/PlanningGrant/Sample%20Plans/Hertford%20Sample%20Plan%20-%20Section%206.pdf

NCDOT. (n.d.). *Planning guide: Plan templates and examples of well prepared bicycle and pedestrian transportation plans*. Raleigh, NC: North Carolina Department of Transportation. Retrieved June 18, 2014, from http://connect.ncdot.gov/municipalities/PlanningGrant/Pages/Planning-Guide.aspx

NDDOT. (2013). *Design Manual*. The North Dakota Department of Transportation. Retrieved July 6, 2014, from www.dot.nd.gov/manuals/design/designmanual/designmanual.htm

NDOR. (2012). *Road Design Manual*. Lincoln, NE: Nebraska Department of Roads. Retrieved July 2, 2014, from http://www.transportation.nebraska.gov/roadway-design/rw-design-man-chapters.htm

NDOT. (2010). *Road Design Guide*. Carson City, NV: Nevada Department of Transportation. Retrieved July 6, 2014, from http://www.nevadadot.com/About_NDOT/NDOT_Divisions/Engineering/Design/Design_Division_-_Road_Design_Guide.aspx

NHDOT. (1999). *Highway Design Manual*. Concord, NH: New Hampshire Department of Transportation. Retrieved July 6, 2014, from http://www.nh.gov/dot/org/projectdevelopment/highwaydesign/designmanual/

NHTSA. (2012). *Traffic Safety Facts, Indiana, 2008–2012*. National Highway Traffic Safety Administration. Retrieved June 1, 2014, from www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa/STSI/18_IN/2012/18_IN_2012.pdf

NJDOT. (2014). *Road Design Guide*. Trenton, NJ: New Jersey Department of Transportation. Retrieved July 6, 2014, from http://www.state.nj.us/transportation/eng/documents/RDM/

NMDOT. (2010–2014). *Plans, Specifications and Estimates (P. S. & E.) Bureau Design Directives*. Santa Fe, NM: New Mexico Department of Transportation. Retrieved July 6, 2014, from http://dot.state.nm.us/en/DesignDirectives.html

NYSDOT. (2014). *Highway Design Manual*. Albany, NY: New York State Department of Transportation. Retrieved June 18, 2014, from https://www.dot.ny.gov/divisions/engineering/design/dqab/hdm

ODOT. (2014). *Traffic Engineering Manual (TEM)*. Ohio Department of Transportation. Retrieved July 6, 2014, from http://www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/traffic/TEM/Pages/default.aspx

OklahomaDOT. (2009). *Roadway Design Standards & Specifications*. Oklahoma Department of Transportation. Retrieved July 6, 2014, from http://www.okladot.state.ok.us/roadway/standards.htm

Oregon DOT. (2012). *Highway Design Manual*. Salem, OR: Oregon Department of Transportation. Retrieved June 19, 2014, from http://www.oregon.gov/ODOT/HWY/ENGSERVICES/Pages/hwy_manuals.aspx#2012_English_Manual.pdf

Oregon DOT. (2013). *Traffic Manual* (2013 edition). Salem, OR: Oregon Department of Transportation. Retrieved June 19, 2014, from http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/traffic_manual_13.pdf

PennDOT. (2014). *Traffic Engineering Manual* (Publication No. 46): The Pennsylvania Department of Transportation. Retrieved June 21, 2014, from ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/PUB%2046.pdf

RIDOT. (2004). *Traffic Design Manual (Rhode Island DOT's Preferences and Practices)*. Providence, RI: Rhode Island Department of Transportation. Retrieved July 6, 2014, from http://www.dot.ri.gov/documents/doingbusiness/trafdesignmanual.pdf

SDDOT. (n.d.). *Road Design Manual*. Pierre, SD: South Dakota Department of Transportation. Retrieved July 7, 2014, from http://sddot.com/business/design/forms/roaddesign/Default.aspx

Sullivan, A., & Jones, S. L. (2007). *Traffic Signal Design Guide & Timing Manual*. Tuscaloosa, AL: The University Transportation Center for Alabama. Retrieved June 1, 2014, from http://www.dot.state.al.us/maweb/frm/ALDOT%20Traffic%20signal%20Design%20&%20Timing%20Manual.pdf

TDOT. (2003). *Traffic Design Manual*. Nashville, TN: Tennessee Department of Transportation. Retrieved July 8, 2014, from http://www.tdot.state.tn.us/chief_engineer/assistant_engineer_design/design/Traffic_Design_Manual.pdf

TRB. (2010). *Roundabouts: An information guide, second edition* (NCHRP Report 672). Washington, DC: Transportation Research Board. Research Board. Retrieved June 7, 2014, from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_672.pdf

TXDOT. (2011). *Texas Manual on Uniform Traffic Control Devices (TMUTCD)*. Austin, TX: Texas Department of Transportation. Retrieved July 8, 2014, from http://www.txdot.gov/government/enforcement/signage/tmutcd.htm

TXDOT. (2013). *Roadway Design Manual*. Austin, TX: Texas Department of Transportation. Retrieved July 8, 2014, from http://onlinemanuals.txdot.gov/txdotmanuals/rdw/rdw.pdf

UDOT. (2009). *Utah Manual on Uniform Traffic Control Devices for Streets and Highways*. Salt Lake City, UT: Utah Department of Transportation. Retrieved June 21, 2014, from http://www.udot.utah.gov/main/f?p=100:pg::1:T,V:4072

UDOT. (2011). *Roadway Design Manual of Instruction*. Salt Lake City, UT: Utah Department of Transportation. Retrieved June 21, 2014, from http://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:1498

VDOT. (2005). *Guideline for the Installation of Marked Crosswalks*. Richmond, VA: Virginia Department of Transportation. Retrieved June 22, 2014 from www.virginiadot.org/business/resources/Marked_20Crosswalks_20Final_20Guidelines_2012-14-05.pdf

VTrans. (2002). *Vermont Pedestrian and Bicycle Facility Planning and Design Manual*. Montpelier, VT: Vermont Agency of Transportation. Retrieved June 29, 2014, from http://vtransengineering.vermont.gov/sites/aot_program_development/files/documents/ltf/PedestrianandBicycleFacilityDesignManual.pdf

VTrans. (2004). *Guideline for the Installation of Crosswalk Markings and Pedestrian Signing at Marked and Unmarked Crossings*. Montpelier, VT: Vermont Agency of Transportation. Retrieved June 22, 2014, from http://vtransengineering.vermont.gov/sites/aot_program_development/files/documents/highway/TrafficOpsCrosswalk_Guidelines_2004.pdf

WisDOT (2004a). *Traffic Guidelines Manual*. Madison, WI: Wisconsin Department of Transportation. Retrieved June 24, 2014, from http://trust.dot.state.wi.us/extntgtwy/dtid_bho/extranet/manuals/tgm/index.shtm

WisDOT. (2004b). *Wisconsin Bicycle Facility Design Handbook*. Madison, WI: Wisconsin Department of Transportation. Retrieved June 24, 2014, from www.dot.wisconsin.gov/projects/state/docs/bike-facility.pdf

WisDOT. (2010). *Wisconsin Guide to Pedestrian Best Practices*. Madison, WI: Wisconsin Department of Transportation. Retrieved June 24, 2014, from http://www.dot.wisconsin.gov/projects/state/ped-guide.htm

WSDOT. (2011). *Traffic Manual*. Olympia, WA: Washington State Department of Transportation. Retrieved June 24, 2014 from www.wsdot.wa.gov/Publications/Manuals/M51-02.htm

WSDOT. (2013). *Design Manual*. Olympia, WA: Washington State Department of Transportation. Retrieved June 22, 2014, from http://www.wsdot.wa.gov/Publications/Manuals/M22-01.htm

WVDOT. (2011). *Traffic Engineering Directives (TEDs)*. Charleston, WV: West Virginia Department of Transportation. Retrieved July 8, 2014, from http://www.transportation.wv.gov/highways/traffic/Pages/TrafficEngineeringDirectives.aspx

WYDOT. (2014). *WYDOT Road Design Manual*. Cheyenne, WY: Wyoming Department of Transportation. Retrieved July 10, 2014, from http://www.dot.state.wy.us/home/engineering_technical_programs/manuals_publications/road_design_manual.html

Zegeer, C. V., Seiderman, C., Lagerwey, P., Cynecki, M., Ronkin, M., & Schneider, R. (2002a). *Pedestrian Facilities User Guide—Providing Safety and Mobility* (Publication No. FHWA-RD-01-102). Retrieved June 17, 2014, from http://www.fhwa.dot.gov/publications/research/safety/01102/

Zegeer, C. V., Stewart, J. R., Huang, H. H., & Lagerwey, P. A. (2002b). *Safety effects of marked vs. unmarked crosswalks at uncontrolled locations: Executive summary and recommended guidelines* (Publication No. FHWA-RD-01-075). McLean, VA: Federal Highway Administration. Retrieved June 1, 2014 from, www.pedbikeinfo.org/collateral/PSAP%20Training/gettraining_references_Effects_Un_MarkedCrosswalks_Summary.pdf

Zegeer, C. V., Stewart, J. R., Huang, H. H., Lagerwey, P. A., Feaganes, J., & Campbell, B. J. (2005). *Safety effects of marked versus unmarked crosswalks at uncontrolled locations: Final report and recommended guidelines* (Publication No. FHWA-HRT-04-100). McLean, VA: Federal Highway Administration. Retrieved June 1, 2014, from www.fhwa.dot.gov/publications/research/safety/04100/

Zegeer, C., Nabors, D., Lagerwey, P., Sundstrom, C., Lovas, D., Huber, T., ... Bushell, M. (2013). *PEDSAFE 2013: Pedestrian Safety Guide and Countermeasure Selection System*. Retrieved June 17, 2014, from http://pedbikesafe.org/PEDSAFE/index.cfm

(From CDOT (2005) *Roadway Design Guide*)

The following are the criteria set in the Roadway Design Guide 2005 of the Colorado Department of Transportation and Development (CDOT).

Traffic Volume in	Recommended
< 6,700 vpd	Table 14-11
6,700 – 12,000 vpd	Table 14-12
>12,000 vpd	Table 14-13

vpd = vehicles per day

Table 14-10 Referral Table for Midblock Crossing Treatments

14.3.9.3 GUIDANCE FOR TRAFFIC CONTROL SELECTION AT MIDBLOCK CROSSINGS

For these guidelines, roadways were stratified into low-, medium-, and high-volume. The threshold volume for low- to medium-volume is determined using the amount of time a pedestrian can expect to wait for an adequate gap in traffic to cross the street. The medium- to high-volume threshold is based upon a midblock crossing safety study prepared by the University of North Carolina's Highway Safety Research Center (CTDOT, 2009). Depending on whether the street being crossed is low, medium or high volume, the corresponding value listed in Table 14-10, would be referenced to determine the recommended traffic control devices for the crossing.

The following general notes should be considered when using Tables 14-11, 14-12, and 14-13.

General notes for applying the Crossing Treatment Guidelines Matrices:

Each column in the table represents a package of traffic control devices recommended for the specific crossing condition.

The designation of "YES" for the median assumes there is potential for installing a raised median at the crossing location and that one will be installed. Raised medians that can be used as pedestrian refuges (6 feet wide or wider in the direction of the roadway cross-section) will allow for less restrictive motor vehicle traffic controls to be used in conjunction with the midblock crossings. Wider refuge islands, 10 feet or more, should be considered to accommodate bicycle with trailers and recumbent bicycles.

1. On multi-lane roadways with medians on the approach, crossing signage for motorists should be placed in the medians as well as on the side of the roadway.
2. The use of angled cuts through the median (sometimes referred to as Danish offsets) should be considered at all crossings with raised medians for two reasons. First, the offset through the median directs the path users' attention toward the traffic about to be crossed. Secondly, of particular importance when using these tables for shared use path intersections, by providing an angled cut through the median, longer users (tandems, bicycles with trailers) may be better accommodated than in a narrower median.
3. When advance yield lines are used on the approach roadways they should be used in conjunction with solid lane lines. The lane lines should extend a distance equal to the stopping sight distance back from the yield lines. This is to enable law enforcement officers to determine when a motorist fails to yield when he could have done so.
4. On six-lane, undivided roadways, strong consideration should be given to providing a signalized crossing of the roadway for pedestrians. Until such time as this can be achieved, aggressive channelization should be used to divert pathway users to the nearest safe crossing.
5. This guidance assumes that lighting will be provided for crossings to be used at night.

Lanes	2 - lanes						4 - lanes					
Median	No			Yes			No			Yes		
Speed	30 mph	35-40 mph	45 mph	30 mph	35-40 mph	45 mph	30 mph	35-40 mph	45 mph	30 mph	35-40 mph	45 mph
Marked Crosswalks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pedestrian Crossing Sign (W11-2) w/ Arrow (W16-7p)[2]	✓		✓	✓	✓			✓	✓			✓
Advance Ped Xing Sign[2] (W1-2)	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Yield Here to Ped Signs (R1-5)[3]		✓	✓			✓			✓	✓	✓	✓
Advance yield lines[4]		✓	✓			✓	✓	✓	✓	✓	✓	✓
Rapid Rectangular Flashing Beacon			✓					✓	✓			✓

[1] Assumes a K factor of 0.097
[2] *The Combined Bicycle/Pedestrian Crossing warning sign may be used at shared use path crossings of roadways. Strong Yellow Green may be used for this sign.*
[3] *MUTCD* 2B.11
[4] Placed 20-50 feet in anvance of the crosswalk (Section 3B.16)

Table 14-11 Roadway Volume less than 650 Vehicles per hour, vph (6,700 vehicles per day[1], vpd)

Lanec	2 - lanes						4 - lanes						6 - lanes
Median	No			Yes			No			Yes			No or Yes
Speed	30 mph	35-40 mph	45 mph	30 mph	35-40 mph	45 mph	30 mph	35-40 mph	45 mph	30 mph	35-40 mph	45 mph	All
Marked Crosswalks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pedestrian Crossing Sign (W11-2) w/ Arrow (W16-7p)[2]	✓			✓		✓	✓	✓			✓		
Ped Xing Sign (advance)[2]	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Yield Here to Ped Signs (R1-5)[3]		✓			✓	✓	✓	✓		✓	✓		
Advance yield lines[4]		✓			✓	✓	✓	✓		✓	✓		
Stop Line			✓						✓			✓	✓
Rapid Rectangular Flashing Beacon						✓	✓	✓			✓		
Pedestrian Hybrid Signals[5]			✓						✓			✓	✓

[1] Assumes a K factor of 0.097
[2] *The Combined Bicycle/Pedestaian Crossing warning sign may be used at shared use path crossing of roadways. Strong Yellow Green may be used for this sign.*
[3] *MUTCD* 2B.11
[4] Placed 20-50 feet in anvance of the crosswalk (Section 3B.16)
[5] MUTCD Chapter 4.F

Table 14-12 Roadway Volume greater than 650 vph[1] (6) vph (6,700 vpd[1], and less than 1,150 (12,000 vpd)

Lanes	2 - lanes						4 - lanes						6 - lanes
Median	No			Yes			No			Yes			No or Yes
Speed	≤ 30 mph	35-40 mph	≥ 45 mph	≤ 30 mph	35-40 mph	≥ 45 mph	≤ 30 mph	35-40 mph	≥ 45 mph	≤ 30 mph	35-40 mph	≥ 45 mph	All
Marked Crosswalks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
/Pedestrian Crossing Sign (W11-2) w/ Arrow (W16-7p)[2]	✓			✓	✓			✓	✓	✓	✓		
Ped Xing Sign (advance)[2]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Yield Here to Ped Signs (R1-5)[3]		✓			✓	✓	✓			✓	✓		
Advance yield lines[4]		✓			✓	✓	✓			✓	✓		
Stop Line[5]			✓					✓	✓			✓	✓
Rapid Rectangular Flashing Beacon						✓	✓			✓	✓		
Pedestrian Hybrid Signals[5]			✓					✓	✓			✓	✓

[1] Assumes a K factor of 0.097
[2] *The Combined Bicycle/Pedestrian Crossing warning sign may be used at shared use path crossing of roadways. Strong Yellow Green may be used for this sign.*
[3] *MUTCD* 2B.11
[4] Placed 20-50 feet in anvance of the crosswalk (Section 3B.16)
[5] *MUTCD* Chapter 4.F

Table 14-13 Roadway Volume greater than 1,150[1] vph (12,000 vpd)

APPENDIX B: MIDBLOCK PEDESTRIAN CROSSING TREATMENTS

(From Section 3.8.6, FDOT (2014b) *Traffic Engineering Manual*)

1. For all midblock crosswalks, a 10-foot wide Special Emphasis Crosswalk markings shall be used, as shown in *the Department's Design Standards, Index No. 17346*.
2. For many situations, a marked crosswalk alone may not be sufficient. Adding a crosswalk alone will not make crossings safer, nor will they necessarily result in more vehicles stopping for pedestrians. Other facility enhancements should be considered in conjunction with a marked crosswalk such as curb extensions, raised crosswalks, speed reduction treatments, additional signing and marking, flashing beacons, or signalized control. The *Department's Design Standards, Index No. 17346* provides three possible configurations of treatments for midblock crossings. Additional guidance on the application of selected signing, marking, and control treatments is provided through the remainder of this section. Additional treatments, not included in this section, may also be appropriate depending upon the individual site characteristics.
3. For locations with sufficiently high pedestrian volume (where signal warrants are met), consideration may be given to providing a pedestrian bridge or tunnel in lieu of an at-grade marked midblock crossing. For further information, refer to the *AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities*.
4. Pedestrian Traffic Control Signal
   a. When pedestrian volumes are of a sufficient level to meet signal warrants, a pedestrian traffic control signal may be installed to serve this demand. Applicable pedestrian signal warrants and installation guidelines are identified in Section 4C.05 of the MUTCD. Considerations for a pedestrian traffic control signal at a midblock location should include availability of adequate gaps for pedestrians to cross the roadway. In some cases a pedestrian signal may not be needed at the study location if adjacent coordinated traffic control signals consistently provided gaps of adequate length for pedestrians to cross the roadway. The Department's MUTS provides additional guidance on conducting Pedestrian Group Size and Vehicle Gap Size studies.
   b. For locations where signalized control is selected for the pedestrian crossing, additional coordination for the crossing location is required with the District Access Management Committee and the District Traffic Operations Engineer.
   c. For six-lane roadways or crossing distances exceeding 80 feet, a two stage pedestrian crossing should be considered where the proposed crossing will be controlled by a warranted pedestrian signal. A two-stage pedestrian crossing may have a lesser impact to vehicle delay (compared to a single crossing) since the signal serves each direction independently while the median serves as a refuge area for pedestrians to wait prior to completing their crossing.
5. Pedestrian Hybrid Beacon
   a. A possible alternative to the pedestrian traffic signal is the "Pedestrian Hybrid Beacon". Chapter 4F of the MUTCD provides volume warrants and additional guidance on the use of Pedestrian Hybrid Beacon where pedestrian volumes do not meet the warrants for a pedestrian traffic signal under Section 4C.05 of the MUTCD.
6. Supplemental Beacons For locations where full pedestrian traffic signals are not warranted, supplemental beacons may be considered to provide additional emphasis of the crosswalk and the presence of pedestrians. Two options are currently available for use: standard flashing yellow warning beacons and Rectangular Rapid Flashing beacons.

   a. Flashing Yellow Warning Beacons

- The use of flashing yellow warning beacons may provide additional emphasis of the crossing location by supplementing the appropriate midblock crossing warning or regulatory signs where pedestrian signals are not warranted. When used, beacons shall meet the requirements of Chapter 4L of the MUTCD. **Any flashing yellow warning beacons installed at a new crosswalk at an uncontrolled location must use pedestrian actuation, as to elicit a more effective response from motorists than continuously flashing beacons.**
- Beacons may be cond either overhead or side mounted; however, the preferred configuration is a side, post-mounting to avoid drivers confusing the beacons for a flashing traffic signal.
- When post mounted, a configuration of two vertically aligned warning beacons is recommended. These beacons should be operated in an alternating flash pattern.
- When beacons are overhead mounted, an internally illuminated pedestrian crossing sign should be used in conjunction with the beacons.

   b. Rectangular Rapid Flashing Beacons (RRFB)

- Experimentation in St. Petersburg, Florida and other locations throughout the U.S. have found promising results from the use of RRFBs, used in conjunction with standard pedestrian regulatory and warning signs. FHWA has issued an interim approval of this treatment *(IA-11)*.
- The rectangular beacons are provided in pairs below the PEDESTRIAN CROSSING warning sign ***(W11-2)*** and operate in a "wig-wag" pattern upon activation by the pedestrian. When used, the beacons must be pedestrian activated, using approved detectors (such as pushbuttons or passive detection devices) that meet ADA requirements for accessibility. An example of the rectangular rapid flashing beacon treatment is shown in ***Figure 3.8.3***. Detailed conditions of use, including sign/beacon assembly, dimensions and placement, and flashing rates are provided in the July 16, 2008 interim approval memorandum (***IA-11***) by FHWA.

7. In-Roadway Lighting
   a. ***Section 4N.02 of the MUTCD, In-Roadway Pedestrian Warning Lighted at Crosswalks*** establishes federal standards by which lighted (illuminated) pedestrian crosswalk edge lines can be installed and operated. Additional guidance and support are provided in ***Section 4N.02 of the MUTCD*** which may be used for the installation and operation of lighted in-roadway pedestrian crosswalks. These additional provisions may be reviewed and considered on a lighted pedestrian walkway.
   b. In-roadway warning lights shall not be used where YIELD or STOP signs, or traffic signals are present.
8. Supplemental Signing and Markings
   a. To provide additional emphasis of the requirement to stop for pedestrians in the crosswalk, a stop line and associated STOP HERE FOR PEDESTRIANS (***R1-5 series***) sign may be used. This treatment is not to be used in combination with other active treatments such as the Pedestrian Hybrid Beacon.

Figure 3.8.3 Rectangular rapid flashing beacons.

- *If used, the stop line shall be placed 40 ft in advance of the midblock crosswalk. See* ***Department's Design Standards, Index No. 17346***. Where a stop line is used, parking should be prohibited in the area between the stop line and the crosswalk.
- *If a stop line is provided, the corresponding STOP HERE FOR PEDESTRIANS (****R1-5 series****)* sign shall be provided. The ***Department's Design Standards, Index No. 17346*** illustrates the placement of these signs. ***Section 2B.11 of the MUTCD*** provides additional guidance on the placement of the R1-5 series sign. At locations where the ***R1-5*** series sign is used in advance of the crosswalk, the PEDESTRIAN CROSSING warning sign (***W11-2***) shall not be post mounted at the crosswalk location; however the W11-2 sign may be mounted overhead at the crosswalk location.
- *An ADVANCE PEDESTRIAN CROSSING warning sign (****W11-2****)* with supplemental AHEAD plaque shall be used in combination with the **R1-5 series** sign. The ***Department's Design Standards, Index No. 17346*** shall be used for mounting locations of advance **W11-2** signs as related to approach speeds.
  b. IN-STREET PEDESTRIAN CROSSING sign (***R1-6 or R1-6a***) may be used on low speed roadways to remind road users of laws regarding right-of-way at an unsignalized pedestrian crosswalk. An IN-STREET PEDESTRIAN CROSSING sign should not be placed in advance of a crosswalk to educate road users about the State law prior to reaching the crosswalk, nor should it be installed as an educational display along the highway that is not near any crosswalk. Additional information is provided in ***Section 2B.12 of the MUTCD***.
- If used, the IN-STREET PEDESTRIAN CROSSING signs shall be placed in the roadway at the crosswalk location on the center line, on a lane line, or on a median island. The IN-STREET PEDESTRIAN CROSSING sign shall not be post-mounted on the left-hand or right-hand side of the roadway.

APPENDIX C: LOUISIANA CRITERIA FOR INSTALLATION OF MARKED CROSSWALKS

(From LADOTD (2012)
Traffic Engineering Manual)

The following are the criteria set in the Traffic Engineering Manual of the Louisiana Department of Transportation and Development (LADOTD).

3B.2.4 REQUIREMENTS FOR ALL CROSSWALKS

A crosswalk may be installed when the following criteria are met:

1. Connect to a sidewalk on each end of the crosswalk unless associated with a pedestrian generator.
2. Intersection must meet ADA compliance.
3. Street parking must be restricted adjacent to the crosswalk. (Typically for a minimum of 50′ in advance.)
4. Adequate sight distance of pedestrians by motorists exists and adequate sight distance of motorists by pedestrians exists.
5. Volume requirements as defined below.

3B.2.6 UNCONTROLLED APPROACH AT AN INTERSECTION

A. May install if:

1. There are a minimum of 20 pedestrians crossing in a 2 hour period during any 24 hour period and the pedestrians have fewer than 5 gaps in traffic per 5 minute period; or
2. Engineering judgment indicated a need.

B. Do not install if:

1. Posted speeds exceed 40 mph;
2. On a roadway with 4 or more lanes:
   a. without a raised median or crossing island that has (or will soon have) an ADT of 12,000 or more;
   b. with an ADA compliant raised median or crossing island that has (or will soon have) an ADT of 15,000 or more;
3. If engineering judgment indicates.

3B.2.7 MIDBLOCK CROSSWALKS

National studies have been conducted on marked midblock crosswalks versus unmarked crosswalks. These studies have shown that pedestrians pay more attention when crossing the street when there is no marked crosswalk at a midblock location. Care must be exercised when determining if a midblock crossing will be marked.

A. May install if:

1. There are 40 or more pedestrians that cross during a one hour period or 25 or more cross per hour for 4 consecutive hours and fewer than 5 gaps in traffic during the peak 5 minute period; and
2. The Average Daily 2 way traffic is above 3500 vehicles per day; or
3. Engineering judgment indicated a need.

B. Do not install if:

1. Another crosswalk exists within 600′; or
2. Posted speeds exceed 40 mph; or
3. If engineering judgment indicates.

3B.2.8 CONTROLLED APPROACH AT AN INTERSECTION

A. May install if:

1. There are a minimum of 20 pedestrians crossing in a 2 hour period during any 8 hour period; or
2. If engineering judgment indicates a need.

Note: If there is a large number of turning vehicles that conflict with the pedestrian movements, then counter-measures such as protected only turns at a signalized intersection should be considered.

7A.2.3 SCHOOL CROSSWALKS

A School Crosswalk shall be warranted when the School Warning Sign Assembly is warranted and the volume of school children crossing the state route exceeds 10 during a period extending from not earlier than 45 minutes before school starts until 15 minutes after school starts or a period from 15 minutes before the end of school to 45 minutes after school ends.

A School Crosswalk shall not be installed:

1. within 600 ft of another school crosswalk or a pedestrian crosswalk
2. at any location that has inadequate stopping sight distance
3. where approach speeds exceed 50 mph
4. for colleges, universities and preschools/daycares
5. for loading and unloading zones

7A.2.4 REDUCED SCHOOL SPEED ZONES

A Reduced School Speed Zone may be installed for schools where the School Warning Sign Assembly is warranted.

7A.2.5 FLASHING SCHOOL SIGNS

DOTD will not install or maintain flashing beacon signs at schools. The school, school board or local government may complete a Warning Sign & School Sign with Flashing Beacon Permit and submit to the appropriate District Office. The sign post shall be break away.

APPENDIX D: PENNDOT ADDITIONAL SIGNAL WARRANTS AND MINIMUM REQUIREMENTS FOR NEW MIDBLOCK INSTALLATIONS

(From PennDOT (2014)
Traffic Engineering Manual)

WARRANT PA-1, ADT VOLUME WARRANT

An "ADT volume warrant" is added in Section 212 and may be used in addition to the nine warrants contained in Sections 4C.02 through 4C.10 of the MUTCD (relating to Warrants 1 through 9). This warrant must apply at a proposed intersection, an intersection revised by a highway construction project, or at the driveway of a proposed commercial or residential development where vehicle counts cannot be taken. If a traffic-control signal is installed under this warrant, a traffic count must be taken within 6 months of the opening of a development or within 2 years of the opening of a highway. If the traffic volumes do not satisfy this warrant, or one or more of the other nine warrants, consideration should be given to removing the traffic-control signal and replacing it with appropriate alternative traffic-control devices, if any are needed.

This warrant is satisfied when the estimated ADT volumes on the major street and on the higher volume minor street or driveway approach to the intersection, when projected using an accepted procedure such as put forth in the latest Trip Generation Manual published by the Institute of Transportation Engineers, equals or exceeds the values in either Condition A or Condition B of the tables found within the warrant.

See Section 212 at http://www.pacode.com/secure/data/067/chapter212/s212.302.html for full details on this warrant [The section is presented below.]

§ 212.302. TRAFFIC-CONTROL SIGNALS

a. *Flashing operation of traffic-control signals*. During flashing operation, a minimum of two vehicular signal heads on each approach must be flashed for the through movement. Any other signal heads may be blanked out.
b. *Warrants*. In addition to the criteria in the MUTCD, the following applies:
    1. *Traffic volumes*. The traffic volume for channelized right-turn movements may not be included in any warrant analysis.
    2. *Vehicle crashes*. The five or more reported crashes within a 12-month period for Warrant 7 in the MUTCD (relating to Warrant 7, crash experience) may include both reportable crashes, and nonreportable crashes that are documented in the police files, that occurred within a 12-month period during the most recent 3 years of available crash data.
    3. *Warrant 9, ADT volume warrant*.
        (i) An "ADT volume warrant" is added as "Warrant 9" and may be used in addition to the eight warrants contained in Sections 4C.02 through 4C.09 of the MUTCD (relating to

Condition A—ADT Volume Warrant

Number of Lanes for Moving Traffic on Each Approach		Estimated ADT*			
				Higher-Volume Minor Street (One Direction Only)	
Major Street	Minor Street	Major Street (Both Approaches)			
		100%	*70%***	*100%*	*70%***
1	1	10,000	7,000	3,000	2,100
2 or more	1	12,000	8,400	3,000	2,100
2 or more	2 or more	12,000	8,400	4,000	2,800
1	2 or more	10,000	7,000	4,000	2,800

Condition B—ADT Volume Warrant

Number of Lanes for Moving Traffic on Each Approach		Estimated ADT*			
				Higher-Volume Minor Street (One Direction Only)	
Major Street	Minor Street	Major Street (Both Approaches)			
		100%	*70%***	*100%*	*70%***
1	1	15,000	10,500	1,500	1,050
2 or more	1	18,000	12,600	1,500	1,050
2 or more	2 or more	18,000	12,600	2,000	1,400
1	2 or more	15,000	10,500	2,000	1,400

* Based on the volume projected to be present within 6 months of the opening of the development or within 2 years of the opening of the highway.

** May be used if the 85th percentile speed of the major street traffic exceeds 40 miles per hour or the intersection lies within the built-up area of an isolated community having a population of less than 10,000.

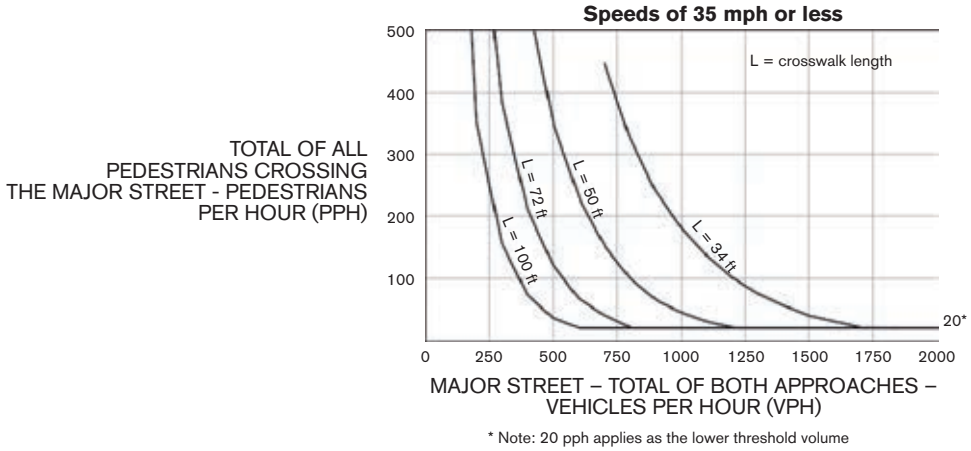


Exhibit 4-6 Guidelines for optional traffic signal warrant for midblock crossing and trail crossings (low-speed roadways).

Warrants 1 through 8). This warrant must apply at a proposed intersection, an intersection revised by a highway construction project, or at the driveway of a proposed commercial or residential development where vehicle counts cannot be taken. If a traffic-control signal is installed under this warrant, a traffic count must be taken within 6 months of the opening of a development or within 2 years of the opening of a highway. If the traffic volumes do not satisfy this warrant, or one or more of the other eight warrants, consideration should be given to removing the traffic-control signal and replacing it with appropriate alternative traffic-control devices, if any are needed.

(ii) This warrant is satisfied when the estimated ADT volumes on the major street and on the higher volume minor street or driveway approach to the intersection, when projected using an accepted procedure such as put forth in the Trip Generation Manual published by the Institute of Transportation Engineers, equals or exceeds the values in either Condition A or Condition B.

WARRANT PA-2, OPTIONAL TRAFFIC SIGNAL WARRANT FOR MIDBLOCK CROSSINGS AND TRAIL CROSSINGS

The guidelines below for the "Optional Traffic Signal Warrant for Midblock Crossings and Trail Crossings" (see Exhibit 4-6 and Exhibit 4-7) requires the approval of the appropriate District Traffic Engineer prior to performing the analysis. The intent of this warrant is to evaluate a traffic control device in locations where safety concerns may exist at a midblock or trail crossing. Since the Department will not permit the use of the Pedestrian Hybrid Beacon, the following will provide an alternative to handling these challenging unique situations. The traffic signal must be at least 100′ away from other intersections.

Additionally, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the marked crosswalk, or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance. Suitable standard signs and pavement markings should be installed in accordance with PennDOT Publication 149 "Traffic Signal Design Handbook."

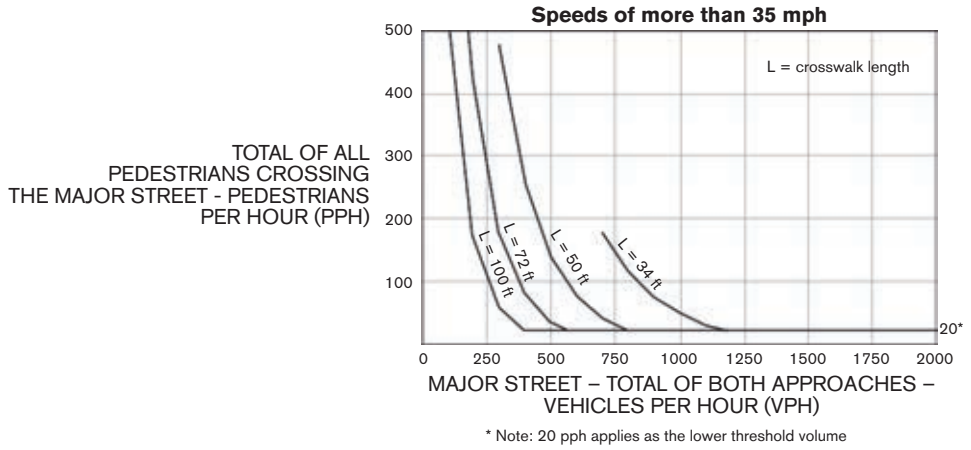
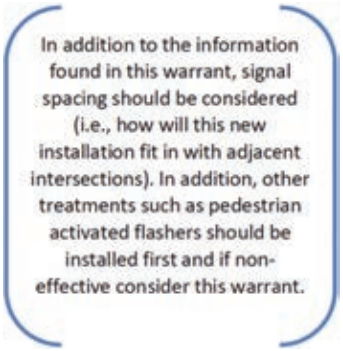


Exhibit 4-7 Guidelines for optional traffic signal warrant for midblock crossing and trail crossings (high-speed roadways).

If this is the only traffic signal warrant that is met then a reevaluation of this warrant shall occur every 5 years. If it is determined that the signal is no longer needed then the traffic signal removal process should begin.



MINIMUM REQUIREMENTS FOR NEW MIDBLOCK INSTALLATIONS

1. Speed Limit. The posted speed limit is 35 mph or less.
2. *Other Marked Crosswalks.* The nearest marked crosswalk on the same roadway is over 300 feet from the proposed crossing.
3. *Number of Pedestrian Crossings.* To qualify for midblock crosswalks, the minimum number of pedestrians crossing the street within 150 feet of the proposed crossing during an average day should be 80 or more during any 1 hour, or 40 or more during each of any 4 hours. However, if there is a high concentration of children, elderly or disabled pedestrians crossing the roadway in the vicinity of the proposed crossing, then these pedestrian volume warrants may be reduced 50 percent.
4. *Traffic Volume.* The maximum traffic volume on the roadway is 10,000 ADT, except on two-lane roadways the maximum traffic volume may be 15,000 ADT. If a raised median or pedestrian refuge island exists where pedestrians are protected from vehicular traffic, the maximum traffic volume applies to each segment of the pedestrian crossing, but no more than three travel lane may be crossed without a raised median or pedestrian refuge island. In order to consider a refuge island, the minimum width of the refuge island is 4 feet from face-of-curb to face-of-curb, but the preferred minimum width is 6 feet. Islands should have a cut through ramp to accommodate wheelchair users.
5. *Parking Restrictions.* To improve visibility, parking is not permitted within 75 feet of the crosswalk, unless a 6- to 8-foot curb extension (sometimes referred to as bulb outs, bump outs, neck downs, sidewalk expansions, etc.) is in place to improve pedestrian visibility. If angle parking is present, any curb extension should place the curb at the inside edge of the parking lane. Curb extensions not only improve visibility between motorists and the pedestrians, but they also reduce the length of the crosswalk and the pedestrian exposure. However, curb extensions may impede drainage, street cleaning and winter maintenance operations, and create a formidable object.
6. *Sight Distance.* The available sight distance between an approaching driver and a person anywhere within the proposed crosswalk must satisfy the following minimum values, where both the eye and the object (i.e., the pedestrian) are assumed to be 3.5 feet above the roadway.

	Minimum Sight Distance for a Corresponding Grade (feet)		
Speed Limit (mph)	**-6%**	**Level**	**+6%**
25	215	200	184
30	271	250	229
35	333	305	278

APPENDIX E: RECOMMENDATIONS FOR INSTALLING MARKED CROSSWALKS AT UNCONTROLLED LOCATIONS

(From Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations Final Report and Recommended Guidelines (Zegeer et al., 2002b))

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

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

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

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

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

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

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

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

Procedure to Identify the Need for Special Pedestrian Crossing Treatment at Uncontrolled Locations

(Adapted from Guideline for the Installation of Marked Crosswalks (VDOT, 2005)) and Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations Final Report and Recommended Guidelines (Zegeer et al., 2002b))

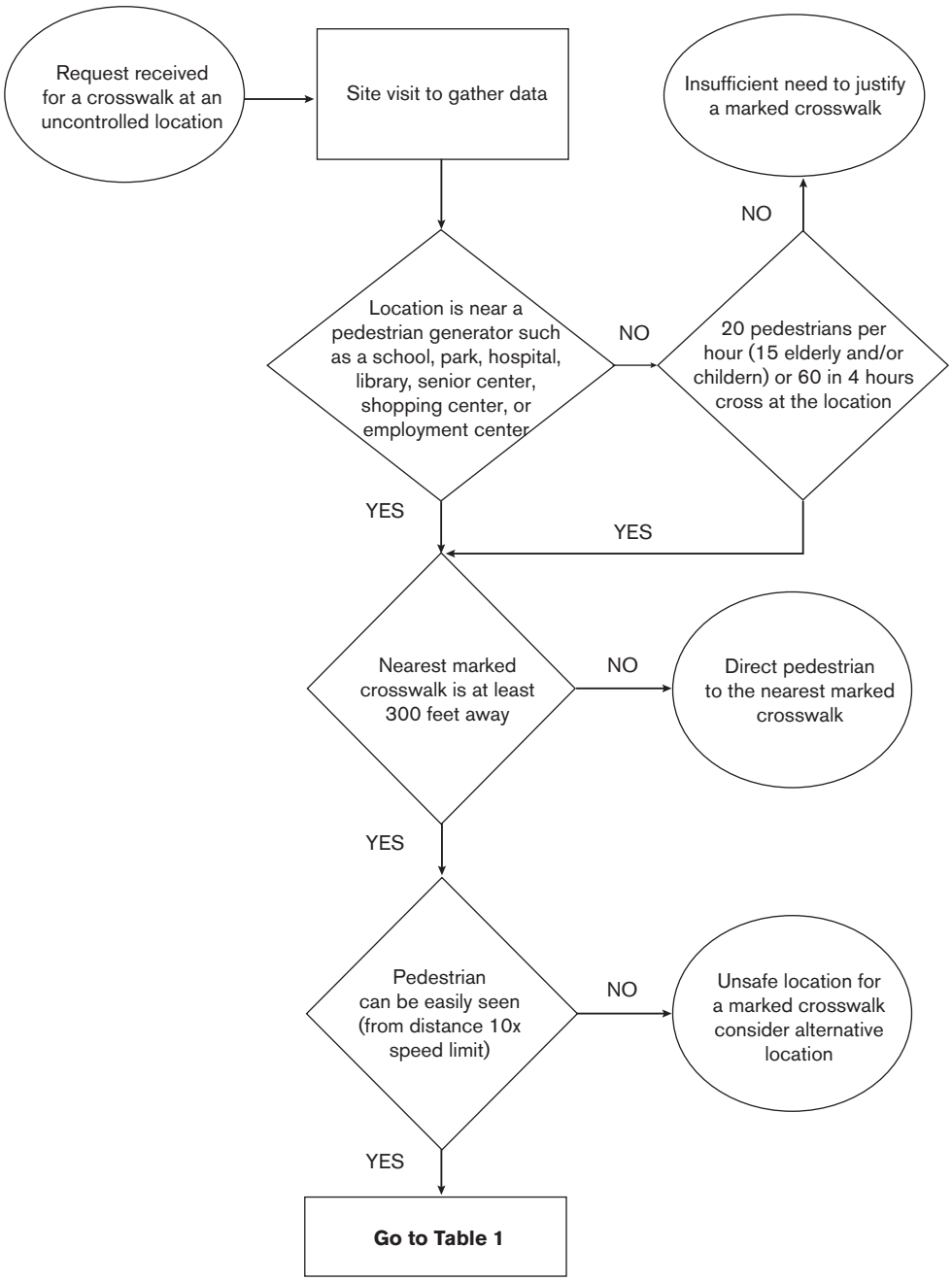


Table 1. Recommendations for Considering Marked Crosswalks and Other Needed Pedestrian Improvements at Uncontrolled Locations[a]

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

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

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

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

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

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

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

APPENDIX F: WORKSHEETS TO IDENTIFY TREATMENT OPTIONS TO IMPROVE PEDESTRIAN ACCESS OR SAFETY

(From Improving Pedestrian Safety at Unsignalized Crossings (Fitzpatrick et al., 2006))

WORKSHEET 1: PEAK-HOUR, 35 MPH (55 KM/H) OR LESS

Analyst and Site Information			
Analyst: Analysis Date: Data Collection Date:		Major Street: Minor Street or Location: Peak Hour:	
Step 1: Select worksheet (speed reflects posted or statutory speed limit or 85th percentile speed on the major street): a) Worksheet 1 – 35 mph (55 km/h) or less b) Worksheet 2 – exceeds 35 mph (55 km/h), communities with less than 10,000, or where major transit stop exists			
Step 2: Does the crossing meet minimum pedestrian volumes to be considered for a TCD type of treatment?			
Peak-hour pedestrian volume (ped/h), V_p		*2a*	
If *2a* ≥ 20 ped/h, then go to Step 3.			
If *2a* < 20 ped/h, then consider median refuge islands, curb extensions, traffic calming, etc. as feasible.			
Step 3: Does the crossing meet the pedestrian volume warrant for a traffic signal?			
Major road volume, total of both approaches during peak hour (veh/h), $V_{maj\text{-}s}$		*3a*	
Minimum signal warrant volume for peak hour (use *3a* for $V_{maj\text{-}s}$), SC $SC = (0.00021\ V_{maj\text{-}s}^2 - 0.74072\ V_{maj\text{-}s} + 734.125)/0.75$ OR $[(0.00021\ 3a^2 - 0.74072\ 3a + 734.125)/0.75]$		*3b*	
If *3b* < 133, then enter 133. If *3b* ≥ 133, then enter *3b*.		*3c*	
If 15th percentile crossing speed of pedestrians is less than 3.5 ft/s (1.1 m/s), then reduce *3c* by up to 50 percent; otherwise enter *3c*.		*3d*	
If *2a* ≥ *3d*, then the warrant has been met and a traffic signal should be considered if not within 300 ft (91 m) of another traffic signal. Otherwise, the warrant has not been met. Go to Step 4.			
Step 4: Estimate pedestrian delay.			
Pedestrian crossing distance, curb to curb (ft), L		*4a*	
Pedestrian walking speed (ft/s), S_p		*4b*	
Pedestrian start-up time and end clearance time (s), t_s		*4c*	
Critical gap required for crossing pedestrian (s), $t_c = (L/S_p) + t_s$ OR [(*4a*/*4b*) + *4c*)]		*4d*	
Major road volume, total both approaches or approach being crossed if median refuge island is present during peak hour (veh/h), $V_{maj\text{-}d}$		*4e*	
Major road flow rate (veh/s), $v = V_{maj\text{-}d}/3600$ OR [*4e*/*3600*]		*4f*	
Average pedestrian delay (s/person), $d_p = (e^{v\ 3c} - v\ t_c - 1) / v$ OR $[\ (e^{4f\ x\ 4d} - 4f\ x\ 4d - 1) / 4f\ ]$		*4g*	
Total pedestrian delay (h), $D_p = (d_p \times V_p)/3{,}600$ OR [(*4g*×*2a*)/3600] (this is estimated delay for all pedestrians crossing the major roadway without a crossing treatment – assumes 0% compliance). This calculated value can be replaced with the actual total pedestrian delay measured at the site.		*4h*	
Step 5: Select treatment based upon total pedestrian delay and expected motorist compliance.			
Expected motorist compliance at pedestrian crossings in region, Comp = high or low		*5a*	

Total Pedestrian Delay, D_p (from *4h*) and Motorist Compliance, Comp (from *5a*)	**Treatment Category** (see Descriptions of Sample Treatments for examples)
$D_p \geq 21.3$ h (Comp = high or low) OR 5.3 h ≤ D_p < 21.3 h and Comp = low	RED
1.3 h ≤ D_p < 5.3 h (Comp = high or low) OR 5.3 h ≤ D_p < 21.3 h and Comp = high	ACTIVE OR ENHANCED
D_p < 1.3 h (Comp = high or low)	CROSSWALK

WORKSHEET 2: PEAK-HOUR, EXCEEDS 35 MPH (55 KM/H)

Analyst and Site Information			
Analyst: Analysis Date: Data Collection Date:		Major Street: Minor Street or Location: Peak Hour:	
Step 1: Select worksheet (speed reflects posted or statutory speed limit or 85th percentile speed on the major street): a) Worksheet 1 – 35 mph (55 km/h) or less b) Worksheet 2 – exceeds 35 mph (55 km/h), communities with less than 10,000, or where major transit stop exists			
Step 2: Does the crossing meet minimum pedestrian volumes to be considered for a TCD type of treatment?			
Peak-hour pedestrian volume (ped/h), V_p		*2a*	
If *2a* ≥ 14 ped/h, then go to Step 3.			
If *2a* < 14 ped/h, then consider median refuge islands, curb extensions, traffic calming, etc. as feasible.			
Step 3: Does the crossing meet the pedestrian volume warrant for a traffic signal?			
Major road volume, total of both approaches during peak hour (veh/h), $V_{maj\text{-}s}$		*3a*	
Minimum signal warrant volume for peak hour (use *3a* for $V_{maj\text{-}s}$), SC $SC = (0.00035\ V_{maj\text{-}s}^2 - 0.80083\ V_{maj\text{-}s} + 529.197)/0.75$ OR $[(0.00035\ 3a^2 - 0.80083\ 3a + 529.197)/0.75]$		*3b*	
If *3b* < 93, then enter 93. If *3b* ≥ 93, then enter *3b*.		*3c*	
If 15th percentile crossing speed of pedestrians is less than 3.5 ft/s (1.1 m/s), then reduce *3c* by up to 50 percent; otherwise enter *3c*.		*3d*	
If *2a* ≥ *3d*, then the warrant has been met and a traffic signal should be considered if not within 300 ft (91 m) of another traffic signal. Otherwise, the warrant has not been met. Go to Step 4.			
Step 4: Estimate pedestrian delay.			
Pedestrian crossing distance, curb to curb (ft), L		*4a*	
Pedestrian walking speed (ft/s), S_p		*4b*	
Pedestrian start-up time and end clearance time (s), t_s		*4c*	
Critical gap required for crossing pedestrian (s), $t_c = (L/S_p) + t_s$ OR [(*4a*/*4b*) + *4c*)]		*4d*	
Major road volume, total both approaches or approach being crossed if median refuge island is present during peak hour (veh/h), $V_{maj\text{-}d}$		*4e*	
Major road flow rate (veh/s), $v = (V_{maj\text{-}d}/0.7)/3600$ OR [(*4e*/*0.7*)/*3600*]		*4f*	
Average pedestrian delay (s/person), $d_p = (e^{v\ tc} - v\ t_c - 1) / v$ OR $[\ (e^{4f\ x\ 4d} - 4f\ x\ 4d - 1) / 4f\ ]$		*4g*	
Total pedestrian delay (h), $D_p = (d_p \times V_p)/3{,}600$ OR [(*4g*×*2a*)/3600] (this is estimated delay for all pedestrians crossing the major roadway without a crossing treatment – assumes 0% compliance). This calculated value can be replaced with the actual total pedestrian delay measured at the site.		*4h*	
Step 5: Select treatment based upon total pedestrian delay and expected motorist compliance.			
Expected motorist compliance at pedestrian crossings in region, Comp = high or low		*5a*	

Total Pedestrian Delay, D_p (from *4h*) and Motorist Compliance, Comp (from *5a*)	**Treatment Category** (see Descriptions of Sample Treatments for examples)
$D_p \geq 21.3$ h (Comp = high or low) OR 5.3 h ≤ D_p < 21.3 h and Comp = low	RED
D_p < 5.3 h (Comp = high or low) OR 5.3 h ≤ D_p < 21.3 h and Comp = high	ACTIVE OR ENHANCED

APPENDIX G: SURVEY RESULTS ON PEDESTRIAN CROSSING TREATMENTS SELECTION CRITERIA

The following tables (Table G.1 through Table G.3) present the summary of the responses to the following survey question: Based on your experience in pedestrian crossing treatment, please select the criteria you use when identifying pedestrian treatments. Please select all that apply.

TABLE G.1
Frequency of Pedestrian Crossing Treatments Criteria Selection—Speed

		Responses					
	Treatment	30 mi/hr or Less	35 mi/hr	40 mi/hr	45 mi/hr or More	Not Used	Total
1	Advance Placement of Stop Line and Sign	5	5	4	3	3	20
2	Advance Signing	6	8	9	8	3	34
3	Automated Detection	1	2	2	1	3	9
4	Curb Extension	9	8	6	2	3	28
5	HAWK Beacon Signal	8	10	9	5	1	33
6	High-Visibility Signs and Markings	8	10	9	6	2	35
7	In-Roadway Warning Lights	1	1	1	1	3	7
8	In-Street Pedestrian Crossing Sign	8	7	3	1	1	20
9	Intersection Pedestrian Signals (Half Signals)	0	1	3	3	2	9
10	Median Refuge Island	7	10	9	7	1	34
11	Overhead Flashing Beacon (Continuous)	4	5	7	6	0	22
12	Overhead Flashing Beacon (Pushbutton)	3	4	5	5	3	20
13	Overhead Flashing Beacon(passive)	2	2	2	2	1	9
14	Overhead Signs	6	7	9	8	1	31
15	Pedestrian Beacon	3	4	4	4	3	18
16	Pedestrian Crossing Flags	0	0	0	0	2	2
17	Pedestrian Crosswalk Signal	4	4	5	5	4	22
18	Pedestrian Railings	2	2	3	2	3	12
19	Roadway Narrowing	5	6	3	2	3	19
20	Split Midblock Signal	1	1	1	1	5	9
21	Traffic Calming	8	5	2	1	1	17
22	Countdown Display at Signalized Intersection	9	9	9	9	3	39
23	Crosswalk Signs and Pavement Markings	12	12	9	7	1	41
24	Midblock Traffic Signal	5	5	6	6	1	23

TABLE G.2
Frequency of Pedestrian Crossing Treatments Criteria Selection—ADT

		Responses					
	Treatment	9,000 or Less	Between 9,000 and 12,000	Between 12,000 and 15,000	More than 15,000	Not Used	Total
1	Advance Placement of Stop Line and Sign	5	6	4	4	4	23
2	Advance Signing	7	10	9	9	2	37
3	Automated Detection	2	2	2	2	3	11
4	Curb Extension	9	8	7	6	3	33
5	HAWK Beacon Signal	5	7	8	7	2	29
6	High-Visibility Signs and Markings	8	10	10	9	2	39
7	In-Roadway Warning Lights	1	1	1	1	3	7
8	In-Street Pedestrian Crossing Sign	6	6	4	3	2	21
9	Intersection Pedestrian Signals (Half Signals)	1	1	3	3	2	10
10	Median Refuge Island	8	10	10	9	2	39
11	Overhead Flashing Beacon (continuous)	4	5	5	5	1	20
12	Overhead Flashing Beacon (pushbutton)	3	4	5	5	3	20
13	Overhead Flashing Beacon (passive)	2	2	2	2	1	9
14	Overhead Signs	6	8	7	6	2	29
15	Pedestrian Beacon	3	5	5	5	3	21
16	Pedestrian Crossing Flags	0	0	0	0	2	2
17	Pedestrian Crosswalk Signal	4	5	5	5	4	23
18	Pedestrian Railings	2	2	2	2	3	11
19	Roadway Narrowing	8	8	4	3	2	25
20	Split Midblock Signal	1	1	1	1	4	8
21	Traffic Calming	7	7	4	2	1	21
22	Countdown Display at Signalized Intersection	9	9	9	8	3	38
23	Crosswalk Signs and Pavement Markings	11	12	10	10	1	44
24	Midblock Traffic Signal	5	7	7	7	2	28

TABLE G.3
Frequency of Pedestrian Crossing Treatments Criteria Selection—Number of Lanes

	Treatment	Responses				
		Two Lanes	Three Lanes	Four or More Lanes with Raised Median	Four or More Lanes without Raised Median	Not Used
1	Advance Placement of Stop Line and Sign	5	4	4	4	3
2	Advance Signing	10	10	10	10	2
3	Automated Detection	1	1	1	1	3
4	Curb Extension	7	7	6	4	4
5	HAWK Beacon Signal	6	6	6	6	2
6	High-Visibility Signs and Markings	8	9	9	8	2
7	In-Roadway Warning Lights	1	1	1	1	2
8	In-Street Pedestrian Crossing Sign	5	3	2	2	2
9	Intersection Pedestrian Signals (Half Signals)	1	1	1	3	2
10	Median Refuge Island	1	4	8	6	2
11	Overhead Flashing Beacon (continuous)	3	4	7	7	0
12	Overhead Flashing Beacon (pushbutton)	4	4	5	5	2
13	Overhead Flashing Beacon(passive)	2	2	2	2	1
14	Overhead Signs	5	7	8	9	0
15	Pedestrian Beacon	4	4	4	5	3
16	Pedestrian Crossing Flags	0	0	0	0	2
17	Pedestrian Crosswalk Signal	4	4	5	5	3
18	Pedestrian Railings	1	1	3	2	2
19	Roadway Narrowing	4	4	3	4	2
20	Split Midblock Signal	0	1	1	1	3
21	Traffic Calming	7	5	2	2	1
22	Countdown Display at Signalized Intersection	8	8	8	8	3
23	Crosswalk Signs and Pavement Markings	11	11	10	9	2
24	Midblock Traffic Signal	4	4	6	6	2

APPENDIX H: SURVEY RESULTS ON ADVANTAGES, DISADVANTAGES, AND RECOMMENDATIONS ON THE USE OF PEDESTRIAN CROSSING TREATMENTS

The following is a list of advantages, disadvantages, and recommendations on the use of pedestrian crossing treatments as presented by the subjects.

1. Advance Placement of Stop Line and Sign

- In Maine, stop lines make little sense. Advance yield lines should always be used but aren't.
- Have only seen this on plans, not in action.
- Helps.
- CTDOT installs stop bars and stop signs in advance of crosswalks and maintain at least 4′ min. distance from stop bar to crosswalk.
- Reduces multiple threat crash issue, hard to see in snow conditions, maintenance is important.

2. Advance Signing

- Appropriate as a should condition.
- Cheap.
- CTDOT installs advance signs for crosswalks at uncontrolled locations. Advance signs are not installed for crosswalks at signalized or stop controlled locations.
- Good where sight distance is less than ideal, or ped crossing is unexpected.
- More signs mean less effect for all signs.
- Should be used when speed above 25 mph.
- Used in all pedestrian crossing installations.

3. Automated Detection

- Eliminates the issue of pedestrians not pushing the button, what happens if it fails.
- Installed first installation a few weeks ago with our first RRFB. Getting false detections.
- Maybe appropriate, may have maintenance and false-call concerns
- Only used this once. Had problems with it. Pedestrians were congregating but not necessarily to cross.
- Should be used for pedestrian detection at some locations.

4. Countdown Display at Signalized Intersection

- Appropriate as a standard, added maintenance costs and needs to be less visible to vehicular traffic.
- For signals with exclusive pedestrian walk phases, CTDOT is installing countdown pedestrian signals for new installations or major revisions.
- Helps bike/walkers adjust their approach speed.
- Pedestrians like the countdown and they seem to respond positively with fewer instances of pedestrians in the crosswalk when the signal changes.
- Pedestrians using the number to rush across intersection when time is too short for walking.
- Required in Minnesota.
- Retrofitting all pedestrian heads. Improved pedestrian compliance with signals.
- Should always be used for red AND green when pre-timed signals. Many other countries are way ahead of the US.

5. Crosswalk Signs and Pavement Markings

- Cost to upkeep, safety neutral treatment.
- CTDOT determines if crosswalk signs and pavement markings should be installed based on a review of volumes, crash data, speeds, pedestrian volume, pedestrian generators (ex. schools), roadway width, roadway curvature, roadway grade, stopping sight distance, distance to nearest traffic signal, distance to nearest crosswalk, and input from the town's Local Traffic Authority
- Markings are a struggle for us to keep visible thru winter/early spring, so we use ped sign with down arrow at every unsignalized marked crossing, and only at marked crossings. Unmarked crossings do not get down arrows, since drivers may not know whether the marking is missing or never there and may not know whether they are obliged to yield.
- MUTCD NEEDS to be changed, that a crosswalk is existing only if there is a sign. Piano or zebra marking is also necessary but should not by itself be enough since drivers cannot see them in winter and spring until May when repainted.
- Need to define or offer guidance on use of standard versus "enhanced"
- Useful.
- Use zebra markings in school areas and parallel lines in non-school areas. Signs consist of black on white rectangular-shaped signs.

6. Curb Extension

- Helpful.
- Installed more and more in communities in Manitoba, typically at school crosswalks.
- Maintenance concerns, doesn't always work well with bike facilities/tradeoffs.
- Site specific.
- Some towns in CT pursue "bump outs" at intersections to reduce the pedestrian crossing distance. However, this needs to be thoroughly reviewed for impacts to turning movements for the appropriate design vehicle and impacts to shoulder width and maintenance activities such as snow plowing.
- Used mostly in village settings. Not popular with plow drivers. Also a challenge to provide adequate truck turning radius. Curb extensions are not allowed to be mountable, for safety reasons. Curb extensions as built are often insufficient to get the ped out from behind parked cars.
- Yes!

7. HAWK Beacon Signal

- CTDOT is in the process of designing the first HAWK signal in Connecticut.
- Disadvantage has been motorist understanding of the operation.
- Only have one of these—an earmark project. Not a huge fan.
- Public doesn't understand wig-wag, not realizing the benefit of the HAWK. It's NOT A SIGNAL
- Site Specific
- Used in place of traffic calming.
- Yes!

8. High-Visibility Signs and Markings

- All of our pedestrian signs are FYG.
- Not important but cannot hurt.
- Questionable.
- Should be standard for 40 MPH or greater.

- These are typically reserved for unique situations and/or where additional emphasis is needed.
- These help drivers to identify the higher volume pedestrian crossings, and/or school crossings.

9. In-Roadway Warning Lights

- CTDOT has allowed Towns to install and maintain in-roadway warning lights at a few locations in the state. There are some concerns with maintenance due to weather and snow plowing.
- Maintenance Issues, short life cycle. Is it cost effective?
- Not as effective as overhead since snow plows damage them.
- Plowing/maintenance issues.
- Poor compliance w/motorists, short term wiring failure rates.

10. In-Street Pedestrian Crossing Sign

- CTDOT allows towns to install the in-street pedestrian crossing sign at unsignalized crosswalks provided it conforms to MUTCD, it is breakaway, and the Town is responsible for owning and maintaining the signs.
- Locals like these signs, difficult to maintain on the higher volume roads with higher speeds.
- Maintenance, can't be kept up in winter.
- Popular–probably helps.
- Should always be on median, and crosswalks without medians should not be marked.
- Site specific.
- Used once for the past two-months on a trial basis. Our policy indicates that they are to be used in conjunction with crossing guards only, and removed after the guard's shift. Will be deciding on continued use shortly.
- We allow these by permit to the municipality, and do not maintain them ourselves. Permit requires them to be removed daily, and in inclement weather. Seem to be quite effective. Get struck a lot, and don't last very long with heavy truck traffic even though they are only allowed midblock.

11. Intersection Pedestrian Signals (Half Signals)

- Do not know
- Not used.
- Used in a number of Manitoba communities, when warranted.

12. Median Refuge Island

- Maintenance/plowing
- Not aware that we've put any median refuges in for the express purpose of pedestrian crossing, unless you count roundabout splitter islands. Our Hawk already had a median, and we did put in the diagonal pathway to make pedestrians face traffic.
- Only considered when a median already exists on the road. I would like to try installing for the purposes of pedestrian safety in the future.
- Provides options for pedestrian timings.
- Should be required, with curb at all crosswalks and many other locations where pedestrians cross.
- Should be used more often.
- Site specific

13. Midblock Traffic Signal

- Can be used where motivated
- Generally avoided where possible.
- If warranted

14. Overhead Flashing Beacon (Continuous)

- Become ineffective in obtaining motorist compliance after long periods of driver exposure to seeing the device do the same thing.
- Loses effectiveness
- More visible to approaching traffic.
- Not important but cannot hurt
- Site specific, high installation cost

15. Overhead Flashing Beacon (Pushbutton)

- Installed where warranted.
- Not a huge fan of flashing beacons anymore, the RRFB is much more effective
- Not important but cannot hurt
- Not used.
- Site specific, high installation cost
- Somewhat more effective as there is meaning when the flash operation begins due to pedestrian presence.

16. Overhead Flashing Beacon (Passive)

- Not important but cannot hurt
- Site specific, high installation costs

17. Overhead Signs

- More visible to approaching traffic.
- Not important but cannot hurt
- Not typically installed however we are not opposed. We have a few cities who use them
- One installation in Manitoba on a trial basis. Will be deciding on continued use shortly.
- Site specific, consider after trial of other mitigation measures including ground mounted signing

18. Pedestrian Beacon

- Can add emphasis to a crossing, but difficult to develop criteria/practice on which crossings justify a beacon and which do not.
- RRFBs are effective, can be put overhead where needed, and don't lose effectiveness.
- Site specific, consider after trial of other mitigation measures including static sign

19. Pedestrian Crossing Flags

- Can be stolen, communities and community groups put these out in places and we're ok with that.
- Not currently used, would be reserved very unique & specific circumstances
- Not important but cannot hurt

20. Pedestrian Crosswalk Signal

- Installed where warranted.
- Of course

21. Pedestrian Railings

- at a few locations
- Not opposed but not typically used

- Used for pedestrian channelization as well as to protect against drop-offs

22. Roadway Narrowing

- Always if lanes more than 10 feet wide
- CTDOT considers this based on the FHWA guidance Add link to FHWA document http://safety.fhwa.dot.gov/provencountermeasures/fhwa_sa_12_013.htm
  Effective and benefits speed control and pedestrians
- Our roads are already pretty narrow for the most part. We do look at narrowing intersection approaches where practical.
- Typically applied concurrent with other measures
- Typically has the effect of vehicular speed reduction and thereby safer for pedestrian crossings when combined with other countermeasures

23. Split Midblock Signal

- If warranted, might consider a two separate signals

24. Traffic Calming

- Mostly used on local roads. We do have some "gateway treatments" on state highway approaches to villages.
- Should be primary application.
- VDOT has a Traffic Calming guidebook, available online
- Yes, most crosswalks should be secured to 20 mph speeds for 90%-iles

25. Other, Please Specify

- Have been a staple part of our safe routes to school program, and gaining popularity at non-school crosswalks. (Beacon envy).
- Maintenance concerns
- Provides excellent nighttime visibility of pedestrians for drivers
- Roundabouts, shared space and other such measures should be the primary form of management in developed areas—plus cycle track that also enhances walker mode safety.

APPENDIX I: SURVEY RESULTS ON HIGH-SPEED DIVIDED HIGHWAY PEDESTRIAN CROSSING TREATMENTS

A. PEDESTRIAN CROSSING TREATMENTS

1. Answers to the potential options in treating pedestrian/trail crossings at high-speed divided highways that are at signals

	Yes		No		
Question	**Response**	**%**	**Response**	**%**	**Total**
I. Do you recommend providing adequate pedestrian timings to cross the entire highway length?	9	82%	2	18%	11
II. As you know, treating this crossing with adequate pedestrian timings would delay vehicular traffic considerably. Do you consider this delay a major concern?	3	27%	8	73%	11

2. Recommendations on providing adequate pedestrian timings to cross the entire highway length?

1. In a high speed situation, I would rather have the ped cross the full width than wait in the median for the next cycle.
2. This would be a very rare situation for us. I'd probably lean towards two phase crossing if the median was sufficient. For our signalized crossings, we do a lot of "ped scrambles", not much concurrent phasing. We don't always provide full timing for diagonal cross.
3. Recommendation would be to accommodate this crossing when demand is present.
4. For signals where there is pedestrian actuated side street green, timing is based from curb line to curb line. Where there is pedestrian actuated exclusive walk phase, 7 seconds is provided for WALK, and then the pedestrian clearance time is based on curb line to the far side of the traveled way.
5. Yes, we always try to cross pedestrians across the entire street. Pedestrian delay is important too—most pedestrians will attempt to cross the entire length, and these signals normally have long cycle lengths, meaning 2+ minutes of wait time for pedestrians. Waiting creates safety issues for impatient peds.

3. Treating this crossing with adequate pedestrian timings would delay vehicular traffic considerably. Do you consider this delay a major concern?

1. Safety trumps congestion when the delays are not unreasonable and ped. Actuations are infrequent.
2. It is a factor/and the operational impact is a concern/issue—but it is something that must be dealt with.
3. It depends on if the intersection is part of a signal system or isolated.
4. It depends. Safety comes first, but we always have to contend with delay. Again, two phase crossing could help.
5. Provide this timing when there is a need, not at all times when pedestrian is not present
6. It is somewhat of a concern at some locations, however, pedestrian safety is important.
7. The only issue we have is with long pedestrian clearance phases in coordinated signal systems.
8. Pedestrian delay is important too—and what is considerably? We have crossed only to the median when considerably means backups that are unacceptable—I did not say LOS F—I said backups that are unacceptable. The backups and delay need to be incredibly bad for us to ever cross to a median.

4. If you indicated that this treatment is a concern, do you have ways to reduce its impact? If your answer is yes, please list the measures you take to reduce the adverse impact of this treatment all in one phase

1. While not considered a "major" concern, we at times have tried to process the high crossing clearance needs using both side street phases, when there are split (protected only) operations.
2. See above.
3. Sometimes only crossing 3 legs in extreme conditions.

B. REFUGE ISLAND

Having a refuge island built with curbs is not typically used on high-speed roadways with speeds equal to or greater than 50 mph. If you recommended providing a refuge island in the median, could you please answer the following questions?

1. Do you recommend providing a refuge island in the median?

- 6 out of 10 (6%) said yes and 4 (40%) said no.

2. Comments:

- In general yes. However, concrete barrier divided roadways are usually not conducive to further widening for refuge areas w/o loss of shoulders (undesirable compromise).
- On this type of facility some type of grade separation would be preferred and pursued if possible (high speed—50 MPH and up).
- Due to higher speeds, believe it is better to not "store" pedestrians in the median. May depend on the median width and treatment.
- Yes, if I were going for a two phase crossing.
- This can assist in mitigation crossing timing needs.
- This would depend on the median width that could be provided, the # of lanes, volumes, other roadway characteristics and would recommend review on a case by case basis. Could other options be pursued—alternate crossing location, pedestrian bridge?
- We do not use two-stage crossings in our state, but Refuge Island is helpful when pedestrians are crossing under no control.
- Not necessary, cross pedestrians the entire length.
- Only in more urban areas.

3. A description of the island and its components:

- Grass Island with mountable curbing around the nose, paved cut through, pedestrian pushbutton provided.
- Raised island with pedestrian ADA ramps.
- See VDOT Road & Bridge standards available online.

4. Please provide, an upper speed limit where a refuge island is not feasible:

- Greater than 55 mph, as that typically negates pedestrian presence (limited access roadways).
- 45 mph
- 40 mph
- This would be a site-specific decision.

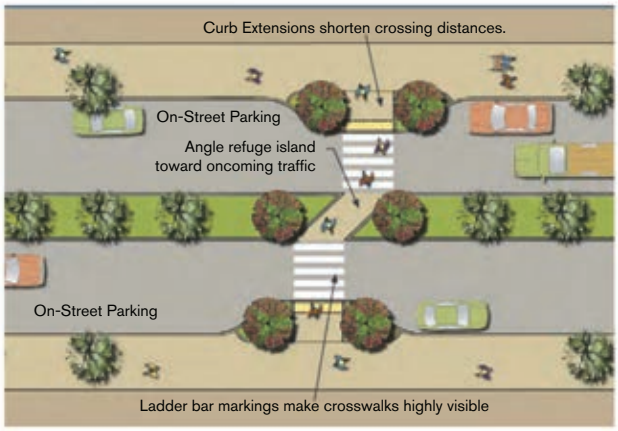


Figure J.1 Mid-Block Pedestrian Refuges Island
Source: HIDOT (2013)

Figure J.2 Grade-Separated Crossings
Source: www.campo-nc.us/BPSG/docs /NCDOT_on_Grade_Separated_Crossings.pdf

Figure J.3 HAWK Beacon Signal
Source: www.pedbikeimages.org/Mike Cynecki

Figure J.4 Grade-Separated Crossings
Source: www.IPFW.edu

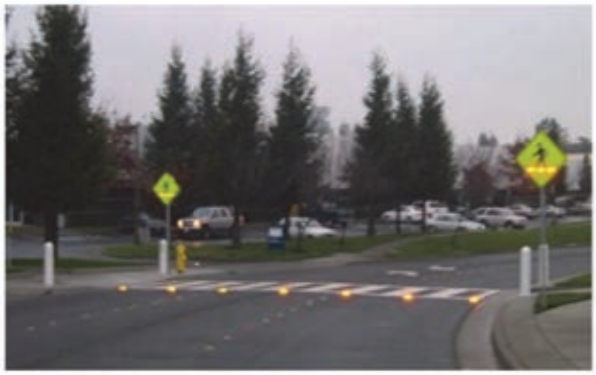


Figure J.5 In-Roadway Warning Lights (IRWLs)
Source: www.jimonlight.com

Figure J.6 Triple-four Crosswalks
Source: City of Stockton Public Works Department (2003)

Figure J.7 Intersections Bulbouts
Source: HIDOT (2013)

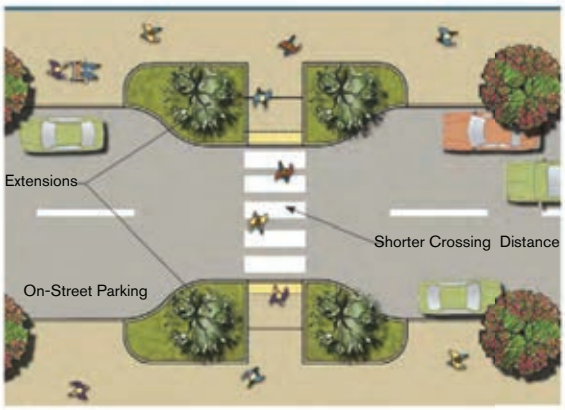


Figure J.8 Midblock Locations Bulbouts
Source: HIDOT (2013)

Figure J.9 Raised Crosswalks
Source: www.pedbikeimages.org/ Larry Shaeffer

Figure J.10 Pedestrian Crossing Flags
Source: http://www.kirklandwa.gov/depart/Public_Works/Transportation_and_Traffic/Pedestrian_Flags_-_FAQs.htm

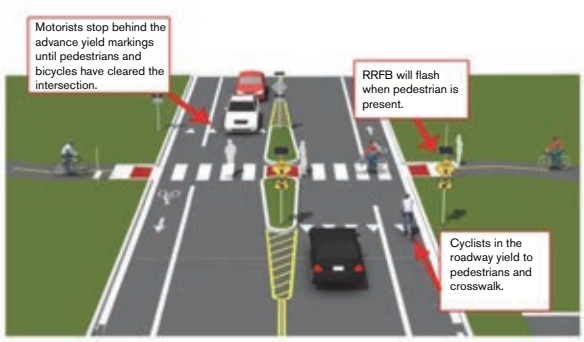


Figure J.11 Rectangular Rapid Flashing Beacon
Source: https://bloomington.in.gov/documents/viewDocument.php?document_id=7158

Figure J.12 Textured pavement Crosswalks
Source: Source: www.pedbikeimages.org/ Dan Burden and Max Bushell

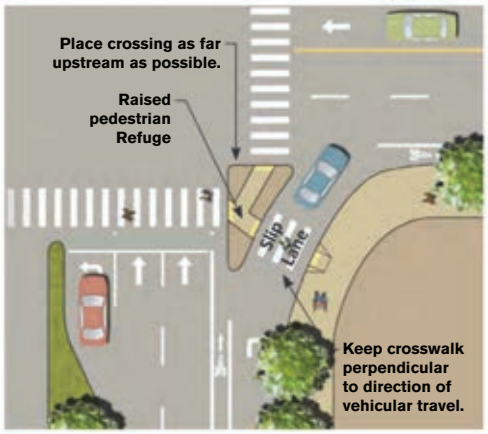
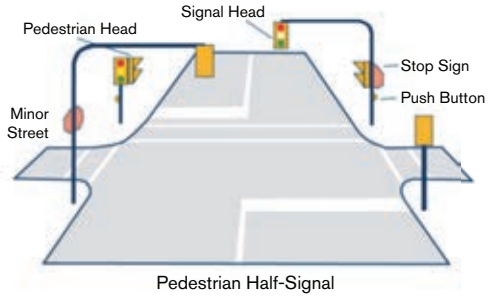


Figure J.13 Raised Pedestrian Refuge at Signalized Right-Turn slip Lane
Source: HIDOT (2013)



Half-Signals interrupt major street traffic only when activated by a pedestrian push-button.A typical configuration is shown above. (Halifax Regional Municipality)

Figure J.14 Intersection Pedestrian Signals (Half Signals)
Source:http://ottawa.ca/calendar/ottawa/citycouncil/trc/2010/04-07/ACS2010-COS-PWS-0001_Doc7_Countermeasure_EN.pdf

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,500 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at: http://docs.lib.purdue.edu/jtrp

Further information about JTRP and its current research program is available at: http://www.purdue.edu/jtrp

About This Report

An open access version of this publication is available online. This can be most easily located using the Digital Object Identifier (doi) listed below. Pre-2011 publications that include color illustrations are available online in color but are printed only in grayscale.

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