



RESEARCH & DEVELOPMENT

North Carolina Pedestrian Crossing Guidance

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Some of the guidance provided in this document is based on the 2009 version of the MUTCD. Future editions of the MUTCD may supersede recommendations or actions conveyed herein and should be consulted before making or implementing decisions.

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EXECUTIVE SUMMARY

The North Carolina Department of Transportation (NCDOT) is frequently faced with the decision of whether or not to provide a marked crosswalk at uncontrolled approaches for pedestrians, and of whether or not to install pedestrian signal heads at existing signalized intersections. Further, the question often arises of what supplemental treatments, in addition to crosswalk markings, may be appropriate or needed at un-signalized intersections or uncontrolled midblock crossing locations.

Oftentimes, specific guidance for provision of these pedestrian facilities is lacking. While the 2009 Manual of Uniform Traffic Control Devices (MUTCD) and existing NCDOT policies cover a variety of applications, there are still significant gaps in the available guidance. In an era of increasing emphasis on complete streets to ensure pedestrian needs are appropriately balanced with other transportation modes, and a focus on assuring an accessible transportation system to all road users, clear guidance is important.



The task of determining which crossing locations warrant the installation of pedestrian facilities is complex but can be approached in a systematic manner to provide benefits to users of the transportation network. This research was particularly focused on guidelines for NCDOT to evaluate the feasibility of including crosswalks and/or pedestrian signalization at signalized intersections and marked crosswalks on the approaches of uncontrolled intersections. Consistent and appropriate guidance can support decision making for whether or not the installation of pedestrian facilities at a particular crossing location provides a safe crossing for pedestrians and is the optimal use of improvement funds. The guidance allows for, and emphasizes the importance of, engineering judgment and some design flexibility while providing the necessary decision support for NCDOT staff in the crosswalk assessment process.

The primary deliverable of the project, the crosswalk assessment flowchart tool, is intended to be a self-contained, wall-mounted poster that fully describes most aspects of the evaluation and decision-making process. This report is intended to supplement that flowchart, providing background for the flowchart, and references to research and underlying data used to develop the guidance.

The guidelines principally consist of four parts: Step 1) Document Existing Characteristics / Signalized Crossing Assessment, Step 2) Unsignalized Crossing or Midblock Crossing Assessment, Step 3) Additional / Alternative Treatments Assessment, and Step 4) Pedestrian Hybrid Beacon (PHB) Assessment. Key inputs in the sequential crosswalk assessment flowchart are pedestrian and vehicular volumes, roadway

cross-section and design attributes, and vehicular speed, as well as various other considerations. The potential outcomes of the assessment process include recommendations for marking crosswalks, installing supplemental treatments, warranting signal or pedestrian hybrid beacon installation, as well as cases where no action is required. Throughout the process, all guidance for marking crosswalks and treatment installations are subject to the availability of funds to install and maintain the treatment.

The development of the guidelines was accomplished through the following tasks including a review of literature; survey of NCDOT, municipal, and state practices; compilation of literature and survey findings; and refinement of the process through collaboration with NCDOT. These research findings will guide future installations of pedestrian treatments with a consistent, repeatable process that will provide a safety benefit for users of the transportation network in North Carolina. While this report focuses towards NCDOT practices, it may serve as guidance for municipalities in North Carolina and perhaps outside the state as well.



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Pedestrian Crossing Guidance

0 INTRODUCTION

This guidebook is intended as supplemental information to a pedestrian crosswalk assessment flowchart tool developed for the North Carolina Department of Transportation (NCDOT), which lays out a series of steps to evaluate the need for treatments to assist pedestrians at potential crossing locations. That product will henceforth be referred to as “the Flowchart” in this document. The Flowchart was designed as a self-contained document; however, some users of the Flowchart may prefer additional detail to the notations provided. Therefore, this guidebook offers the same process that is laid out in the Flowchart, while offering additional resources and references to support the process. The Flowchart itself may be accessed on NCDOT’s website (www.ncdot.gov) and is designed to be printed as a 36 in. by 85 in. poster.



0.1 EVALUATE CROSSINGS BY APPROACH

The pedestrian crossing treatment evaluative process is designed to be applied at the approach level (i.e., each approach to the crossing should be considered individually) for each leg of an intersection or for mid-block crossing locations. While the guidance may also be applied to crossings of shared use paths, trails, or other locations where bicyclists may share the facility with pedestrians, it is important to note that the research supporting the guidance and Flowchart are based on pedestrian-only usage.

Crossing needs and considerations for bicyclists may differ: they are able to travel at speeds greater than pedestrians; space requirements on crossing islands or medians for any queuing or storage of bicyclists may be larger; lateral clearance needs may be wider to allow for the maneuverability of slower moving bicyclists who are more likely to weave to maintain balance; and sight distances for bicyclists approaching an intersection differ from pedestrians, due to differences in speed and stopping distance. Additional guidance on design considerations for shared use path crossings can be found in the *Guide for the Development of Bicycle Facilities*. (AASHTO, 2012)

0.2 GENERAL PRINCIPLES AND CONSIDERATIONS

There are several general principles and considerations for the use of this guide.

- Engineering judgement is always encouraged when considering the appropriateness of a desired crossing location, as well as what traffic control device(s), if any, may be suitable to assist pedestrians with crossing. While thresholds for factors are provided, particular consideration or

additional study may be necessary for sites near threshold values, or where special circumstances or special populations are present.

- Field investigations are strongly recommended to confirm site characteristics and input data, and to observe pedestrian and driver behaviors. In some cases, field visits may be required to collect data needed to move through the crossing treatment evaluation process.
- Only one scenario results in an endpoint where the action indicated is required (See Section 1.3.2). Following the Flowchart and guidance through to an endpoint will typically result in one of the following recommended actions to consider:
 - Pedestrian signal heads at an existing signalized intersection,
 - Marked crosswalk at a previously uncontrolled intersection or midblock location,
 - Geometric improvements to the pedestrian crossing,
 - Supplemental warning signs, markings, actuated beacons or Rectangular Rapid Flashing Beacons,
 - Pedestrian Hybrid Beacon,
 - Traffic signal to assist pedestrians at a previously uncontrolled location, or
 - No action required.
- Decisions that lead to the consideration of or need for a treatment should only be implemented if financial resources are available to install and maintain the treatment. Local participation is encouraged to support the installation of treatments identified as appropriate.



Figure 1 Following the Flowchart and guidance through to an endpoint will result in one of six potential recommended outcomes.

0.3 INAPPROPRIATE USE OF GUIDANCE

The pedestrian crossing treatment evaluative process is not intended to be used to prioritize sidewalk improvements or to evaluate the connectivity of a pedestrian network. National Cooperative Highway Research Program Report 803 *Pedestrian and Bicycle Transportation along Existing Roads – ActiveTrans Priority Tool Guidebook* provides a methodology and tool to assist agencies in evaluating and prioritizing the need to provide or improve facilities for active travelers, (Lagerwey, Hintze, Elliott, Toole, & Schneider, 2015)

Crossing locations within school zones or along school walking routes are a specialized type of crossing that may require additional considerations. Therefore, school-related crossing evaluations are outside the scope of this crossing treatment evaluative process.

Crossing locations called to the Department’s attention through a written request for reasonable access under the Americans with Disabilities Act (ADA) should not be evaluated using this guide or Flowchart.¹ ADA requests follow a different process established through the “Standard Practice for Pedestrian Reasonable Access requests from Pedestrians with Qualifying Disabilities under the Americans with Disabilities Act.” (NCDOT, 2009)

0.4 WHEN TO USE THE GUIDANCE

The pedestrian crossing treatment evaluation process may be prompted through a variety of mechanisms. Most commonly, it is expected that the Department will initiate an evaluation of a crossing location at the request of a municipality or citizen. Pedestrian crash hot spot locations identified through crash analyses may also trigger an investigation for alternative or additional crossing treatments using the Flowchart as a means to mitigate possible crash factors. As local agencies develop pedestrian or greenway plans, it may be beneficial to review crossing locations identified and prioritized through the planning process to better evaluate infrastructure needs and develop useful cost estimates.

While it is more likely that this evaluation process will be performed in response to a particular request or prioritized location, it could also be utilized as a proactive means to systematically review existing crossing locations as part of a basic needs assessment and inventory. It is possible to envelop the Flowchart as a component within established operations and maintenance assessment workflows currently implemented in the Department.

0.5 OVERVIEW OF PROCESS STEPS

There are four main steps to move through when evaluating a pedestrian crossing. These steps are intended to be performed in sequential order:

Step 1: Document Existing Characteristics / Signalized Crossing Assessment

Step 2: Unsignalized Crossing or Midblock Crossing Assessment

¹ ADA compliance for equivalent facilitation only applies to locations with existing pedestrian facilities. Crosswalks constitute distinct elements of the right-of-way intended to facilitate pedestrian traffic, and as such, they must comply with ADA regulations when installed or resurfaced. Resurfacing of a crosswalk requires the provision of curb ramps at that crosswalk. (DOJ/DOT, 2013)

Step 3: Additional / Alternative Treatments Assessment

Step 4: Pedestrian Hybrid Beacon (PHB) Assessment

While some requests may be for a specific treatment at a crossing location, following the steps in the Flowchart sequentially ensures that the crossing location is reviewed comprehensively. For example, a municipality may request a PHB at a particular location. Rather than jumping to Step 4 to evaluate the location for a PHB, it is prudent for the evaluator to remove all preconceived notions of the solutions or outcomes that may result, and, instead, he/she should objectively apply the Flowchart guidance beginning with the first step. This ensures that all relevant factors and road characteristics are considered when determining a potential course of action.

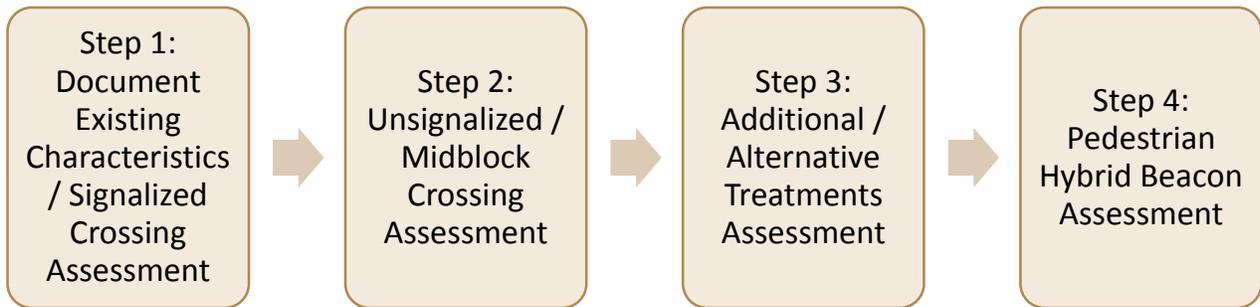


Figure 2 Overview of Pedestrian Crossing Treatment Evaluation Process

1 STEP 1: DOCUMENT EXISTING CHARACTERISTICS / SIGNALIZED CROSSING ASSESSMENT

There are six (6) potential checks to complete as part of Step 1. The first three checks will be performed for all crossing locations under evaluation, while the fourth and fifth check applies only to locations at existing signals, and the sixth check applies only to unsignalized locations:

- 1) Gather relevant data
- 2) Check for presence of ADA compliant path
- 3) Check crossing type
- 4) Check for the application of 2009 MUTCD 4E.03 conditions
- 5) Check pedestrian volume
- 6) Check for the presence of an adjacent crossing opportunity

After moving through the Step 1 Flowchart element, an evaluator will end at one of four (4) potential outcomes:

- No Action Required
- Install Pedestrian Signal Heads (Required)
- Consider Installing Pedestrian Signal Heads
- Move to Step 2

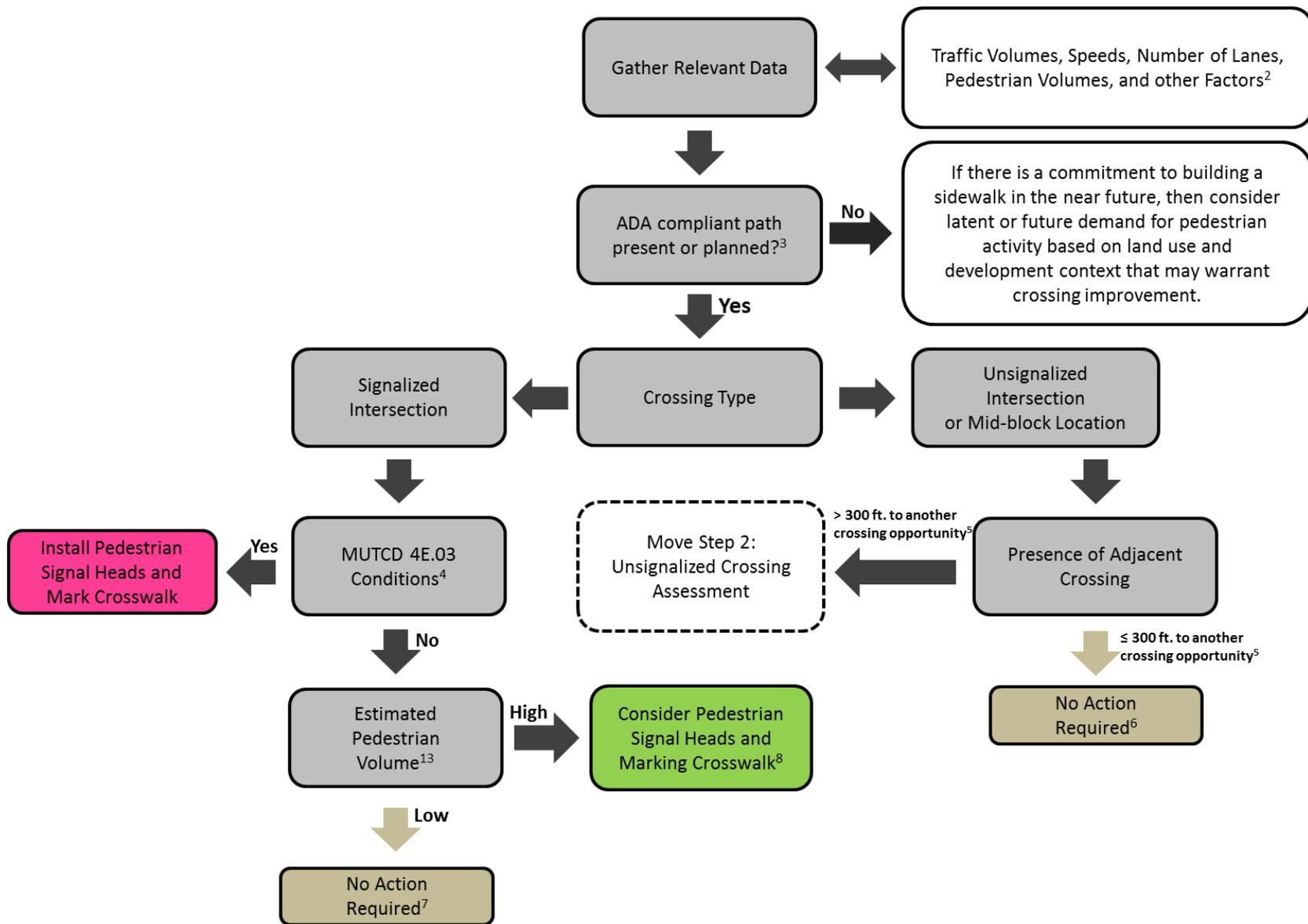


Figure 3 Flowchart Element for Step 1: Document Existing Characteristics / Signalized Crossing Assessment

1.1 GATHER RELEVANT DATA

Based on current research, the Flowchart utilizes six primary factors as data inputs the evaluator should gather as part of Step 1. These key variables of interest may be needed at more than one junction within the Flowchart:

- Distance to Adjacent Crossing
- Vehicle Traffic Volume
- Speed Limit and/or Operating Speed
- Pedestrian Volume
- Number of Lanes and/or Crossing Distance
- Total Pedestrian Delay

Additional factors may be considered when installing or improving a pedestrian crossing as they can enhance an understanding of the local context of the pedestrian facility in question. Some of these factors may need to be gathered as part of Step 1, or the evaluator may find the additional data is needed after working through the Flowchart to conduct an engineering study or to better apply engineering judgement prior to determining a treatment outcome. While specific thresholds or measures are not given for the factors below, gathering these additional data upfront when possible will enable the evaluator to more holistically assess the potential need for a crossing or crossing improvement, or may influence whether a combination of treatments is best suited at a particular location. These additional factors include:

- Site distance restrictions and obstructions,
- Driver yielding rates,
- Pedestrian compliance,
- Observed crossing behaviors and travel paths,
- Crash history,
- Heavy truck traffic,
- Lighting considerations,
- Proximity to or location of transit stops,
- Presence of special pedestrian populations (e.g. children and/or the elderly),
- Future traffic and or pedestrian volumes (5 to 10 years out), and
- Future nearby land use changes, growth, or development patterns (5 to 10 years out).

1.2 CHECK FOR PRESENCE OF EXISTING OR PLANNED ADA COMPLIANT PATH

Evaluators must check for sidewalk or other existing pedestrian facilities that comprise the portion of an accessible route as defined by the US Access Board.² When these facilities are present, the check is satisfied and the evaluator may move on to the next check.

² “*Accessible Route* – A continuous unobstructed path connecting all accessible elements and... may include parking access aisles, curb ramps, crosswalks at vehicular ways, walks, ramps, and lifts.” (US Access Board, 2002) The path is considered ADA compliant when the prepared surface is intended for pedestrian use and it meets current regulations.



Figure 4 Sidewalk, ramps, and detectable warnings at this corner serve as an ADA compliant path.

If pedestrian facilities are not present, the evaluator should consult with the local agency to determine if there are plans to build them in the near future.³ For locations where agencies demonstrate a firm commitment to provide a sidewalk and secure the funds to do so within the next five (5) years, the evaluator can proceed with the crossing assessment, as this check is satisfied.

If facilities are not present and there are no plans to install them, the check is not satisfied and the evaluator halts progress through the Flowchart. However, this does not mean that the original request for crossing assistance is without merit. Evaluators should consider pedestrian activity at the potential crossing location and within 150 feet of either side of the location. If there is sufficient pedestrian activity or indications of latent or future demand based on land use and development context, the Department may consider initiating a separate project development process with the local agency outside the scope of the Flowchart process to discern the feasibility of constructing an ADA compliant path, and then reevaluate the crosswalk configuration at that time.

1.3 CHECK CROSSING TYPE

Simply put, the evaluator indicates whether the crossing location is at a signalized or unsignalized location. This decision point in the Flowchart determines the type of crossing assessment to apply. For signalized intersections, evaluators will complete Step 1. Unsignalized or midblock locations will be further assessed through Steps 2, 3, and 4 of the Flowchart.

³ This guidance is aligned with a memorandum on alternate curb ramp designs, which states, “during the preliminary engineering design, if an entity expresses a firm comment to provide sidewalks in the near future of completing a project, curb ramps can be shown on the pavement marking plans provided by the Signing and Delineation Unit.” (Lacy, 2011)

1.3.1 Unsignalized Intersection or Mid-block Crossing Type

For locations that are unsignalized, evaluators must first consider the proximity of the potential crossing to adjacent existing crossings.

- If the potential crossing is less than or equal to 300 feet to another unsignalized crossing opportunity, or less than 400 feet to a signalized intersection, then No Action is required.⁴ The evaluator should confirm that the existing nearby crossing location can sufficiently meet pedestrian needs. If observed pedestrian activity reveals that they do not use the existing crossing location, further investigation may be needed to assess the existing crossing opportunity. In some cases, the existing adjacent crossing may need to be improved and/or enhanced with landscaping or other positive guidance to encourage and direct pedestrians to cross at the existing location. Engineering judgement should be used for unique circumstances where closely spaced crosswalks may be needed due to pedestrian activity.
- If the potential crossing is greater than 300 feet to another unsignalized crossing opportunity, or greater than 400 feet to a signalized intersection⁵, then the evaluator moves to Step 2 in the Flowchart for further assessment.



Figure 5 Midblock crossing of a shared use path.

1.3.2 Signalized Intersection Type

If the crossing type is at a signalized location, then the crossing is evaluated for the need for pedestrian signal heads. Where the crosswalk is not currently marked, if the decision is made to install pedestrian signal heads, the crosswalk should also be marked.⁶

Two checks are performed as part of the Signalized Crossing Assessment. The crossing is first checked to determine if pedestrian signal heads are required, per 2009 MUTCD 4E.03. If not, then the estimated

⁴ From section 4D.01.06 of the MUTCD, “Midblock crosswalks shall not be signalized if they are located within 300 feet from the nearest traffic control signal, unless the proposed traffic control signal will not restrict the progressive movement of traffic.” Additional guidance is given that midblock crossings should not be signalized if located within 100 feet from STOP or YIELD controlled side streets or driveways. (Federal Highway Administration, 2009)

⁵ The NCDOT clarified that “mid-block crosswalks should not be located within 300 feet of a non-signalized intersection and 400 feet of a signalized intersection, as to not interfere with the functionality of the intersection.” (NCDOT, 2008) This standard practice guidance is irrespective of whether the mid-block crossing will be signalized.

⁶ Use engineering judgment based on location context to determine what type of pattern is most appropriate. High-visibility markings may be appropriate for school crosswalks or where pedestrians or marked crosswalks may not be expected by drivers. (National Committee on Uniform Traffic Control Devices, 2011)

pedestrian volume is checked. It is also recommended to consider pedestrian signal head installations where:

- The estimated pedestrian volume is above a specified “low volume” threshold discussed below,
- To be consistent with adjacent intersections (e.g. in a downtown area), or
- Where they may otherwise enhance pedestrian safety.

1.3.2.1 Check for 2009 MUTCD 4E.03 Conditions

At a signalized crossing location, the evaluator must review the crossing to determine if it meets any of the conditions listed in 4E.03 of the MUTCD:

01 Pedestrian signal heads shall be used in conjunction with vehicular traffic control signals under any of the following conditions:

- A. If a traffic control signal is justified by an engineering study and meets either Warrant 4, Pedestrian Volume or Warrant 5, School Crossing (see Chapter 4C);*
- B. If an exclusive signal phase is provided or made available for pedestrian movements in one or more directions, with all conflicting vehicular movements being stopped;*
- C. At an established school crossing at any signalized location; or*
- D. Where engineering judgment determines that multi-phase signal indications (as with split-phase timing) would tend to confuse or cause conflicts with pedestrians using a crosswalk guided only by vehicular signal indications. (Federal Highway Administration, 2009)*

If the crossing meets any of items A through D, then the standard **requires** that pedestrian signal heads be installed. Installed pedestrian signal heads should conform to MUTCD’s guidance on signal timing to provide sufficient pedestrian clearance times for crossing. See Section 4E.06 of the 2009 MUTCD for further details.



Figure 6 Protective-permissive left turn signals may be confusing to pedestrians attempting to rely on the vehicular traffic signals to know when it is their turn to cross, and therefore engineering judgement must determine whether Section 1.3.2.1 D of the 2009 MUTCD applies.

1.3.2.2 Check Estimated Pedestrian Volume

In most cases, existing pedestrian volume data will be sparse. Therefore, two primary options are available to gather such data: 1) conduct an observational study or 2) estimate volume using proxy measures.

If the evaluator elects to conduct a study, the following is recommended to gather pedestrian counts:

- Seven continuous days of counts are preferred, when possible. Where resources are not available to collect a week’s worth of data, a minimum of one weekend and one weekday

should be collected. The days of the week selected should target when the highest pedestrian activity is expected.⁷

- Restricting data collection to during daylight hours only is acceptable unless the land use context around the site suggests that nighttime pedestrian activity should be expected.
- Counts at the potential crossing location under study should include pedestrians that cross within 150 feet of either side of the crossing.
- Coordinate effort with the Division of Bicycle and Pedestrian Transportation for feedback on additional or unique site-specific considerations prior to conducting the study, and to obtain guidance on data collection protocols for pedestrian studies.

When observational data does not exist and will not be collected, proxy measures can be estimated based on land use context and are sufficient to estimate pedestrian volume at a crossing. Crossings that are near pedestrian trip generators or destinations, or those that may connect complementary land uses should be considered for enhancement. Where proxy measures are used, they should be well documented in the evaluator's assessment.

Because existing pedestrian volume data is limited, the evaluator must use engineering judgement to choose the appropriate low volume threshold from the following considerations:

- The crossing area has less than 25 pedestrians per pedestrian peak hour OR less than 100 pedestrians per day.
- At mid-block locations only: crossing area has less than 25 pedestrians per pedestrian peak hour for at least four hours. (NCDOT, 2008)
- The crossing area is not near high pedestrian trip generators.
- The crossing area does not connect complementary land uses.

Lower volume thresholds may be considered for crossings with a significant presence of a special population, such as children or the elderly. Where the estimated pedestrian volume is considered low, no action is required.

⁷Bicycle and pedestrian volumes are lower and more variable due to weather (e.g., temperature and precipitation) and other factors than motor vehicle traffic. Therefore, it is more difficult to calculate AADT from shorter durations than seven days. (Nordback, Marshall, Janson, & Stolz, 2013) The *Traffic Monitoring Guide* suggests a 7 day duration, noting that "depending on several other factors...the preferred duration of automatic counts could be as long as 14 days." If manual observers are used to collect the counts due to resource limitations, a 12-hour count is preferred. (Federal Highway Administration, 2013)

Regardless of whether pedestrian signal heads are required or recommended for consideration, the evaluator may also review the signalized crossing for geometric or other improvements that could enhance pedestrian safety, accessibility, and comfort. For example, treatments such as curb extensions or median islands, where appropriate, can shorten crossing distances or allow for two-stage crossings while improving signal timing and intersection capacity. Necessary upgrades to curb ramp placement and design (i.e. slope, cross-slope, level landing,



Figure 7 While pedestrian signal heads may not be required at a typical urban signalized intersection, pedestrian signal heads and marked crosswalks may make sense to provide consistency in application throughout a downtown system.

detectable warnings, etc.) required for ADA compliance should be documented. Where vehicles are observed consistently encroaching on the crosswalk at a signalized location, the evaluator may consider other aspects, such as stop bar placement, or the need for NO RIGHT TURN ON RED signage.

2 STEP 2: UNSIGNALIZED / MID-BLOCK CROSSING ASSESSMENT

There are four (4) potential checks to complete as part of Step 2:

- 1) Check the number of lanes
- 2) Check posted or operating speed
- 3) Check vehicular traffic volume
- 4) Check pedestrian volume

After moving through the Step 2 Flowchart element, an evaluator will end at one of three (3) potential outcomes:

- No Action Required
- Consider Marking Crosswalk
- Move to Step 3

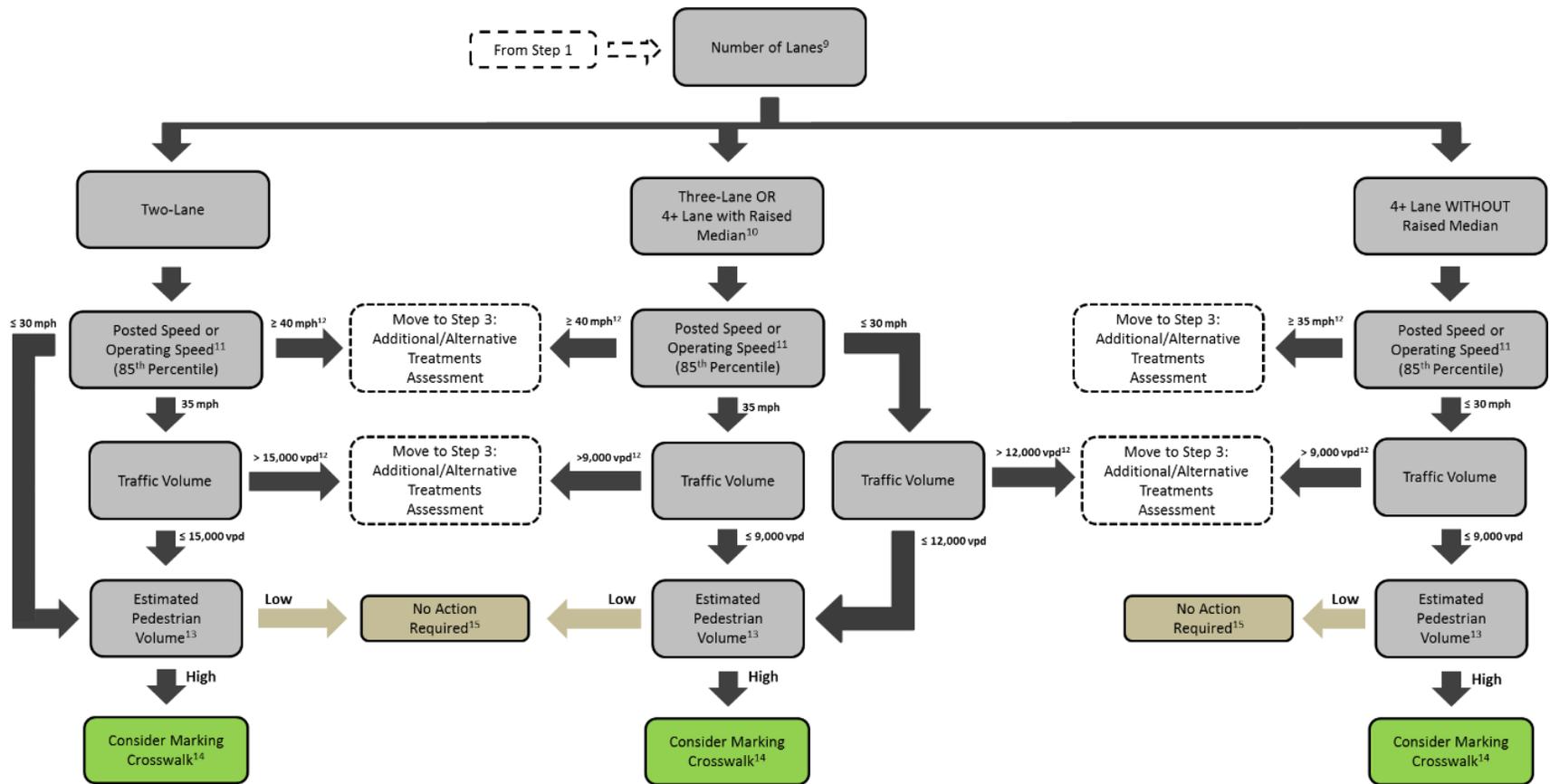


Figure 8 Flowchart Element for Step 2: Unsignalized or Midblock Crossing Assessment

2.1 CHECK NUMBER OF LANES

The number of lanes is a metric that serves as a proxy for crossing distance. Longer crossing distances are more challenging for pedestrians to cross safely without assistance. When counting the number of lanes at a potential crossing location, in general, they should be counted from one edge of right-of-way to the other, to encompass the full crossing. Multiple lanes in one direction may also increase the potential for a multiple-threat crash, where a near-lane vehicle who yields to a crossing pedestrian may block the view of an approaching far-lane vehicle.

The evaluator may also consider each stage of a two-stage pedestrian crossing as a discrete crossing when counting the number of lanes, provided there is sufficient storage and refuge space in the median to clearly separate the two crossing directions.

Raised medians that function as a pedestrian refuge or crossing island affect how an evaluator categorizes the number of lanes metric. These medians must be at least 6 feet wide to function as a refuge area for pedestrians, as shown in Figure 9. As an indication of median length, basic island design from the 2011 AASTHO Green Book indicates that urban curbed corner islands should be no less than 50 ft² and those at rural intersections should be a minimum of 75 ft². (AASHTO, 2011) Multi-lane undivided roads or roads with painted medians are considered as having no raised median. Two-way center turn lanes are also not considered medians and should be counted as a lane.

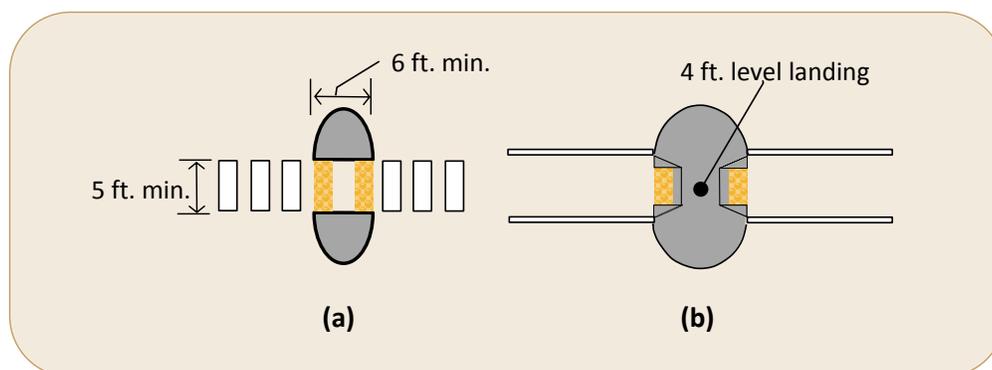


Figure 9 Raised medians must be at least 6 feet wide to serve as a pedestrian refuge island (part a). Crossing islands that include ramps must be wide enough to include a 4-foot square level landing as well as the ramp depths necessary to comply with ADA slope requirements (part b).

The Flowchart does not consider on-street parking, bike lanes, or other features that may increase the overall crossing distance. Therefore, the evaluator may use engineering judgement to adjust the number of lanes to better reflect existing street characteristics that may result in longer crossing distances.

After determining the number of lanes, the evaluator assigns the crossing to one of three options:

- 2-lane crossing,
- 3-lane crossing or 4- or more lane crossing with a raised median, or
- 4- or more lane without a raised median,

and continues to assess the next factor on the Flowchart, posted or operating speed.

2.2 CHECK POSTED SPEED OR OPERATING SPEED

For many crossings, the posted speed limit can be used as an approximation of operating conditions. Where there is a concern that the 85th percentile operating speeds may be near or exceed speed thresholds indicated on the Flowchart (which are based on posted speeds), a speed study should be conducted to determine the 85th percentile speed. If both posted and operating speed data are available, the evaluator should conservatively use whichever speed is higher.

The thresholds below reflect recommendations based on the research findings of a 2005 FHWA study on *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations*. (Zegeer, 2005) The researchers compared five years of crash data from 2,000 crossings across 30 U.S. cities where marked and unmarked crosswalk sites with otherwise similar characteristics were paired for comparison. The majority of these sites (93%) had speed limits between 25 to 35 mph, so the lack of variation in speed limits across sites made it difficult to find a direct relationship between speed and the frequency of pedestrian crashes. However, the study confirmed the relationship between speed and crash severity, where speed limits of 35 mph or greater correlated to more fatal or type A (serious or incapacitating) pedestrian injuries. Given the increase in crash severity, and given that it is not standard practice in the United States to mark a crosswalk at uncontrolled locations where speed limits are 40 mph or greater, Zegeer *et al.* do not recommend marking crosswalks alone under this condition (Zegeer, 2005). Additionally, pedestrians may have more difficulty judging available gaps as vehicle speeds increase.

Regardless of the number of lanes, for crossings where vehicle speed is greater than or equal to 40 mph, the evaluator automatically moves to Step 3 to consider additional treatments. Marking the crosswalk alone under this condition is not suitable, as it may increase the risk of a pedestrian crash. (Zegeer, 2005) Likewise, for locations with four or more lanes without a raised median where the vehicle speed is greater than or equal to 35 mph, the Flowchart directs the evaluator to automatically move to Step 3.

2.2.1 On Two-Lane Roads

For two-lane roads, the posted speed or 85th percentile operating speed is evaluated against three thresholds. A two-lane road typically refers to two-way traffic with one lane in each direction. However, for four-lane divided facilities, each side of the crossing may be evaluated as a two-lane road, if the crossing is completed in two distinct stages (interrupted by a median refuge).

- Where speed is less than or equal to 30 mph, the speed check is satisfied, and the evaluator moves to check pedestrian volume.
- Where speed is 35 mph, the speed check is satisfied, and the evaluator moves to check traffic volume.
- Where speed is greater than or equal to 40 mph, the speed check fails, and the evaluator moves to Step 3.



Figure 10 At an unsignalized intersection, if the posted or operating speed of a two-lane road is greater than or equal to 40 mph, marking a crosswalk alone is not recommended as it may increase the risk of a pedestrian crash.

2.2.2 On Three-Lane Roads or Four-or-More-Lane Roads with a Raised Median

For three-lane roads, or roads with four or more lanes with a raised median, the posted speed or 85th percentile operating speed is evaluated against only two thresholds.

- Where speed is less than or equal to 35 mph, the speed check is satisfied and the evaluator moves to check traffic volume.
- Where speed is greater than or equal to 40 mph, the speed check fails, and the evaluator moves to Step 3.

2.2.3 On Four-or-More-Lane Roads without a Raised Median

For roads with four or more lanes that do not have a raised median, the posted speed or 85th percentile operating speed is evaluated against two thresholds.

- Where speed is less than or equal to 30 mph, the speed check is satisfied, and the evaluator moves to check traffic volume.
- Where speed is greater than or equal to 35 mph, the speed check fails, and the evaluator moves to Step 3.

2.3 CHECK VEHICLE VOLUME

Gap opportunities are a function of vehicle volume. While multilane facilities may be associated with higher vehicle volumes, they may not be inherently more difficult to cross. The same number of vehicles per day on a two-lane road compared to a multilane road could allow pedestrians more gap opportunities on the multilane facility, thereby making it effectively easier to cross. Therefore, only checking the number of lanes of a crossing is an insufficient proxy for measuring vehicle volumes and understanding gap opportunities. Zegeer *et al.* found that traffic volume is one of the primary factors associated with pedestrian crashes. (2005) It is noted though that multilane facilities may pose a risk of multiple threat situations as discussed above, which should be included as an additional safety consideration in the overall assessment.

The traffic volume thresholds below are supported by the 2005 study by Zegeer. At potential crossing locations where the traffic volume is close to a given threshold, engineering judgement should be used with consideration of additional factors, such as crash history, presence of special pedestrian

populations like the elderly, heavy truck volumes, etc. to decide which branch of the Flowchart to follow.

Regardless of the number of lanes or speed, for crossings where traffic volume is greater than or equal to 15,000 vpd, the evaluator automatically moves to Step 3 to consider additional treatments. Marking the crosswalk alone under this condition is not suitable, as it may increase the risk of a pedestrian crash. (Zegeer, 2005)

2.3.1 On Two-Lane Roads, 35 mph

For two-lane roads with a speed of 35 mph, the traffic volumes are evaluated based on a threshold volume of 15,000 vehicles per day (vpd).

- Where traffic volume is less than or equal to 15,000 vpd, the traffic volume is satisfied, and the evaluator moves to check pedestrian volume.
- Where traffic volume is greater than 15,000 vpd, the traffic volume check fails, and the evaluator moves to Step 3.

2.3.2 On Three-Lane Roads or Four-or-More-Lane Roads with a Raised Median, 30 mph or Less

For three-lane roads, or roads with four or more lanes with a raised median and a speed for 30 mph or less, the traffic volumes are evaluated based on a threshold volume of 12,000 vpd.

- Where traffic volume is less than 12,000 vpd, the traffic volume check is satisfied and the evaluator moves to check pedestrian volume.
- Where traffic volume is greater than or equal to 12,000 vpd, the traffic volume check fails, and the evaluator moves to Step 3.

2.3.3 On Three-Lane Roads or Four-or-More-Lane Roads with a Raised Median, 35 mph

For three-lane roads, or roads with four or more lanes with a raised median and a speed for 35 mph, the traffic volumes are evaluated based on a threshold volume of 9,000 vpd.

- Where traffic volume is less than or equal to 9,000 vpd, the traffic volume check is satisfied and the evaluator moves to check pedestrian volume.
- Where traffic volume is greater than 9,000 vpd, the traffic volume check fails, and the evaluator moves to Step 3.

2.3.4 On Four-or-More-Lane Roads without a Raised Median, 30 mph or Less

For roads with four or more lanes without a raised median and a speed for 30 mph or less, the traffic volumes are evaluated based on a threshold volume of 9,000 vpd.

- Where traffic volume is less than or equal to 9,000 vpd, the traffic volume check is satisfied, and the evaluator moves to check pedestrian volume.
- Where traffic volume is greater than 9,000 vpd, the traffic volume check fails, and the evaluator moves to Step 3.



Figure 11 On roads with 4 or more lanes without a raised median, if the posted or operating speed is 35 mph or more, marking a crosswalk alone is not recommended. Even if vehicle speeds are 30 mph or less, if the traffic volume is greater than 9,000 vpd, marking a crosswalk alone may increase the risk of a pedestrian crash. Instead, additional/alternative treatments should be considered.

2.4 CHECK PEDESTRIAN VOLUME

See Section 1.3.2.2 above for more on how to conduct this check to determine whether the estimated pedestrian volume at a potential crossing is low.

- Where pedestrian volume is Low, no action is required. The gap availability, based on number of lanes, speed, and traffic volume, should allow for sufficient crossing opportunities.
- Where pedestrian volume is not Low, the evaluator may consider marking a crosswalk.⁸

⁸ Use engineering judgment based on location context to determine if the crosswalk should be marked and what type of pattern is most appropriate. Mid-block crosswalks should be marked using a high-visibility pattern. (NCDOT, 2008) High-visibility markings may also be appropriate for school crosswalks or where pedestrians or marked crosswalks may not be expected by drivers. (National Committee on Uniform Traffic Control Devices, 2011)

3 STEP 3: ADDITIONAL / ALTERNATIVE TREATMENTS ASSESSMENT

There are four (4) potential checks to complete as part of Step 3:

- 1) Check posted or operating speed
- 2) Check pedestrian volume
- 3) Check MUTCD signal warrants
- 4) Check pedestrian delay

After moving through the Step 3 Flowchart element, an evaluator will end at one of five (5) potential outcomes:

- Consider Geometric Improvements
- Consider Installing a Traffic Signal
- Consider Marking Crosswalk
- Consider Supplemental Treatments
- Move to Step 4

Factors and thresholds within Step 3 are predicated on research findings and guidance conveyed in *NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings*. (Fitzpatrick, et al., NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings, 2006) This report includes “Appendix A. Guidelines for Pedestrian Crossing Treatments” which comprises a process and worksheet tools to determine general recommendations for crossing treatment types to consider at an unsignalized location. The inputs used in Fitzpatrick’s guidance are reflected in the checks within Step 3 of NCDOT’s Flowchart.

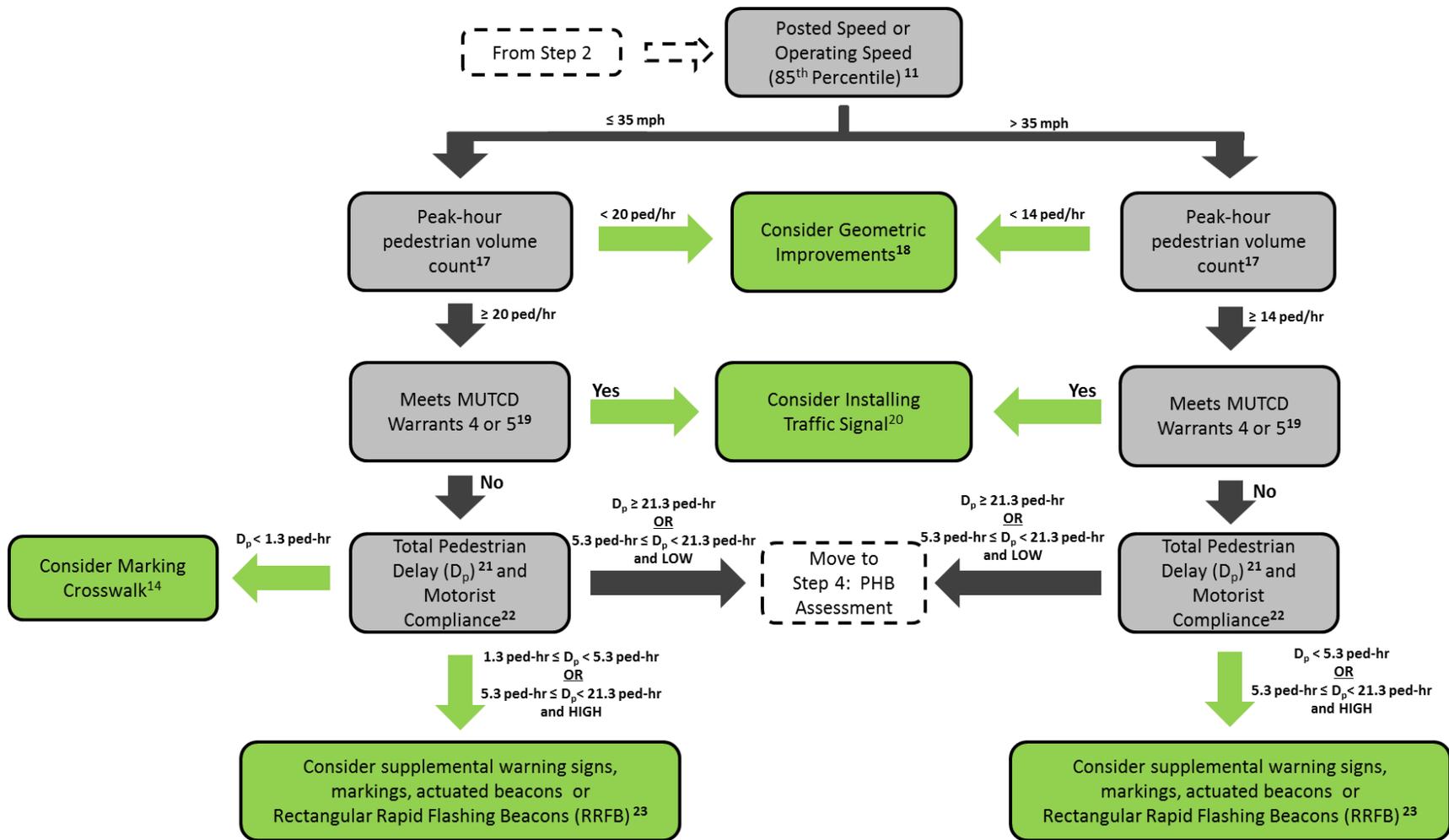


Figure 12 Flowchart Element for Step 3: Additional / Alternative Treatments Assessment

3.1 CHECK SPEED

For many crossings, the posted speed limit can be used as an approximation of operating conditions. Where there is a concern or evidence that the 85th percentile operating speeds may be near or exceed 35 mph, a speed study can be conducted to determine the 85th percentile speed. If both posted and operating speed data are available, the evaluator should conservatively use whichever speed is higher.

When comparing motorist yielding compliance at a variety of crossing treatments on roads with posted speed limits ranging from 25 to 40 mph, Fitzpatrick *et al.* found a critical speed of 35 mph – the best compliance of non-red indicating devices was observed at treatments on roads with posted speeds less than 35 mph. (2006) Therefore, the path to proceed through Step 3 depends on whether the crossing location is on a roadway with a posted speed limit above 35 mph or at 35 mph or below.

3.2 CHECK PEAK-HOUR PEDESTRIAN VOLUME

Step 3 requires *observed* pedestrian volume data, rather than *estimated* volume based on proxy information. Count thresholds include pedestrians crossing the roadway within 150 ft. of the crossing location being assessed. At an intersection, pedestrians are counted crossing in both directions and across both legs of the roadway assessed, as shown in Figure 13. Note that this check is for the pedestrian peak-hour volume, which may not necessarily be the same peak-hour as the vehicles. For example, near a school, the pedestrian peak-hour may align with school dismissal, whereas the vehicle peak-hour may be up to three hours later. If the pedestrian peak hour time is not known, an initial pedestrian count study should be conducted using the general guidelines recommended in section 1.3.2.2 above.

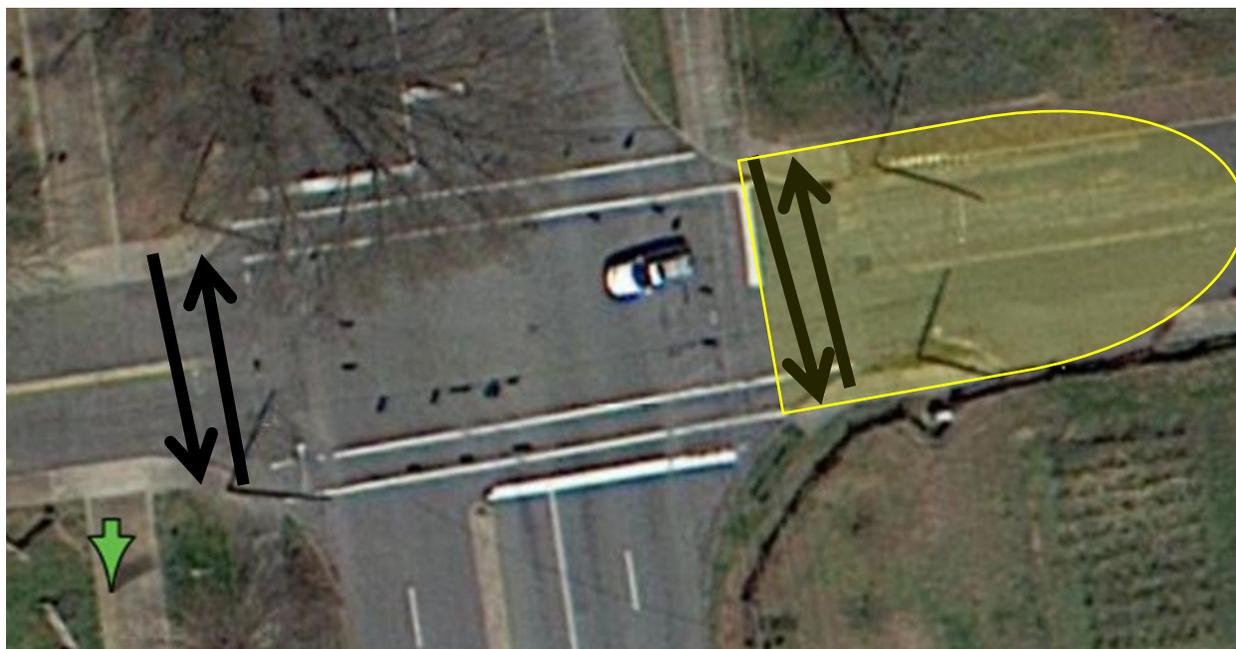


Figure 13 In this example, the crossing being evaluated is the west leg. Pedestrians are counted crossing northbound and southbound on the east and west legs (shown by black arrows) and up to 150 feet away from the intersection (shown by yellow highlighted area).

3.2.1 On Road with Speed 35 mph or Less

On roads with a posted speed or 85th percentile operating speed of 35 mph or less, a pedestrian volume threshold of 20 pedestrians per pedestrian peak hour applies.

- Where the peak-hour pedestrian volume is less than 20 pedestrians per hour, consider geometric improvements.
- Where the peak-hour pedestrian volume is greater than or equal to 20 pedestrians per hour, check MUTCD signal warrants.

3.2.2 On Road with Speed Greater than 35 mph

On roads with a posted speed or 85th percentile operating speed greater than 35 mph, a pedestrian volume threshold of 14 pedestrians per pedestrian peak hour applies.

- Where the peak-hour pedestrian volume is less than 14 pedestrians per hour, consider geometric improvements.
- Where the peak-hour pedestrian volume is greater than or equal to 14 pedestrians per hour, check MUTCD signal warrants.

When considering geometric improvements, further engineering study is needed to determine what, if any modifications should be implemented. These improvements may include the installation of median refuge islands, curb extensions, or traffic calming devices. Improvements may also include other modifications that minimize the crossing distance, straighten crossings to be as perpendicular as feasible to the traffic being crossed, and enhance visibility of and by the pedestrian by removing obstacles to lines of sight. See the common resources list in Appendix A for more on the countermeasures studied for *NCHRP Report 562* and a link to PEDSAFE for other countermeasure options.

3.3 CHECK MUTCD WARRANTS 4 OR 5

A traffic signal may be warranted based on pedestrian volume. The evaluator must conduct an engineering study per the MUTCD to determine if a traffic signal may be justified based on minimum conditions.⁹ While other relevant traffic signal warrants may simultaneously be analyzed through the study, of particular relevance to the pedestrian crossing evaluation process is whether Warrant 4 - Pedestrian Volume or Warrant 5 - School Crossing, is satisfied. The following is paraphrased from the 2009 MUTCD. The full language of the MUTCD for Warrants 4 and 5, including the referenced charts, are provided in Appendix B.

Per Section 4C.05, the Pedestrian Volume signal warrant is met and a traffic signal must be considered if:

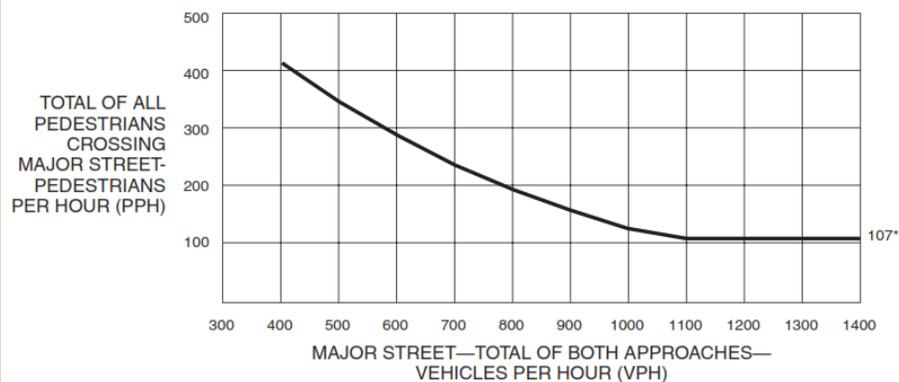
- For each of any 4 hours of an average day, there are at least 107 pedestrians per hour crossing a street with at least 1,100 vehicles per hour; or
- For any 1 hour of an average day, there are at least 133 pedestrians per hour crossing a street with at least 1,450 vehicles per hour.

⁹ 2009 MUTCD 4C.01 indicates the “satisfaction of a traffic signal warrant shall not in itself require the installation of a traffic control signal.” (Federal Highway Administration, 2009)

If the posted or 85th percentile operating speeds are greater than 35 mph or if the crossing location is in a “built-up area of an isolated community having a population of less than 10,000” then the pedestrian volume thresholds are lowered to:

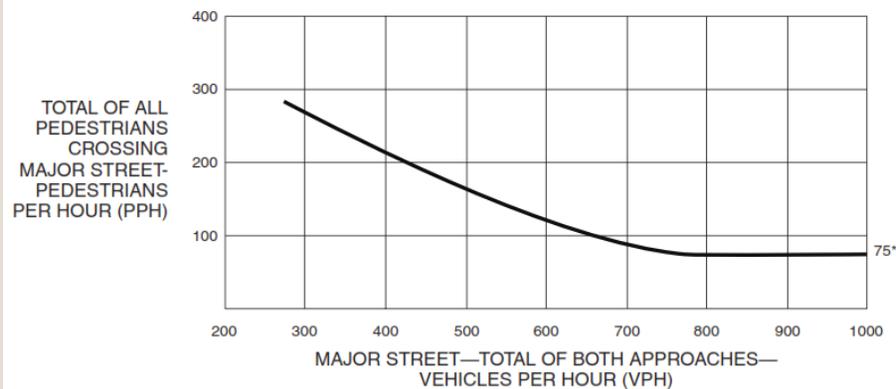
- At least 75 pedestrians per hour where for any 4 hours crossing at least 750 vehicles per hour;
or
- At least 93 pedestrians per hour for any 1 hour crossing at least 1,050 vehicles per hour.

Figure 4C-5. Warrant 4, Pedestrian Four-Hour Volume



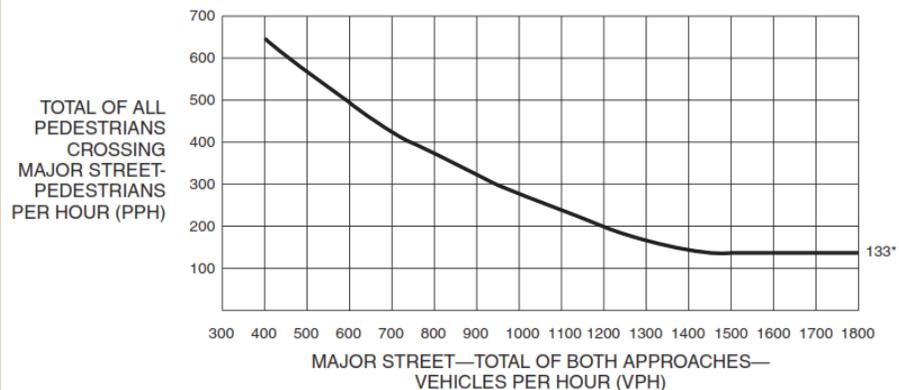
*Note: 107 pph applies as the lower threshold volume.

Figure 4C-6. Warrant 4, Pedestrian Four-Hour Volume (70% Factor)



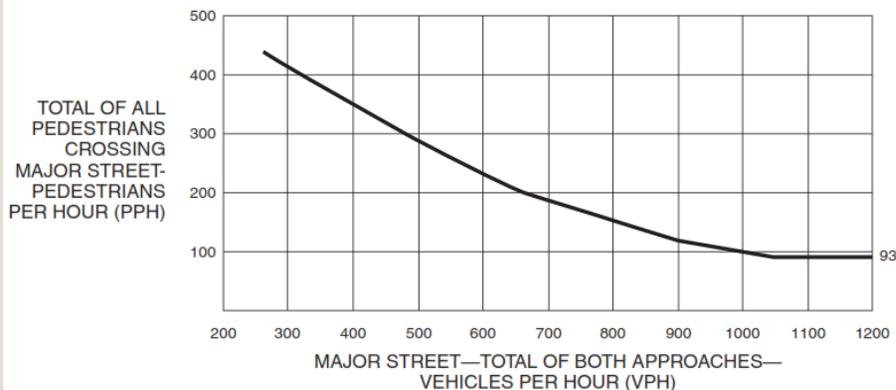
*Note: 75 pph applies as the lower threshold volume.

Figure 4C-7. Warrant 4, Pedestrian Peak Hour



*Note: 133 pph applies as the lower threshold volume.

Figure 4C-8. Warrant 4, Pedestrian Peak Hour (70% Factor)



*Note: 93 pph applies as the lower threshold volume.

Figure 14 Traffic Signal Warrant 4, Pedestrian Volume figures from the 2009 MUTCD. When pedestrian and vehicle volumes at a potential crossing location are plotted, points that fall above the curve in the appropriate graph indicate that a traffic signal is warranted.

Meeting Warrant 4 is a function of both pedestrian and vehicle volumes at the crossing. Therefore, as vehicle volumes decrease, the threshold for the pedestrian volume needed to meet the warrant rises. See the figures in Figure 14 above for more details – plotted points that fall above the curve in the appropriate figure from the 2009 MUTCD (4C-5, -6, -7, or -8) indicate the Warrant is met.

Warrant 5 applies when a particular subset of pedestrians at a crossing is schoolchildren, and the crossing is established as a school crossing. The warrant is a function of gap frequency and schoolchildren volume. It is met if at least 20 schoolchildren are crossing at the peak crossing hour and the number of gaps is less than the number of minutes during the period when they are crossing.



Figure 15 Depending on pedestrian and traffic volumes, a traffic signal may be warranted. If Warrant 4 or 5 of the MUTCD are met, and the traffic signal is installed, then pedestrian signal heads are also required. Photo credit: Caroline Culler, Wikimedia Commons

Neither Warrant applies if the crossing location is less than 300 feet of another signalized or STOP controlled intersection unless the proposed signal will not restrict progressive movement of traffic. (4C.05.04 and 4C.06.04)

- If Warrants 4 or 5 are met, consider installing a traffic signal. There is no requirement to install the signal, per 4C.01 - engineering judgment and other operational considerations should be factored in when making this decision. (Federal Highway Administration, 2009) Other treatment options, like the pedestrian hybrid beacon, may be able to be used instead of a signal to mitigate impacts on vehicular delay. If the decision is made to install the traffic signal, the installation of pedestrian signal heads is also required. See Section 1.3.2.1 above. Financial resources must be available to install and maintain the signals.
- If Warrants 4 or 5 are not met, then check pedestrian delay.

3.4 CHECK PEDESTRIAN DELAY

In general, pedestrian delay increases as vehicle volume increases, as adequate gap opportunities become less frequent. Pedestrians may be willing to accept increased delay at some crossings where gap opportunities are controlled by an upstream signal; however, at locations where the next opportunity for a gap is uncertain or random, pedestrians may engage in more risky crossing behaviors as pedestrian delay increases.

Total pedestrian delay is calculated by multiplying the average delay per pedestrian by the number of pedestrians in the peak-hour. Average pedestrian delay is calculated using Equation 18-21 of the 2000 *Highway Capacity Manual*. The 2000 HCM was the most recent version of the HCM at the time the

Fitzpatrick et al (2006) study was conducted. Newer versions of the HCM feature slightly revised pedestrian analysis methods, but the crosswalk research was calibrated based on the 2000 HCM. Average pedestrian delay is a function of crossing distance, walking speed, pedestrian start-up and end clearance time, and traffic volume and flow rate. The peak-hour pedestrian volume gathered in Section 3.2 above is used for the number of pedestrians. For example, if the *HCM* delay is estimated as 40 seconds per pedestrian, and the peak-hour volume observed is 90 pedestrians, then:

$$Total\ Delay = 40 \frac{sec}{ped} \times 90 \frac{ped}{hr} \times \frac{1\ hr}{3600\ sec} = 1\ ped-hr$$

The Total Pedestrian Delay thresholds and treatment considerations below are based on the research conducted to inform the “Guidelines for Pedestrian Crossing Treatments” described in Appendix A of *NCHRP Report 562*. (Fitzpatrick, et al., NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings, 2006) The worksheets, inputs, and variables from *Report 562* used to calculate total pedestrian delay are also included in Appendix C of this guidebook.

3.4.1 On Road with Speed 35 mph or Less

On roads with a posted speed or 85th percentile operating speed of 35 mph or less, three potential conditions are distinguished, based on pedestrian delay and motorist compliance.

- Where the total pedestrian delay is less than 1.3 pedestrian-hours, consider marking a crosswalk.¹⁰
- Where motorist compliance is LOW¹¹:
 - And the total pedestrian delay is greater than or equal to 1.3 pedestrian-hours but less than 5.3 pedestrian-hours, consider supplemental warning signs, markings, actuated beacons or Rectangular Rapid Flashing Beacons (RRFB).
 - And the total pedestrian delay is greater than or equal to 5.3 pedestrian-hours but less than 21.3 pedestrian-hours, move to Step 4.
- Where motorist compliance is HIGH:
 - And the total pedestrian delay is greater than or equal to 5.3 pedestrian-hours but less than 21.3 pedestrian-hours, consider supplemental warning signs, markings, actuated beacons or Rectangular Rapid Flashing Beacons (RRFB).
 - And the total pedestrian delay is greater than 21.3 pedestrian-hours, move to Step 4.

¹⁰ Use engineering judgment based on location context to determine if the crosswalk should be marked and what type of pattern is most appropriate. Mid-block crosswalks should be marked using a high-visibility pattern. (NCDOT, 2008) High-visibility markings may also be appropriate for school crosswalks or where pedestrians or marked crosswalks may not be expected by drivers. (National Committee on Uniform Traffic Control Devices, 2011)

¹¹ Motorist compliance is considered “HIGH” if, within the general vicinity of the crossing location, driver culture is such that motorists tend to yield to a pedestrian attempting to cross at an uncontrolled location. If motorists rarely stop for a crossing pedestrian, then compliance is considered “LOW”. (Fitzpatrick, et al., NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings, 2006)

3.4.2 On Road with Speed Greater than 35 mph

On roads with a posted speed or 85th percentile operating speed greater than 35 mph, two potential conditions are distinguished, based on pedestrian delay and motorist compliance.

- Where motorist compliance is LOW:
 - And the total pedestrian delay is less than 5.3 pedestrian-hours, consider supplemental warning signs, markings, actuated beacons or Rectangular Rapid Flashing Beacons (RRFB).
 - And the total pedestrian delay is greater than or equal to 5.3 pedestrian-hours but less than 21.3 pedestrian-hours, move to Step 4.
- Where motorist compliance is HIGH:
 - And the total pedestrian delay is greater than or equal to 5.3 pedestrian-hours but less than 21.3 pedestrian-hours, consider supplemental warning signs, markings, actuated beacons or Rectangular Rapid Flashing Beacons (RRFB).
 - And the total pedestrian delay is greater than 21.3 pedestrian-hours, move to Step 4.

Supplemental signs, markings, and beacons include devices that enhance the visibility of the crossing beyond the standard marked crosswalk and pedestrian crossing signs. These devices may include advanced yield lines and signage, in-street Yield-to-Pedestrian signs, overhead signage, or pedestrian-actuated beacons such as the RRFB, among others. Additional study is needed to determine what, if any enhanced or active traffic control devices should be implemented. See the Common Resources List in Appendix A for more on these or other options.

3.4.3 Quick Reference Charts to Estimate Total Pedestrian Delay

While the evaluator may choose to employ the worksheets provided in *NCHRP Report 562* to calculate Total Pedestrian Delay, a series of charts are provided in Appendix C to quickly estimate this factor. These charts are organized by posted speed limit, crossing distance, and community population thresholds, and are a function of peak-hour pedestrian volumes and peak-hour traffic volumes. The evaluator selects the appropriate chart and then plots the peak-hour pedestrian and traffic volumes at the potential crossing location. Three curves are given on each chart, which reflect the 1.3, 5.3, and 21.3 pedestrian-hour thresholds of Total Pedestrian Delay. Depending on where a point is plotted, Total Pedestrian Delay may be Low, Medium-Low, Medium-High, or High:

- Plotted points that fall below the 1.3 ped-hr line are considered Low;
- Plotted points that fall between the 1.3 ped-hr and 5.3 ped-hr lines are considered Medium-Low;
- Plotted points that fall between the 5.3 ped-hr and 21.3 ped-hr lines are considered Medium-High;
- Plotted points that fall above the 21.3 ped-hour line are considered High.

Table 1 is used to then identify the appropriate treatment category based on the speed limit, motorist compliance and type of Total Pedestrian Delay.

Table 1 Total Pedestrian Delay – Treatment Selection Guidance

Speed	Motorist Compliance	Total Pedestrian Delay Type			
		Low (< 1.3 ped-hrs)	Medium-Low (≥ 1.3 to < 5.3 ped-hrs)	Medium-High (≥ 5.3 to < 21.3 ped-hrs)	High (≥ 21.3 ped-hrs)
≤ 35 mph	Low	Consider Marking Crosswalk	Consider Supplemental Treatments	Move to Step 4	Move to Step 4
	High	Consider Marking Crosswalk	Consider Supplemental Treatments	Consider Supplemental Treatments	Move to Step 4
> 35 mph	Low	Consider Supplemental Treatments	Consider Supplemental Treatments	Move to Step 4	Move to Step 4
	High	Consider Supplemental Treatments	Consider Supplemental Treatments	Consider Supplemental Treatments	Move to Step 4

Figure 16 illustrates a plotted point in the Medium-High category. In this example, because the Total Pedestrian Delay is Medium High, the speed is less than 35 mph, and motorist compliance is low, Table 1 indicates that the evaluator move to Step 4 to continue to assess the crossing location for a Pedestrian Hybrid Beacon.

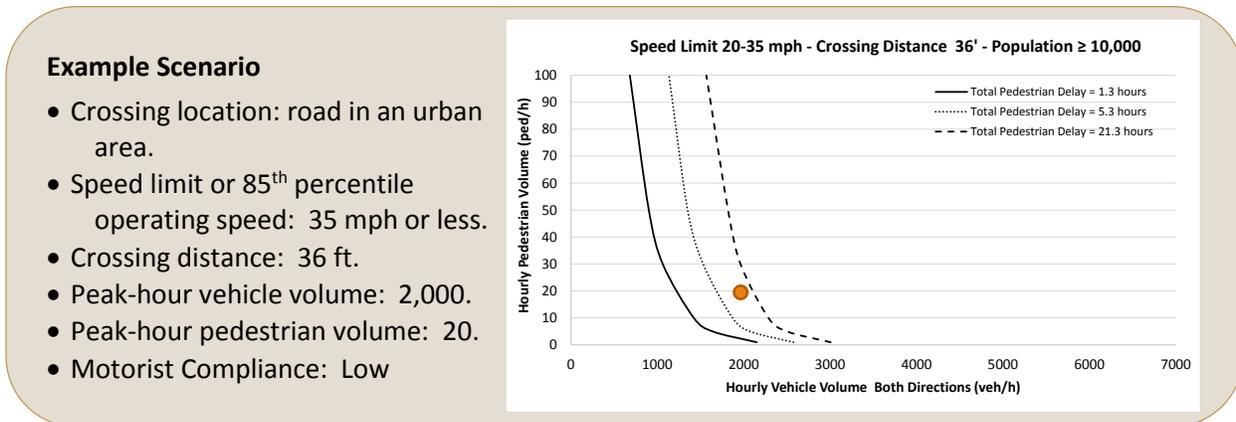


Figure 16 Example scenario using the “Speed Limit 20-35 mph – Crossing Distance 36’ – Population ≥ 10,000” chart from Appendix C. to determine Total Pedestrian Delay type. Example shows a Medium-High delay between 5.3 and 21.3 ped-hrs.

4 STEP 4: PEDESTRIAN HYBRID BEACON ASSESSMENT

There are four (4) checks to complete as part of Step 4:

- 1) Check posted or operating speed
- 2) Check crosswalk length
- 3) Check pedestrian volume
- 4) Check vehicle volume

After moving through the Step 4 Flowchart element, the evaluator will determine whether to consider installing a Pedestrian Hybrid Beacon (PHB).

Factors and thresholds within Step 4 are from the 2009 MUTCD in Section 4F.01.06 and 4F.01.07, which is predicated on research findings and guidance conveyed in *NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings*. (Fitzpatrick, et al., NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings, 2006) Step 4 of the Flowchart is essentially a continuation of Step 3. While Step 3 follows the guidelines in *Report 562* to reach treatment category endpoints of “Crosswalk” or “Active or Enhanced”, the “Red” treatment category of *Report 562* is assessed through Step 4.

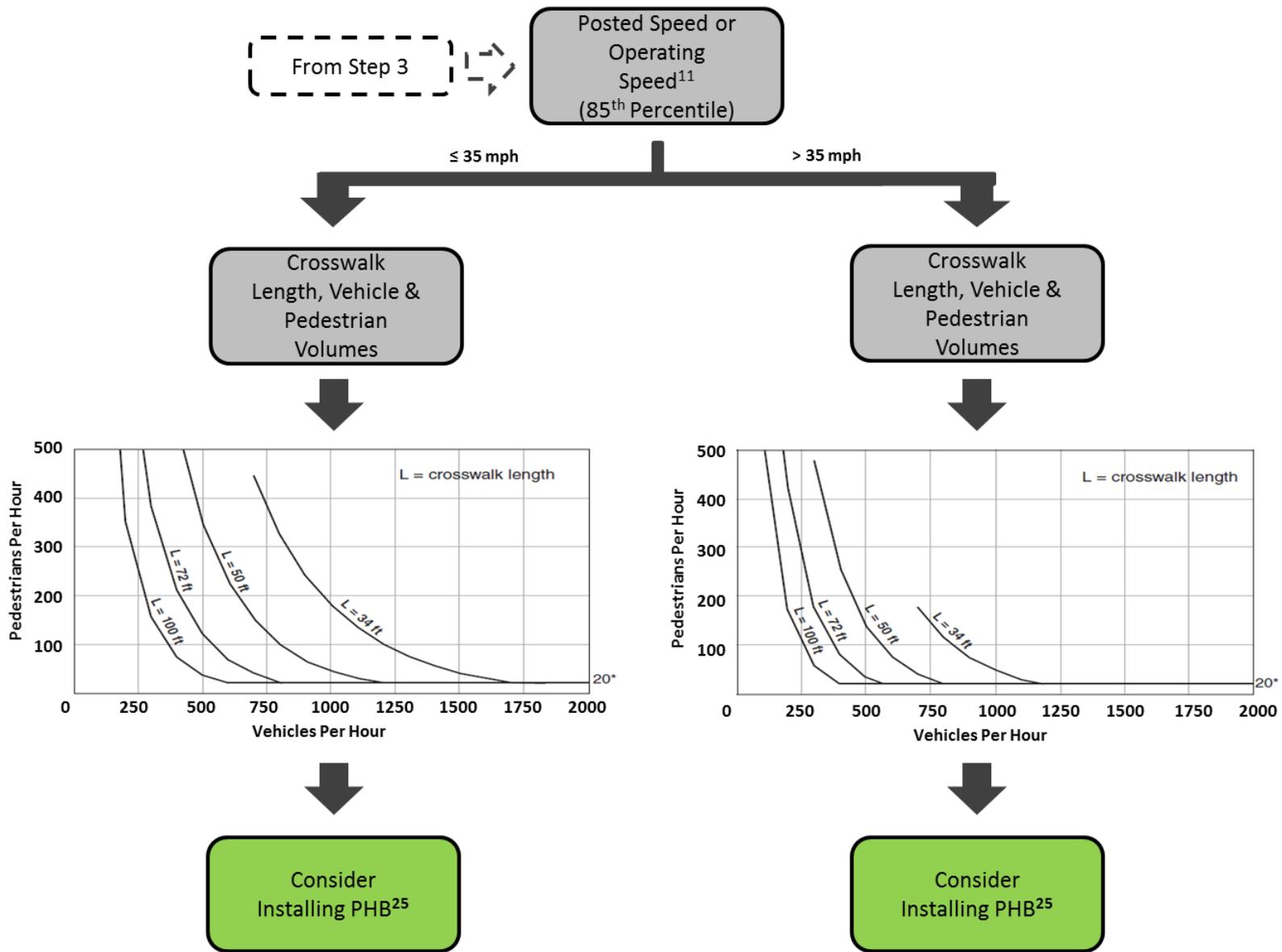


Figure 17 Flowchart Element for Step 4: Pedestrian Hybrid Beacon (PHB) Assessment

4.1 CHECK SPEED

See Section 3.1 above – the posted or operating speed used in Step 3 is carried through to Step 4.

4.2 CHECK CROSSWALK LENGTH, VEHICLE & PEDESTRIAN VOLUMES

Crosswalk length represents the distance a pedestrian would need to cross before reaching either a raised median refuge island or the far curb or edge of pavement. On-street parking, bike lanes, or other features that may increase the overall crossing distance should be included in the crosswalk length measurement.

When determining the number of vehicles per peak-hour, the evaluator must first consider whether vehicle volume should represent one or both approaches. Per Section 4F.07 of the 2009 MUTCD, the total of both approaches should be used. This assumes that a pedestrian should be able to cross from one curb to the far curb. Where a raised median is sufficiently designed to serve as a pedestrian refuge island (see Section 2.1 for minimum island design dimensions), the crossing task may effectively function as a two-stage crossing. In this case, each approach can be separately assessed, using the peak-hour vehicle volume for an approach and the corresponding crosswalk length to the island.

See Section 3.2 above for determining pedestrian volume.

Once vehicle and pedestrian volumes are known, the evaluator plots the point on the appropriate graph based on the posted or operating speed. Figure 4F-1 from the 2009 MUTCD (shown in Figure 18) is used where the roadway is 35 mph or less while Figure 4F-2 (shown in Figure 19) is used if the speed is greater than 35mph.

4.2.1 On Road with Speed Less Than or Equal to 35 mph

On roads with a posted speed or 85th percentile operating speed of 35 mph or less, two potential conditions are distinguished, based on the crosswalk length curve.

- A PHB is recommended for consideration where the plotted point falls above the curve for the appropriate crosswalk length line on the graph in Figure 18.
- If the plotted point falls below the applicable curve, consider supplemental warning signs, markings, actuated beacons or RRFBs.

4.2.2 On Road with Speed Greater than 35 mph

On roads with a posted speed or 85th percentile operating speed of greater than 35, two potential conditions are distinguished, based on the crosswalk length curve.

- A PHB is recommended for consideration where the plotted point falls above the curve for the appropriate crosswalk length line on the graph Figure 19.
- If the plotted point falls below the applicable curve, consider supplemental warning signs, markings, actuated beacons or RRFBs.

The evaluator interpolates values between curves if the measured crosswalk length is not represented by one of the four graphed. Consideration for installation of a PHB assumes that a traffic signal was not

warranted, or, if warranted, that the installation of a traffic signal was rejected after conducting an engineering study.

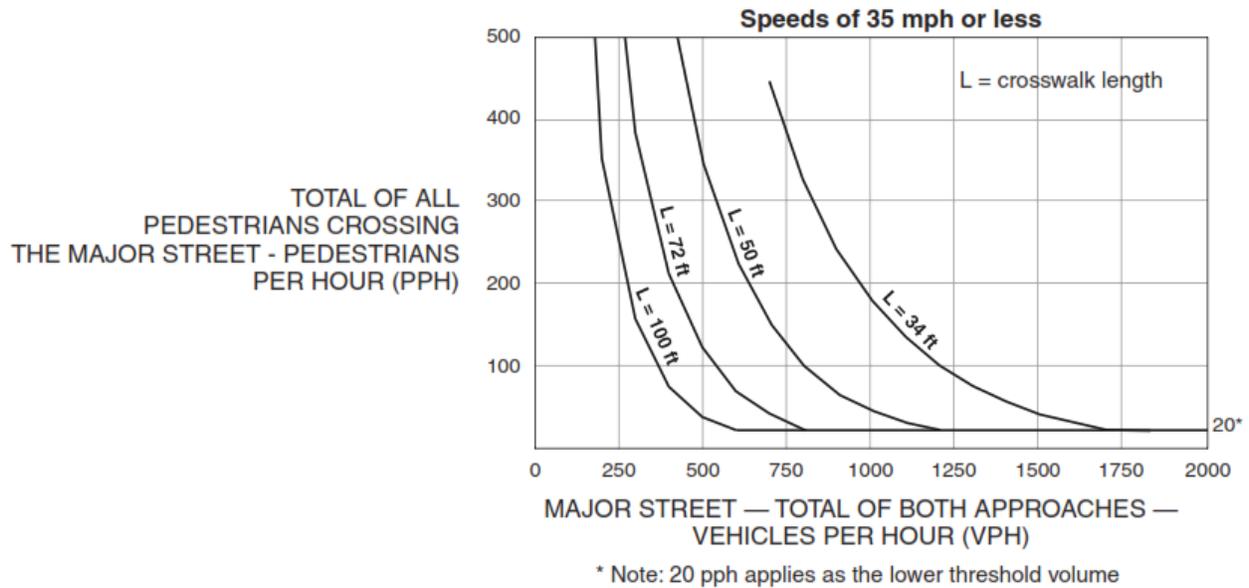


Figure 18 From the 2009 MUTCD, PHB application should be considered to assist pedestrians crossing roads less than or equal to 35 mph when the plotted point falls above the curve for a given crosswalk length.

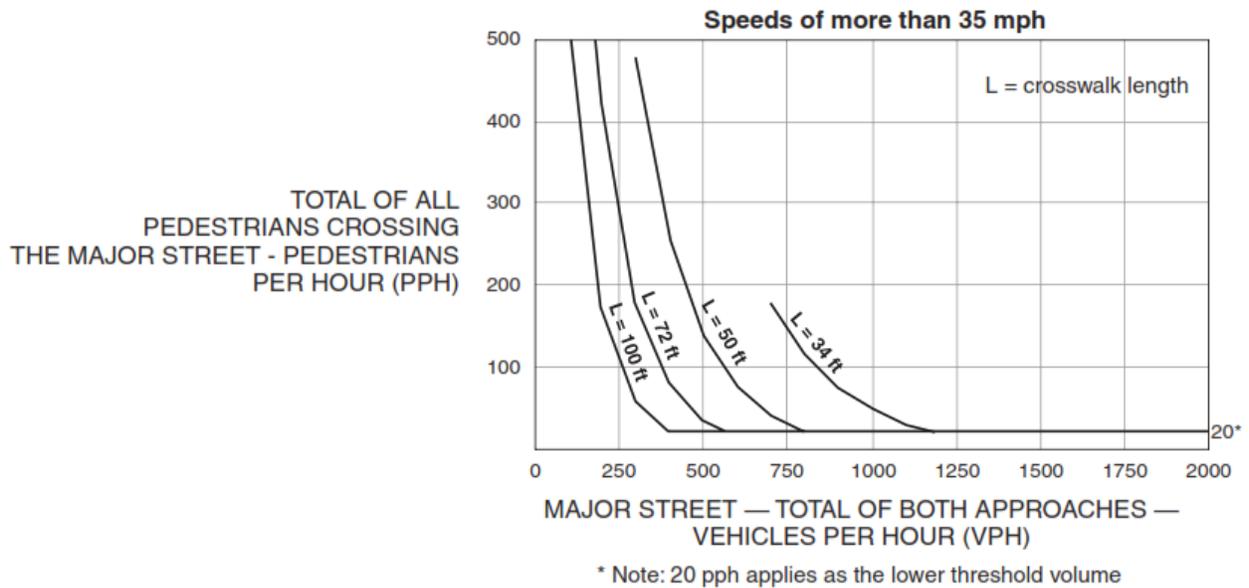


Figure 19 From the 2009 MUTCD, PHB application should be considered to assist pedestrians crossing roads greater than 35 mph when the plotted point falls above the curve for a given crosswalk length.

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Appendix A. COMMON RESOURCES LIST

Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations – Final Report and Recommended Guidelines (2005)

<http://www.fhwa.dot.gov/publications/research/safety/04100/04100.pdf>

Step 2: Unsignalized or Midblock Crossing Assessment is largely founded upon FHWA’s *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations*. This study determined a relationship between an increased risk of pedestrian crashes and marked crosswalks on roads with certain cross-sections, vehicle volumes, and speeds.

Zegeer et al.’s report recommends where marked crosswalks may be considered and where marking them alone may increase the risk of a pedestrian crash. The recommendations laid out in Table 11 in the report served as the basis for the Flowchart paths laid out in Step 2.



Table 11. 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 >9,000 to 12,000			Vehicle ADT >12,000–15,000			Vehicle ADT > 15,000		
	Speed Limit**											
	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)	≤ 48.3 km/h (30 mi/h)	56.4 km/h (35 mi/h)	64.4 km/h (40 mi/h)
Two lanes	C	C	P	C	C	P	C	C	N	C	P	N
Three lanes	C	C	P	C	P	P	P	P	N	P	N	N
Multilane (four or more lanes) with raised median***	C	C	P	C	P	N	P	P	N	N	N	N
Multilane (four or more lanes) without raised median	C	P	N	P	P	N	N	N	N	N	N	N

* 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 64.4 km/h (40 mi/h), marked crosswalks alone should not be used at unsignalized locations.

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

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 indepth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, and other factors may be needed at other sites. It is recommended that a minimum utilization of 20 pedestrian crossings per peak hour (or 15 or more elderly and/or child pedestrians) be confirmed at a location before placing a high priority on the installation of a marked crosswalk alone.

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

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

Figure 20 Copy of Table 11 from Zegeer's report.

NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_562.pdf

Steps 3 and 4 of the Flowchart are based on research findings and recommendations from NCHRP 562: *Improving Pedestrian Safety at Unsignalized Crossings*. Fitzpatrick's research team studied pedestrian behavior and motorist compliance in 42 study sites across seven states. This report is the source for the updated 2009 MUTCD pedestrian signal warrant and PHB application guidance. The researchers also made recommendations to reduce the pedestrian walking speed to 3.5 seconds when calculating signal timing, which is also reflected in the 2009 MUTCD, based on their study.

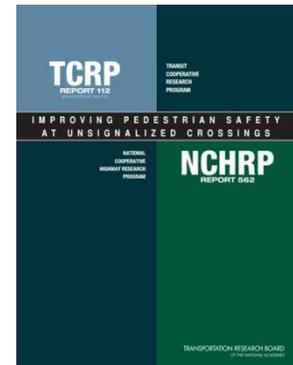


Figure 21 shows that treatments indicating a red signal or beacon, which are circled in red, are most effective at getting drivers to yield for pedestrians, given the clear regulatory message they convey. Treatments that enhance a marked crosswalk, circled in blue, vary in their effectiveness to encourage motorist yielding. Overhead flashing beacons, circled in yellow, also range in their effectiveness; however drivers appear more likely to yield when pedestrians actuate the flashing beacon (OfPb) using a pushbutton rather than where it is passively activated through some sensor technology.

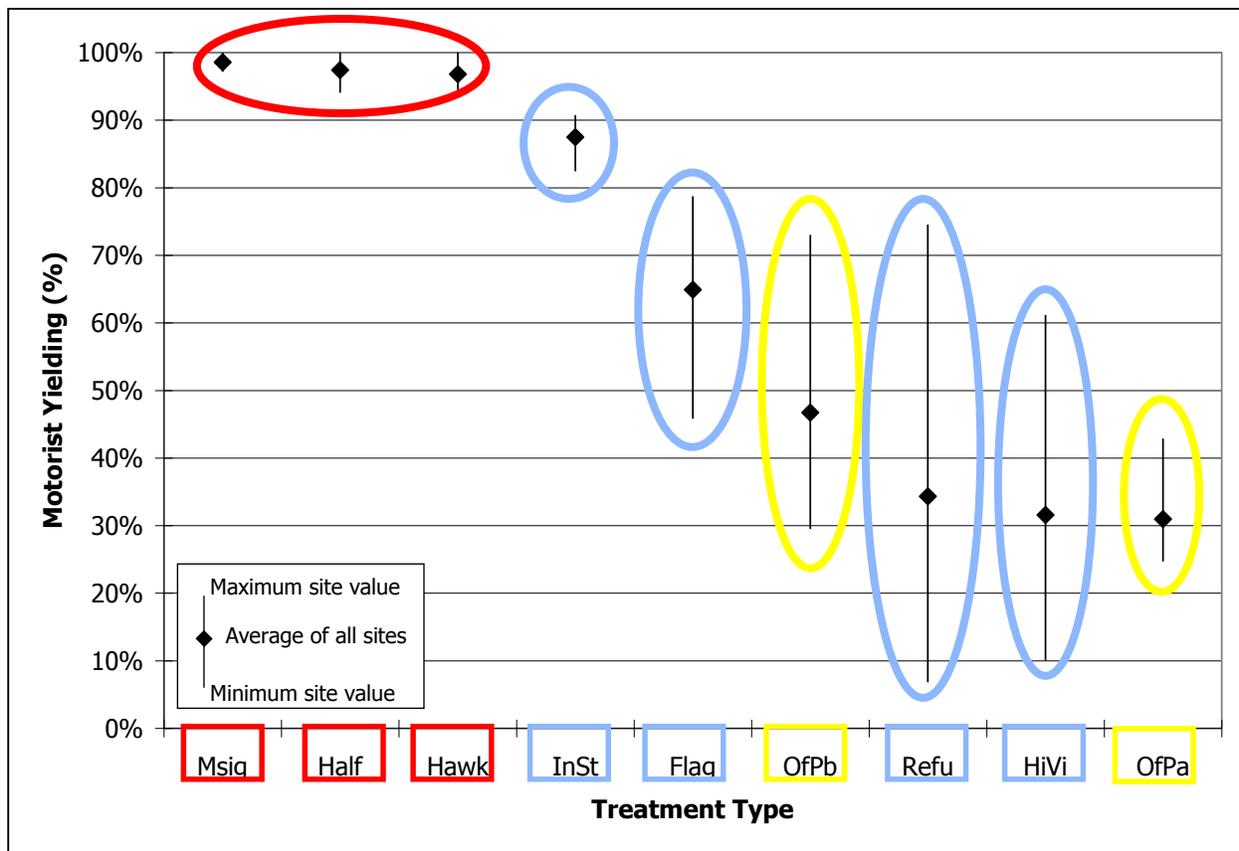


Figure 21 From Figure 24 in NCHRP Report 562 showing the average motorist yielding compliance percentages for each treatment. Abbreviations: Msig=midblock signal; Half=half signal; Hawk=HAWK signal beacon (PHB); InSt=in-street crossing signs; Flaq=pedestrian crossing flags; OfPb=overhead flashing beacon (pushbutton activation); Refu=median refuge island; HiVi=high-visibility signs and markings; OfPa=overhead flashing beacons (passive activation)

In general, each treatment’s effectiveness is influenced by the characteristics of the roadway (such as speed, number of lanes, and traffic volume) and the land use context (commercial versus residential area) in which it is implemented. For example, median refuge islands are much more likely to influence motorist yielding on a two-lane or low-speed road than a 4-lane or high-speed road.

A quick-reference visual of each treatment studied in NCHRP 562 are provided below. Additional information for each can be obtained through PEDSAFE.

<p>Midblock Traffic Signal Tucson, AZ – image from FHWA</p>	 <p>Mike Cynecki</p>
<p>Half Signal Portland, OR – image from FHWA</p>	

Pedestrian Hybrid Beacon
Charlotte, NC – Beatties Ford Rd.



In-Street Yield to Pedestrian
Signage
Raleigh, NC



Pedestrian Crossing Flags
Davidson, NC – Image from
Brenda
Barger/Davidsonnews.net



Overhead Flashing Beacon
San Antonio, TX – image from
USTA Today



Median Refuge Island
Asheville, NC – image from
www.pedbikeimages.org/
Lyubov Zuyeva



High-Visibility Markings
Cary, NC – Park Village Dr.



PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System

<http://www.pedbikesafe.org/PEDSAFE/>

This online guide includes a matrix of pedestrian treatments and a selection tool to help evaluators form a 'short list' of candidate countermeasures for a given issue. Options can also be selected based on the crash type to be mitigated or the performance objective targeted. It includes basic descriptions, considerations, safety effectiveness, cost estimates, and case study examples for the following treatments related to pedestrian crossings:

- Marked Crosswalks and Enhancements
- Crossing Islands
- Raised Medians
- Curb Extensions
- Modify Skewed Intersections
- Pedestrian Signals
- Pedestrian Hybrid Beacon
- Rectangular Rapid Flash Beacon
- Signing



MUTCD: Manual on Uniform Traffic Control Devices

http://mutcd.fhwa.dot.gov/hfm/2009r1r2/html_index.htm

Pertinent Chapters and Sections in the 2009 version related to pedestrian crossing devices:

- Section 2C.50 Non-Vehicular Warning Signs
- Section 3B.18 Crosswalk Markings
- Section 4C.05 Warrant 4, Pedestrian Volume
- Section 4C.06 Warrant 5, School Crossing
- Chapter 4E. Pedestrian Control Features
- Chapter 4F. Pedestrian Hybrid Beacons
- Chapter 4N. In-Roadway Lights

See excerpts of 2009 MUTCD included in Appendix B.

NCDOT Policies:

- Standard Practice for Crosswalks – Mid-Block (Unsignalized) Signing (Feb. 2, 2008)
https://connect.ncdot.gov/resources/safety/Teppl/TEPPL%20All%20Documents%20Library/C-36_pr.pdf
- Alternate Curb Ramp Designs Memorandum (Oct. 20, 2011)
<https://connect.ncdot.gov/resources/safety/Teppl/TEPPL%20All%20Documents%20Library/C53%20%E2%80%93%20Memo%20111020.pdf>

- Interim Approval for Optional Use of Rectangular Rapid Flashing Beacons (RRFBs)
<https://connect.ncdot.gov/resources/safety/Teppl/TEPPL%20All%20Documents%20Library/App%20rovalLetter.PDF>

Pedestrian Hybrid Beacon Guide – Recommendations and Case Study

http://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa14014/

Informational Report on Lighting Design for Midblock Crosswalks (2008)

<http://www.fhwa.dot.gov/publications/research/safety/08053/08053.pdf>

This brief document includes information on lighting parameters and design criteria that should be considered when installing fixed roadway lighting for midblock crosswalks. It includes guidance for lighting placement and lumens levels, as well as minor guidance for lighting at intersections.

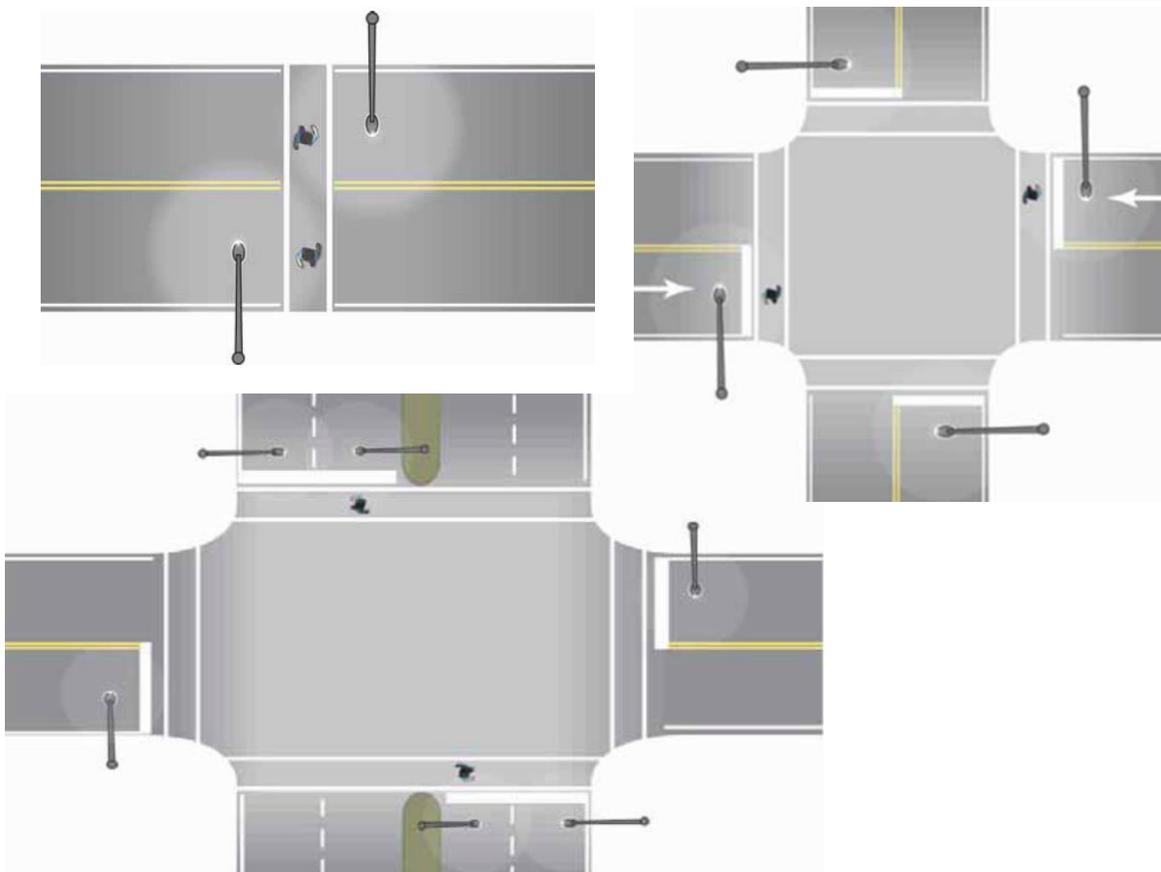
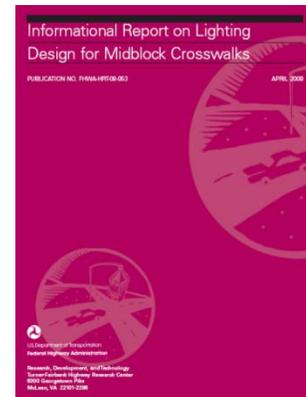


Figure 22 New lighting layout designs to illuminate pedestrians in crosswalks. In general, lighting should be placed downstream of the crosswalk to silhouette the pedestrian at a recommended lighting level of 20 lux at five feet above the pavement. From Figures 12 (midblock), 14 (intersection), and 15 (wide intersection) of Informational Report. (2008)

Appendix B. EXCERPTS FROM THE 2009 MUTCD

The following pages include excerpts from the MUTCD of the following sections or full chapters:

- Section 4C.05 Warrant 4, Pedestrian Volume
- Section 4C.06 Warrant 5, School Crossing
- Chapter 4E. Pedestrian Control Features
- Chapter 4F. Pedestrian Hybrid Beacons

Section 4C.05 Warrant 4, Pedestrian Volume

Support:

- 01 The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.

Standard:

- 02 **The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that one of the following criteria is met:**
- A. **For each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) all fall above the curve in Figure 4C-5; or**
 - B. **For 1 hour (any four consecutive 15-minute periods) of an average day, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) falls above the curve in Figure 4C-7.**

Option:

- 03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 35 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-6 may be used in place of Figure 4C-5 to evaluate Criterion A in Paragraph 2, and Figure 4C-8 may be used in place of Figure 4C-7 to evaluate Criterion B in Paragraph 2.

Standard:

- 04 **The Pedestrian Volume signal warrant shall not be applied at locations where the distance to the nearest traffic control signal or STOP sign controlling the street that pedestrians desire to cross is less than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

- 05 **If this warrant is met and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads complying with the provisions set forth in Chapter 4E.**

Guidance:

- 06 *If this warrant is met and a traffic control signal is justified by an engineering study, then:*
- A. *If it is installed at an intersection or major driveway location, the traffic control signal should also control the minor-street or driveway traffic, should be traffic-actuated, and should include pedestrian detection.*
 - B. *If it is installed at a non-intersection crossing, the traffic control signal should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs, and should be pedestrian-actuated. If the traffic control signal is installed at a non-intersection crossing, at least one of the signal faces should be over the traveled way for each approach, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the crosswalk or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance, and the installation should include suitable standard signs and pavement markings.*
 - C. *Furthermore, if it is installed within a signal system, the traffic control signal should be coordinated.*

Option:

- 07 The criterion for the pedestrian volume crossing the major street may be reduced as much as 50 percent if the 15th-percentile crossing speed of pedestrians is less than 3.5 feet per second.

- 08 A traffic control signal may not be needed at the study location if adjacent coordinated traffic control signals consistently provide gaps of adequate length for pedestrians to cross the street.

Section 4C.06 Warrant 5, School Crossing

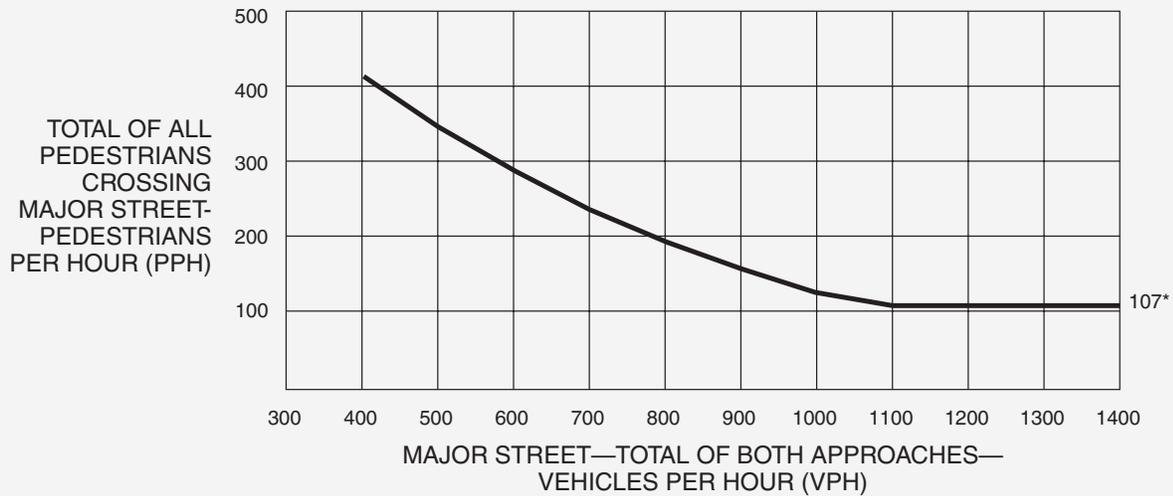
Support:

- 01 The School Crossing signal warrant is intended for application where the fact that schoolchildren cross the major street is the principal reason to consider installing a traffic control signal. For the purposes of this warrant, the word “schoolchildren” includes elementary through high school students.

Standard:

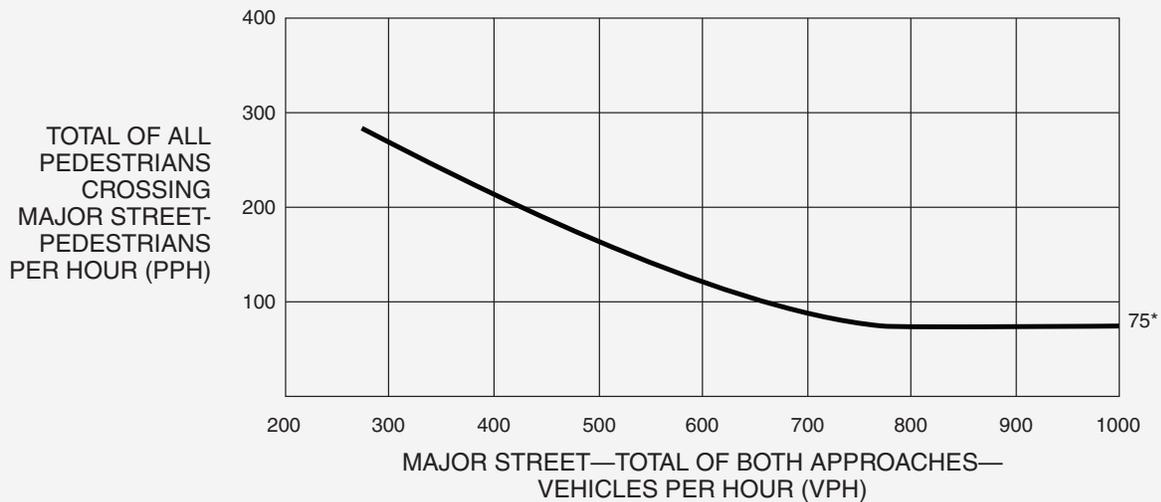
- 02 **The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of schoolchildren at an established school crossing across the major street shows that the number of adequate gaps in the traffic stream during the period when the schoolchildren are using the crossing is less than the number of minutes in the same period (see Section 7A.03) and there are a minimum of 20 schoolchildren during the highest crossing hour.**

Figure 4C-5. Warrant 4, Pedestrian Four-Hour Volume



*Note: 107 pph applies as the lower threshold volume.

Figure 4C-6. Warrant 4, Pedestrian Four-Hour Volume (70% Factor)



*Note: 75 pph applies as the lower threshold volume.

Figure 4C-7. Warrant 4, Pedestrian Peak Hour



*Note: 133 pph applies as the lower threshold volume.

Figure 4C-8. Warrant 4, Pedestrian Peak Hour (70% Factor)



*Note: 93 pph applies as the lower threshold volume.

03 **Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing.**

04 **The School Crossing signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

Guidance:

05 *If this warrant is met and a traffic control signal is justified by an engineering study, then:*

- A. *If it is installed at an intersection or major driveway location, the traffic control signal should also control the minor-street or driveway traffic, should be traffic-actuated, and should include pedestrian detection.*
- B. *If it is installed at a non-intersection crossing, the traffic control signal should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs, and should be pedestrian-actuated. If the traffic control signal is installed at a non-intersection crossing, at least one of the signal faces should be over the traveled way for each approach, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the crosswalk or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance, and the installation should include suitable standard signs and pavement markings.*
- C. *Furthermore, if it is installed within a signal system, the traffic control signal should be coordinated.*

Section 4C.07 Warrant 6, Coordinated Signal System

Support:

01 Progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that one of the following criteria is met:**

- A. **On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.**
- B. **On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.**

Guidance:

03 *The Coordinated Signal System signal warrant should not be applied where the resultant spacing of traffic control signals would be less than 1,000 feet.*

Section 4C.08 Warrant 7, Crash Experience

Support:

01 The Crash Experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that all of the following criteria are met:**

- A. **Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and**
- B. **Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and**
- C. **For each of any 8 hours of an average day, the vehicles per hour (vph) given in both of the 80 percent columns of Condition A in Table 4C-1 (see Section 4C.02), or the vph in both of the 80 percent columns of Condition B in Table 4C-1 exists on the major-street and the higher-volume minor-street approach, respectively, to the intersection, or the volume of pedestrian traffic is not less than 80 percent of the requirements specified in the Pedestrian Volume warrant. These major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.**

CHAPTER 4E. PEDESTRIAN CONTROL FEATURES

Section 4E.01 Pedestrian Signal Heads

Support:

- 01 Pedestrian signal heads provide special types of traffic signal indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRAISED HAND (symbolizing DONT WALK).

Guidance:

- 02 *Engineering judgment should determine the need for separate pedestrian signal heads (see Section 4D.03) and accessible pedestrian signals (see Section 4E.09).*

Support:

- 03 Chapter 4F contains information regarding the use of pedestrian hybrid beacons and Chapter 4N contains information regarding the use of In-Roadway Warning Lights at unsignalized marked crosswalks.

Section 4E.02 Meaning of Pedestrian Signal Head Indications

Standard:

- 01 **Pedestrian signal head indications shall have the following meanings:**
- A. A steady WALKING PERSON (symbolizing WALK) signal indication means that a pedestrian facing the signal indication is permitted to start to cross the roadway in the direction of the signal indication, possibly in conflict with turning vehicles. The pedestrian shall yield the right-of-way to vehicles lawfully within the intersection at the time that the WALKING PERSON (symbolizing WALK) signal indication is first shown.
 - B. A flashing UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not start to cross the roadway in the direction of the signal indication, but that any pedestrian who has already started to cross on a steady WALKING PERSON (symbolizing WALK) signal indication shall proceed to the far side of the traveled way of the street or highway, unless otherwise directed by a traffic control device to proceed only to the median of a divided highway or only to some other island or pedestrian refuge area.
 - C. A steady UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not enter the roadway in the direction of the signal indication.
 - D. A flashing WALKING PERSON (symbolizing WALK) signal indication has no meaning and shall not be used.

Section 4E.03 Application of Pedestrian Signal Heads

Standard:

- 01 **Pedestrian signal heads shall be used in conjunction with vehicular traffic control signals under any of the following conditions:**
- A. If a traffic control signal is justified by an engineering study and meets either Warrant 4, Pedestrian Volume or Warrant 5, School Crossing (see Chapter 4C);
 - B. If an exclusive signal phase is provided or made available for pedestrian movements in one or more directions, with all conflicting vehicular movements being stopped;
 - C. At an established school crossing at any signalized location; or
 - D. Where engineering judgment determines that multi-phase signal indications (as with split-phase timing) would tend to confuse or cause conflicts with pedestrians using a crosswalk guided only by vehicular signal indications.

Guidance:

- 02 *Pedestrian signal heads should be used under any of the following conditions:*
- A. *If it is necessary to assist pedestrians in deciding when to begin crossing the roadway in the chosen direction or if engineering judgment determines that pedestrian signal heads are justified to minimize vehicle-pedestrian conflicts;*
 - B. *If pedestrians are permitted to cross a portion of a street, such as to or from a median of sufficient width for pedestrians to wait, during a particular interval but are not permitted to cross the remainder of the street during any part of the same interval; and/or*
 - C. *If no vehicular signal indications are visible to pedestrians, or if the vehicular signal indications that are visible to pedestrians starting a crossing provide insufficient guidance for them to decide when to begin crossing the roadway in the chosen direction, such as on one-way streets, at T-intersections, or at multi-phase signal operations.*

Option:

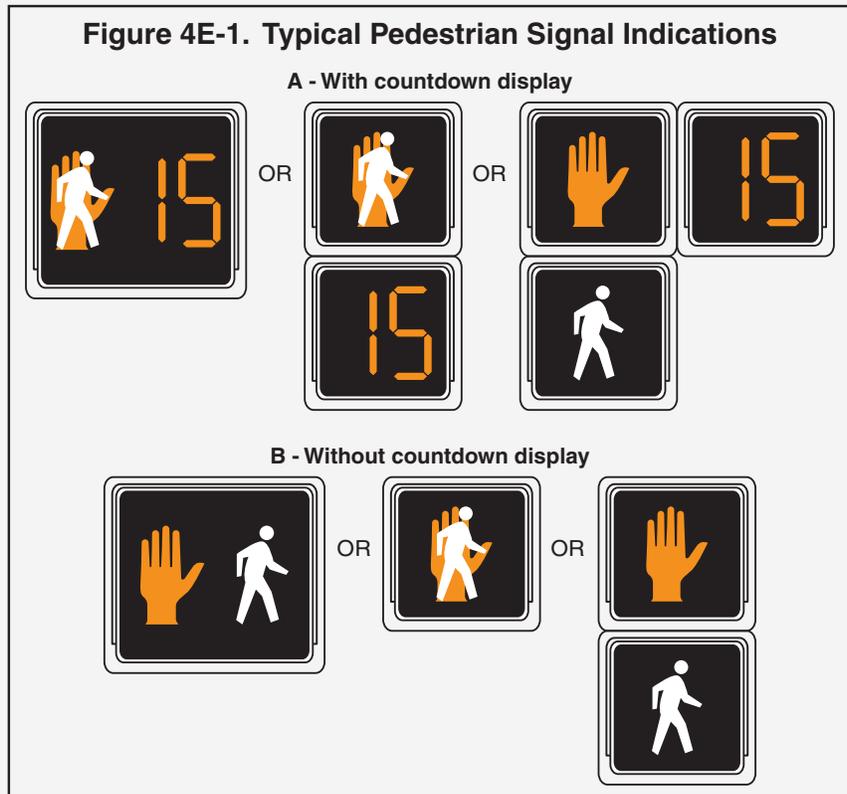
- 03 Pedestrian signal heads may be used under other conditions based on engineering judgment.

Section 4E.04 Size, Design, and Illumination of Pedestrian Signal Head Indications

Standard:

- 01 All new pedestrian signal head indications shall be displayed within a rectangular background and shall consist of symbolized messages (see Figure 4E-1), except that existing pedestrian signal head indications with lettered or outline style symbol messages shall be permitted to be retained for the remainder of their useful service life. The symbol designs that are set forth in the "Standard Highway Signs and Markings" book (see Section 1A.11) shall be used. Each pedestrian signal head indication shall be independently displayed and emit a single color.

- 02 If a two-section pedestrian signal head is used, the UPRAISED HAND (symbolizing DONT WALK) signal section shall be mounted directly above the WALKING PERSON (symbolizing WALK) signal section. If a one-section pedestrian signal head is used, the symbols shall be either overlaid upon each other or arranged side-by-side with the UPRAISED HAND symbol to the left of the WALKING PERSON symbol, and a light source that can display each symbol independently shall be used.



- 03 The WALKING PERSON (symbolizing WALK) signal indication shall be white, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see Section 1A.11), with all except the symbol obscured by an opaque material.

- 04 The UPRAISED HAND (symbolizing DONT WALK) signal indication shall be Portland orange, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see Section 1A.11), with all except the symbol obscured by an opaque material.

- 05 When not illuminated, the WALKING PERSON (symbolizing WALK) and UPRAISED HAND (symbolizing DONT WALK) symbols shall not be readily visible to pedestrians at the far end of the crosswalk that the pedestrian signal head indications control.

- 06 For pedestrian signal head indications, the symbols shall be at least 6 inches high.

- 07 The light source of a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall be flashed continuously at a rate of not less than 50 or more than 60 times per minute. The displayed period of each flash shall be a minimum of 1/2 and a maximum of 2/3 of the total flash cycle.

Guidance:

- 08 Pedestrian signal head indications should be conspicuous and recognizable to pedestrians at all distances from the beginning of the controlled crosswalk to a point 10 feet from the end of the controlled crosswalk during both day and night.

- 09 For crosswalks where the pedestrian enters the crosswalk more than 100 feet from the pedestrian signal head indications, the symbols should be at least 9 inches high.

- 10 If the pedestrian signal indication is so bright that it causes excessive glare in nighttime conditions, some form of automatic dimming should be used to reduce the brilliance of the signal indication.

Option:

- 11 An animated eyes symbol may be added to a pedestrian signal head in order to prompt pedestrians to look for vehicles in the intersection during the time that the WALKING PERSON (symbolizing WALK) signal indication is displayed.

Standard:

- 12 **If used, the animated eyes symbol shall consist of an outline of a pair of white steadily-illuminated eyes with white eyeballs that scan from side to side at a rate of approximately once per second. The animated eyes symbol shall be at least 12 inches wide with each eye having a width of at least 5 inches and a height of at least 2.5 inches. The animated eyes symbol shall be illuminated at the start of the walk interval and shall terminate at the end of the walk interval.**

Section 4E.05 Location and Height of Pedestrian Signal Heads**Standard:**

- 01 **Pedestrian signal heads shall be mounted with the bottom of the signal housing including brackets not less than 7 feet or more than 10 feet above sidewalk level, and shall be positioned and adjusted to provide maximum visibility at the beginning of the controlled crosswalk.**
- 02 **If pedestrian signal heads are mounted on the same support as vehicular signal heads, there shall be a physical separation between them.**

Section 4E.06 Pedestrian Intervals and Signal Phases**Standard:**

- 01 **At intersections equipped with pedestrian signal heads, the pedestrian signal indications shall be displayed except when the vehicular traffic control signal is being operated in the flashing mode. At those times, the pedestrian signal indications shall not be displayed.**
- 02 **When the pedestrian signal heads associated with a crosswalk are displaying either a steady WALKING PERSON (symbolizing WALK) or a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication, a steady or a flashing red signal indication shall be shown to any conflicting vehicular movement that is approaching the intersection or midblock location perpendicular or nearly perpendicular to the crosswalk.**
- 03 **When pedestrian signal heads are used, a WALKING PERSON (symbolizing WALK) signal indication shall be displayed only when pedestrians are permitted to leave the curb or shoulder.**
- 04 **A pedestrian change interval consisting of a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall begin immediately following the WALKING PERSON (symbolizing WALK) signal indication. Following the pedestrian change interval, a buffer interval consisting of a steady UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed for at least 3 seconds prior to the release of any conflicting vehicular movement. The sum of the time of the pedestrian change interval and the buffer interval shall not be less than the calculated pedestrian clearance time (see Paragraphs 7 through 16). The buffer interval shall not begin later than the beginning of the red clearance interval, if used.**

Option:

- 05 During the yellow change interval, the UPRAISED HAND (symbolizing DON'T WALK) signal indication may be displayed as either a flashing indication, a steady indication, or a flashing indication for an initial portion of the yellow change interval and a steady indication for the remainder of the interval.

Support:

- 06 Figure 4E-2 illustrates the pedestrian intervals and their possible relationships with associated vehicular signal phase intervals.

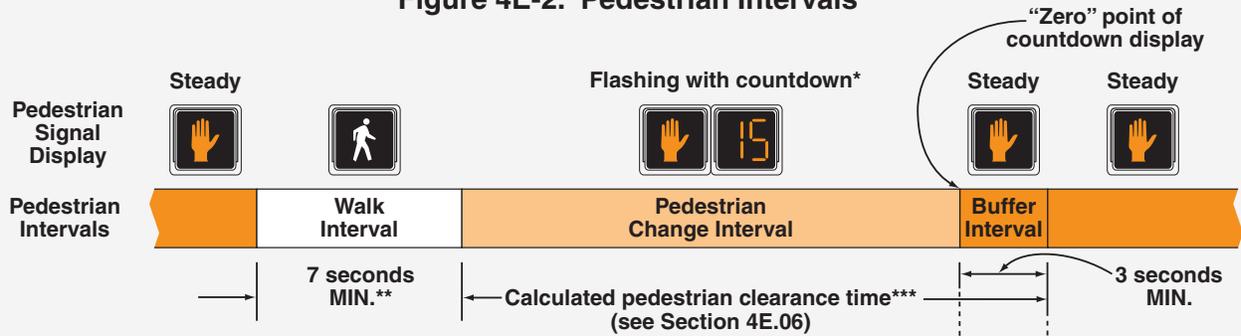
Guidance:

- 07 *Except as provided in Paragraph 8, the pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder at the end of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 3.5 feet per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait.*

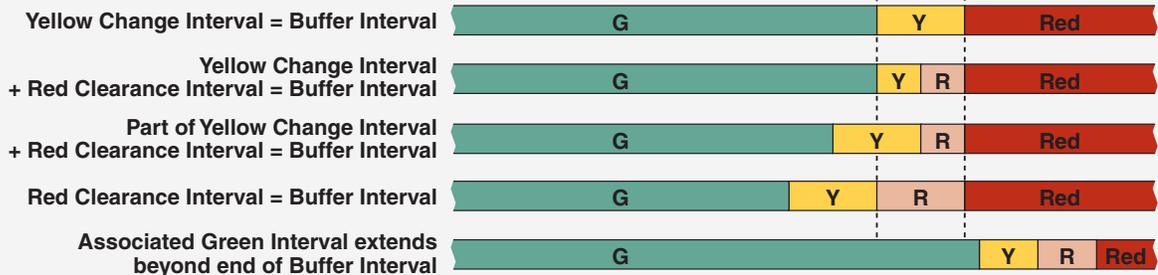
Option:

- 08 A walking speed of up to 4 feet per second may be used to evaluate the sufficiency of the pedestrian clearance time at locations where an extended pushbutton press function has been installed to provide slower pedestrians an opportunity to request and receive a longer pedestrian clearance time. Passive pedestrian detection may also be used to automatically adjust the pedestrian clearance time based on the pedestrian's actual walking speed or actual clearance of the crosswalk.

Figure 4E-2. Pedestrian Intervals



Relationship to associated vehicular phase intervals:



Legend

- * The countdown display is optional for Pedestrian Change Intervals of 7 seconds or less.
- ** The Walk Interval may be reduced under some conditions (see Section 4E.06).
- *** The Buffer Interval, which shall always be provided and displayed, may be used to help satisfy the calculated pedestrian clearance time, or may begin after the calculated pedestrian clearance time has ended.
- G** = Green Interval
- Y** = Yellow Change Interval (of at least 3 seconds)
- R** = Red Clearance Interval
- Red** = Red because conflicting traffic has been released

09 The additional time provided by an extended pushbutton press to satisfy pedestrian clearance time needs may be added to either the walk interval or the pedestrian change interval.

Guidance:

10 Where pedestrians who walk slower than 3.5 feet per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 3.5 feet per second should be considered in determining the pedestrian clearance time.

11 Except as provided in Paragraph 12, the walk interval should be at least 7 seconds in length so that pedestrians will have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins.

Option:

12 If pedestrian volumes and characteristics do not require a 7-second walk interval, walk intervals as short as 4 seconds may be used.

Support:

13 The walk interval is intended for pedestrians to start their crossing. The pedestrian clearance time is intended to allow pedestrians who started crossing during the walk interval to complete their crossing. Longer walk intervals are often used when the duration of the vehicular green phase associated with the pedestrian crossing is long enough to allow it.

Guidance:

14 The total of the walk interval and pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the pedestrian detector (or, if no pedestrian detector is present, a location 6 feet from the face of the curb or from the edge of the pavement) at the beginning of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 3 feet per second to the far side of the traveled way being crossed or to the median if a two-stage pedestrian crossing sequence is used. Any additional time that is required to satisfy the conditions of this paragraph should be added to the walk interval.

Option:

- 15 On a street with a median of sufficient width for pedestrians to wait, a pedestrian clearance time that allows the pedestrian to cross only from the curb or shoulder to the median may be provided.

Standard:

- 16 **Where the pedestrian clearance time is sufficient only for crossing from the curb or shoulder to a median of sufficient width for pedestrians to wait, median-mounted pedestrian signals (with pedestrian detectors if actuated operation is used) shall be provided (see Sections 4E.08 and 4E.09) and signing such as the R10-3d sign (see Section 2B.52) shall be provided to notify pedestrians to cross only to the median to await the next WALKING PERSON (symbolizing WALK) signal indication.**

Guidance:

- 17 *Where median-mounted pedestrian signals and detectors are provided, the use of accessible pedestrian signals (see Sections 4E.09 through 4E.13) should be considered.*

Option:

- 18 During the transition into preemption, the walk interval and the pedestrian change interval may be shortened or omitted as described in Section 4D.27.

- 19 At intersections with high pedestrian volumes and high conflicting turning vehicle volumes, a brief leading pedestrian interval, during which an advance WALKING PERSON (symbolizing WALK) indication is displayed for the crosswalk while red indications continue to be displayed to parallel through and/or turning traffic, may be used to reduce conflicts between pedestrians and turning vehicles.

Guidance:

- 20 *If a leading pedestrian interval is used, the use of accessible pedestrian signals (see Sections 4E.09 through 4E.13) should be considered.*

Support:

- 21 If a leading pedestrian interval is used without accessible features, pedestrians who are visually impaired can be expected to begin crossing at the onset of the vehicular movement when drivers are not expecting them to begin crossing.

Guidance:

- 22 *If a leading pedestrian interval is used, it should be at least 3 seconds in duration and should be timed to allow pedestrians to cross at least one lane of traffic or, in the case of a large corner radius, to travel far enough for pedestrians to establish their position ahead of the turning traffic before the turning traffic is released.*

- 23 *If a leading pedestrian interval is used, consideration should be given to prohibiting turns across the crosswalk during the leading pedestrian interval.*

Support:

- 24 At intersections with pedestrian volumes that are so high that drivers have difficulty finding an opportunity to turn across the crosswalk, the duration of the green interval for a parallel concurrent vehicular movement is sometimes intentionally set to extend beyond the pedestrian clearance time to provide turning drivers additional green time to make their turns while the pedestrian signal head is displaying a steady UPRAISED HAND (symbolizing DONT WALK) signal indication after pedestrians have had time to complete their crossings.

Section 4E.07 Countdown Pedestrian Signals**Standard:**

- 01 **All pedestrian signal heads used at crosswalks where the pedestrian change interval is more than 7 seconds shall include a pedestrian change interval countdown display in order to inform pedestrians of the number of seconds remaining in the pedestrian change interval.**

Option:

- 02 Pedestrian signal heads used at crosswalks where the pedestrian change interval is 7 seconds or less may include a pedestrian change interval countdown display in order to inform pedestrians of the number of seconds remaining in the pedestrian change interval.

Standard:

- 03 **Where countdown pedestrian signals are used, the countdown shall always be displayed simultaneously with the flashing UPRAISED HAND (symbolizing DONT WALK) signal indication displayed for that crosswalk.**

- 04 **Countdown pedestrian signals shall consist of Portland orange numbers that are at least 6 inches in height on a black opaque background. The countdown pedestrian signal shall be located immediately adjacent to the associated UPRAISED HAND (symbolizing DONT WALK) pedestrian signal head indication (see Figure 4E-1).**

05 **The display of the number of remaining seconds shall begin only at the beginning of the pedestrian change interval (flashing UPRAISED HAND). After the countdown displays zero, the display shall remain dark until the beginning of the next countdown.**

06 **The countdown pedestrian signal shall display the number of seconds remaining until the termination of the pedestrian change interval (flashing UPRAISED HAND). Countdown displays shall not be used during the walk interval or during the red clearance interval of a concurrent vehicular phase.**

Guidance:

07 *If used with a pedestrian signal head that does not have a concurrent vehicular phase, the pedestrian change interval (flashing UPRAISED HAND) should be set to be approximately 4 seconds less than the required pedestrian clearance time (see Section 4E.06) and an additional clearance interval (during which a steady UPRAISED HAND is displayed) should be provided prior to the start of the conflicting vehicular phase.*

08 *For crosswalks where the pedestrian enters the crosswalk more than 100 feet from the countdown pedestrian signal display, the numbers should be at least 9 inches in height.*

09 *Because some technology includes the countdown pedestrian signal logic in a separate timing device that is independent of the timing in the traffic signal controller, care should be exercised by the engineer when timing changes are made to pedestrian change intervals.*

10 *If the pedestrian change interval is interrupted or shortened as a part of a transition into a preemption sequence (see Section 4E.06), the countdown pedestrian signal display should be discontinued and go dark immediately upon activation of the preemption transition.*

Section 4E.08 Pedestrian Detectors

Option:

01 Pedestrian detectors may be pushbuttons or passive detection devices.

Support:

02 Passive detection devices register the presence of a pedestrian in a position indicative of a desire to cross, without requiring the pedestrian to push a button. Some passive detection devices are capable of tracking the progress of a pedestrian as the pedestrian crosses the roadway for the purpose of extending or shortening the duration of certain pedestrian timing intervals.

03 The provisions in this Section place pedestrian pushbuttons within easy reach of pedestrians who are intending to cross each crosswalk and make it obvious which pushbutton is associated with each crosswalk. These provisions also position pushbutton poles in optimal locations for installation of accessible pedestrian signals (see Sections 4E.09 through 4E.13). Information regarding reach ranges can be found in the “Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)” (see Section 1A.11).

Guidance:

04 *If pedestrian pushbuttons are used, they should be capable of easy activation and conveniently located near each end of the crosswalks. Except as provided in Paragraphs 5 and 6, pedestrian pushbuttons should be located to meet all of the following criteria (see Figure 4E-3):*

- A. *Unobstructed and adjacent to a level all-weather surface to provide access from a wheelchair;*
- B. *Where there is an all-weather surface, a wheelchair accessible route from the pushbutton to the ramp;*
- C. *Between the edge of the crosswalk line (extended) farthest from the center of the intersection and the side of a curb ramp (if present), but not greater than 5 feet from said crosswalk line;*
- D. *Between 1.5 and 6 feet from the edge of the curb, shoulder, or pavement;*
- E. *With the face of the pushbutton parallel to the crosswalk to be used; and*
- F. *At a mounting height of approximately 3.5 feet, but no more than 4 feet, above the sidewalk.*

05 *Where there are physical constraints that make it impractical to place the pedestrian pushbutton adjacent to a level all-weather surface, the surface should be as level as feasible.*

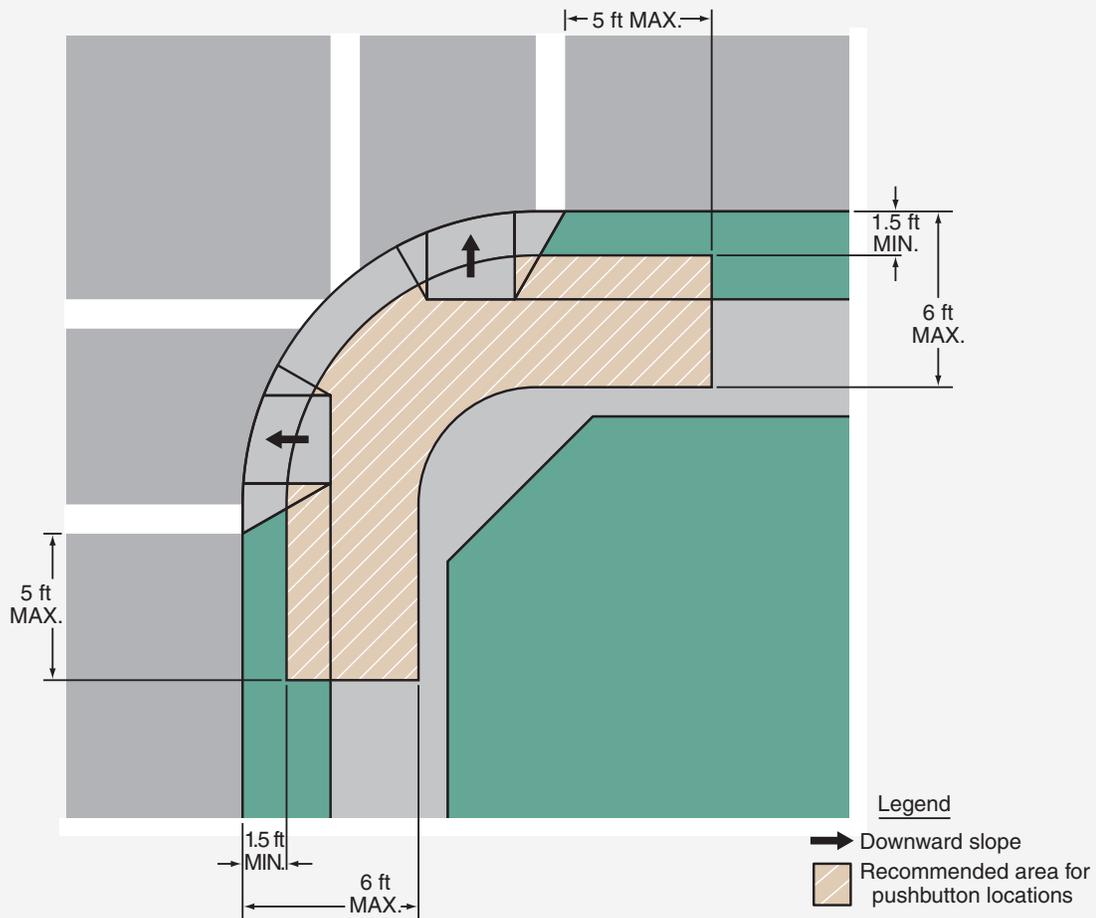
06 *Where there are physical constraints that make it impractical to place the pedestrian pushbutton between 1.5 and 6 feet from the edge of the curb, shoulder, or pavement, it should not be farther than 10 feet from the edge of curb, shoulder, or pavement.*

07 *Except as provided in Paragraph 8, where two pedestrian pushbuttons are provided on the same corner of a signalized location, the pushbuttons should be separated by a distance of at least 10 feet.*

Option:

08 *Where there are physical constraints on a particular corner that make it impractical to provide the 10-foot separation between the two pedestrian pushbuttons, the pushbuttons may be placed closer together or on the same pole.*

Figure 4E-3. Pushbutton Location Area



Notes:

1. Where there are constraints that make it impractical to place the pedestrian pushbutton between 1.5 feet and 6 feet from the edge of the curb, shoulder, or pavement, it should not be further than 10 feet from the edge of curb, shoulder, or pavement.
2. Two pedestrian pushbuttons on a corner should be separated by 10 feet.
3. This figure is not drawn to scale.
4. Figure 4E-4 shows typical pushbutton locations.

Support:

09 Figure 4E-4 shows typical pedestrian pushbutton locations for a variety of situations.

Standard:

10 **Signs (see Section 2B.52) shall be mounted adjacent to or integral with pedestrian pushbuttons, explaining their purpose and use.**

Option:

11 At certain locations, a supplemental sign in a more visible location may be used to call attention to the pedestrian pushbutton.

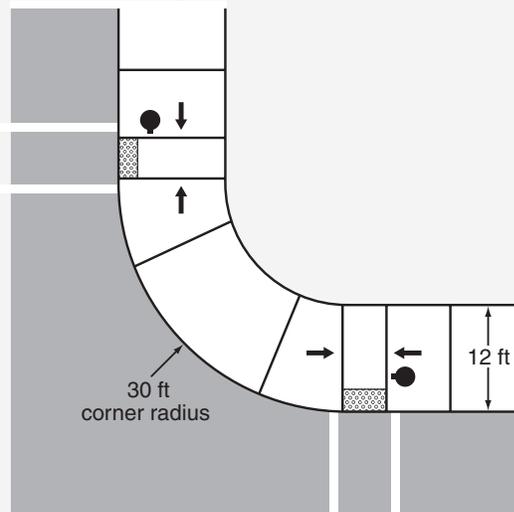
Standard:

12 **The positioning of pedestrian pushbuttons and the legends on the pedestrian pushbutton signs shall clearly indicate which crosswalk signal is actuated by each pedestrian pushbutton.**

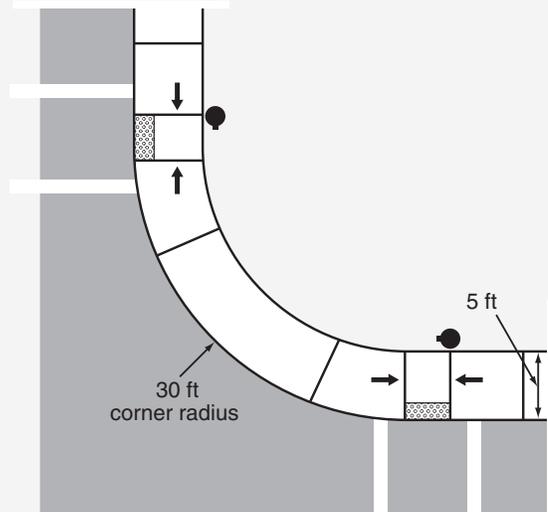
13 **If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and the signals are pedestrian actuated, an additional pedestrian detector shall be provided in the median.**

Figure 4E-4. Typical Pushbutton Locations (Sheet 1 of 2)

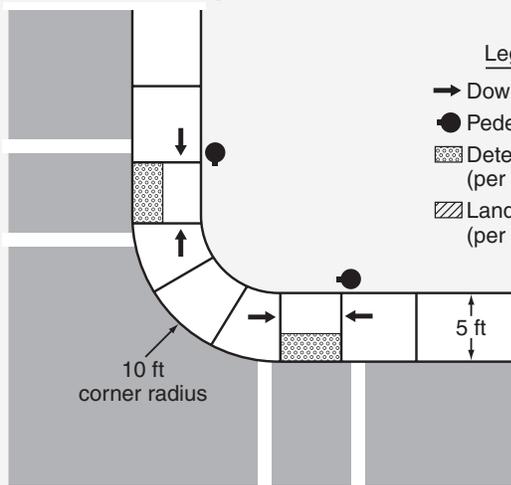
A - Parallel ramps with wide sidewalk



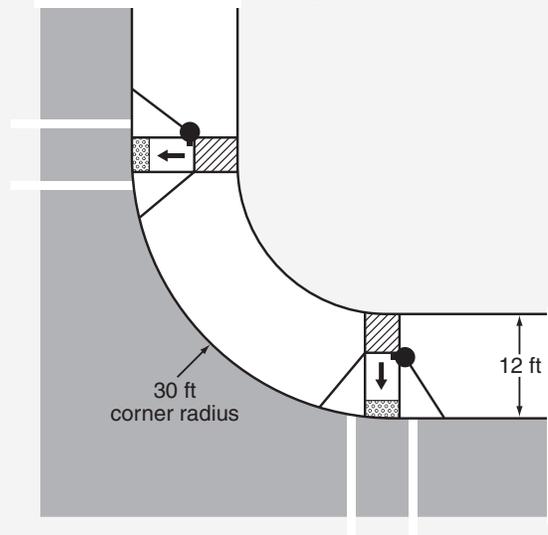
B - Parallel ramps with narrow sidewalk



C - Parallel ramps with narrow sidewalk and tight corner radius



D - Perpendicular ramps with crosswalks far apart



Legend

- Downward slope
- Pedestrian pushbutton
- ▨ Detectable warning (per ADAAG)
- ▩ Landing area (per ADAAG)

Notes:

1. This figure is not drawn to scale.
2. These drawings are intended to describe the typical locations for pedestrian pushbutton installations. They are not intended to be a guide for the design of curb cut ramps.
3. Figure 4E-3 shows the recommended area for pushbutton locations.

Guidance:

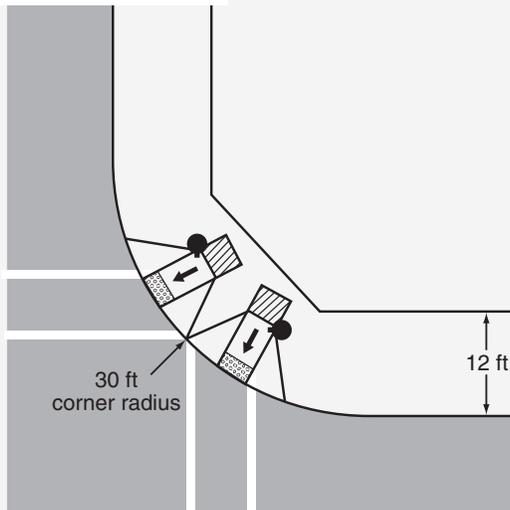
- 14 *The use of additional pedestrian detectors on islands or medians where a pedestrian might become stranded should be considered.*
- 15 *If used, special purpose pushbuttons (to be operated only by authorized persons) should include a housing capable of being locked to prevent access by the general public and do not need an instructional sign.*

Standard:

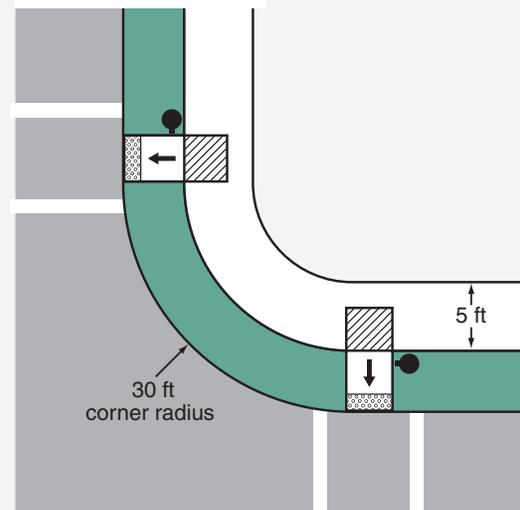
- 16 **If used, a pilot light or other means of indication installed with a pedestrian pushbutton shall not be illuminated until actuation. Once it is actuated, the pilot light shall remain illuminated until the pedestrian's green or WALKING PERSON (symbolizing WALK) signal indication is displayed.**

Figure 4E-4. Typical Pushbutton Locations (Sheet 2 of 2)

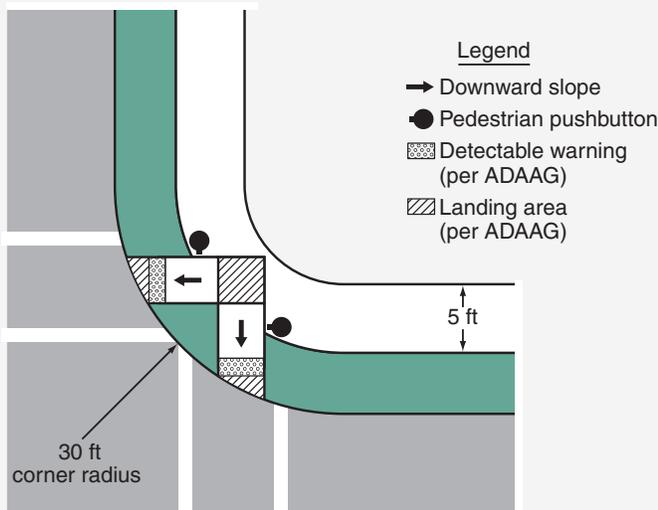
E - Perpendicular ramps with crosswalks close together



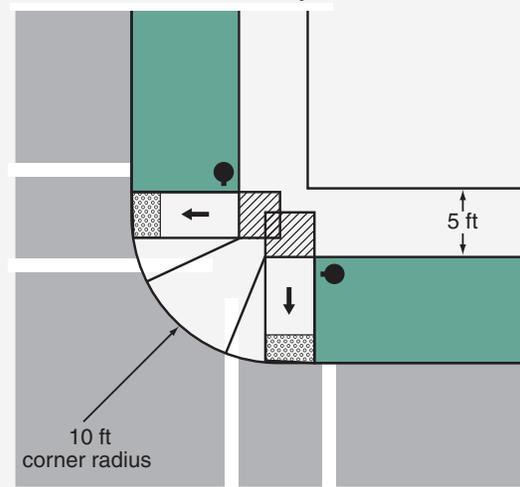
F - Perpendicular ramps with sidewalk set back from road with crosswalks far apart



G - Perpendicular ramps with sidewalk set back from road with crosswalks close together



H - Perpendicular ramps with sidewalk set back from road with continuous sidewalk between ramps



Notes:

1. This figure is not drawn to scale.
2. These drawings are intended to describe the typical locations for pedestrian pushbutton installations. They are not intended to be a guide for the design of curb cut ramps.
3. Figure 4E-3 shows the recommended area for pushbutton locations.

17 **If a pilot light is used at an accessible pedestrian signal location (see Sections 4E.09 through 4E.13), each actuation shall be accompanied by the speech message “wait.”**

Option:

18 At signalized locations with a demonstrated need and subject to equipment capabilities, pedestrians with special needs may be provided with additional crossing time by means of an extended pushbutton press.

Standard:

19 **If additional crossing time is provided by means of an extended pushbutton press, a PUSH BUTTON FOR 2 SECONDS FOR EXTRA CROSSING TIME (R10-32P) plaque (see Figure 2B-26) shall be mounted adjacent to or integral with the pedestrian pushbutton.**

Section 4E.09 Accessible Pedestrian Signals and Detectors – General

Support:

- 01 Accessible pedestrian signals and detectors provide information in non-visual formats (such as audible tones, speech messages, and/or vibrating surfaces).
- 02 The primary technique that pedestrians who have visual disabilities use to cross streets at signalized locations is to initiate their crossing when they hear the traffic in front of them stop and the traffic alongside them begin to move, which often corresponds to the onset of the green interval. The existing environment is often not sufficient to provide the information that pedestrians who have visual disabilities need to cross a roadway at a signalized location.

Guidance:

- 03 *If a particular signalized location presents difficulties for pedestrians who have visual disabilities to cross the roadway, an engineering study should be conducted that considers the needs of pedestrians in general, as well as the information needs of pedestrians with visual disabilities. The engineering study should consider the following factors:*
- A. *Potential demand for accessible pedestrian signals;*
 - B. *A request for accessible pedestrian signals;*
 - C. *Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes;*
 - D. *The complexity of traffic signal phasing (such as split phases, protected turn phases, leading pedestrian intervals, and exclusive pedestrian phases); and*
 - E. *The complexity of intersection geometry.*

Support:

- 04 The factors that make crossing at a signalized location difficult for pedestrians who have visual disabilities include: increasingly quiet cars, right turn on red (which masks the beginning of the through phase), continuous right-turn movements, complex signal operations, traffic circles, and wide streets. Furthermore, low traffic volumes might make it difficult for pedestrians who have visual disabilities to discern signal phase changes.
- 05 Local organizations, providing support services to pedestrians who have visual and/or hearing disabilities, can often act as important advisors to the traffic engineer when consideration is being given to the installation of devices to assist such pedestrians. Additionally, orientation and mobility specialists or similar staff also might be able to provide a wide range of advice. The U.S. Access Board (www.access-board.gov) provides technical assistance for making pedestrian signal information available to persons with visual disabilities (see Page i for the address for the U.S. Access Board).

Standard:

- 06 **When used, accessible pedestrian signals shall be used in combination with pedestrian signal timing. The information provided by an accessible pedestrian signal shall clearly indicate which pedestrian crossing is served by each device.**
- 07 **Under stop-and-go operation, accessible pedestrian signals shall not be limited in operation by the time of day or day of week.**

Option:

- 08 Accessible pedestrian signal detectors may be pushbuttons or passive detection devices.
- 09 At locations with pretimed traffic control signals or non-actuated approaches, pedestrian pushbuttons may be used to activate the accessible pedestrian signals.

Support:

- 10 Accessible pedestrian signals are typically integrated into the pedestrian detector (pushbutton), so the audible tones and/or messages come from the pushbutton housing. They have a pushbutton locator tone and tactile arrow, and can include audible beaconing and other special features.

Option:

- 11 The name of the street to be crossed may also be provided in accessible format, such as Braille or raised print. Tactile maps of crosswalks may also be provided.

Support:

- 12 Specifications regarding the use of Braille or raised print for traffic control devices can be found in the “Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)” (see Section 1A.11).

Standard:

- 13 **At accessible pedestrian signal locations where pedestrian pushbuttons are used, each pushbutton shall activate both the walk interval and the accessible pedestrian signals.**

Section 4E.10 Accessible Pedestrian Signals and Detectors – Location**Support:**

- 01 Accessible pedestrian signals that are located as close as possible to pedestrians waiting to cross the street provide the clearest and least ambiguous indication of which pedestrian crossing is served by a device.

Guidance:

- 02 *Pushbuttons for accessible pedestrian signals should be located in accordance with the provisions of Section 4E.08 and should be located as close as possible to the crosswalk line furthest from the center of the intersection and as close as possible to the curb ramp.*

Standard:

- 03 **If two accessible pedestrian pushbuttons are placed less than 10 feet apart or on the same pole, each accessible pedestrian pushbutton shall be provided with the following features (see Sections 4E.11 through 4E.13):**
- A. A pushbutton locator tone,
 - B. A tactile arrow,
 - C. A speech walk message for the WALKING PERSON (symbolizing WALK) indication, and
 - D. A speech pushbutton information message.
- 04 **If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and accessible pedestrian detectors are used, an additional accessible pedestrian detector shall be provided in the median.**

Section 4E.11 Accessible Pedestrian Signals and Detectors – Walk Indications**Support:**

- 01 Technology that provides different sounds for each non-concurrent signal phase has frequently been found to provide ambiguous information. Research indicates that a rapid tick tone for each crossing coming from accessible pedestrian signal devices on separated poles located close to each crosswalk provides unambiguous information to pedestrians who are blind or visually impaired. Vibrotactile indications provide information to pedestrians who are blind and deaf and are also used by pedestrians who are blind or who have low vision to confirm the walk signal in noisy situations.

Standard:

- 02 **Accessible pedestrian signals shall have both audible and vibrotactile walk indications.**
- 03 **Vibrotactile walk indications shall be provided by a tactile arrow on the pushbutton (see Section 4E.12) that vibrates during the walk interval.**
- 04 **Accessible pedestrian signals shall have an audible walk indication during the walk interval only. The audible walk indication shall be audible from the beginning of the associated crosswalk.**
- 05 **The accessible walk indication shall have the same duration as the pedestrian walk signal except when the pedestrian signal rests in walk.**

Guidance:

- 06 *If the pedestrian signal rests in walk, the accessible walk indication should be limited to the first 7 seconds of the walk interval. The accessible walk indication should be recalled by a button press during the walk interval provided that the crossing time remaining is greater than the pedestrian change interval.*

Standard:

- 07 **Where two accessible pedestrian signals are separated by a distance of at least 10 feet, the audible walk indication shall be a percussive tone. Where two accessible pedestrian signals on one corner are not separated by a distance of at least 10 feet, the audible walk indication shall be a speech walk message.**
- 08 **Audible tone walk indications shall repeat at eight to ten ticks per second. Audible tones used as walk indications shall consist of multiple frequencies with a dominant component at 880 Hz.**

Guidance:

- 09 *The volume of audible walk indications and pushbutton locator tones (see Section 4E.12) should be set to be a maximum of 5 dBA louder than ambient sound, except when audible beaconing is provided in response to an extended pushbutton press.*

Standard:

- 10 **Automatic volume adjustment in response to ambient traffic sound level shall be provided up to a maximum volume of 100 dBA.**

Guidance:

- 11 *The sound level of audible walk indications and pushbutton locator tones should be adjusted to be low enough to avoid misleading pedestrians who have visual disabilities when the following conditions exist:*
- A. *Where there is an island that allows unsignalized right turns across a crosswalk between the island and the sidewalk.*
 - B. *Where multi-leg approaches or complex signal phasing require more than two pedestrian phases, such that it might be unclear which crosswalk is served by each audible tone.*
 - C. *At intersections where a diagonal pedestrian crossing is allowed, or where one street receives a WALKING PERSON (symbolizing WALK) signal indication simultaneously with another street.*

Option:

- 12 An alert tone, which is a very brief burst of high-frequency sound at the beginning of the audible walk indication that rapidly decays to the frequency of the walk tone, may be used to alert pedestrians to the beginning of the walk interval.

Support:

- 13 An alert tone can be particularly useful if the walk tone is not easily audible in some traffic conditions.
- 14 Speech walk messages communicate to pedestrians which street has the walk interval. Speech messages might be either directly audible or transmitted, requiring a personal receiver to hear the message. To be a useful system, the words and their meaning need to be correctly understood by all users in the context of the street environment where they are used. Because of this, tones are the preferred means of providing audible walk indications except where two accessible pedestrian signals on one corner are not separated by a distance of at least 10 feet.
- 15 If speech walk messages are used, pedestrians have to know the names of the streets that they are crossing in order for the speech walk messages to be unambiguous. In getting directions to travel to a new location, pedestrians with visual disabilities do not always get the name of each street to be crossed. Therefore, it is desirable to give users of accessible pedestrian signals the name of the street controlled by the pushbutton. This can be done by means of a speech pushbutton information message (see Section 4D.13) during the flashing or steady UPRAISED HAND intervals, or by raised print and Braille labels on the pushbutton housing.
- 16 By combining the information from the pushbutton message or Braille label, the tactile arrow aligned in the direction of travel on the relevant crosswalk, and the speech walk message, pedestrians with visual disabilities are able to correctly respond to speech walk messages even if there are two pushbuttons on the same pole.

Standard:

- 17 **If speech walk messages are used to communicate the walk interval, they shall provide a clear message that the walk interval is in effect, as well as to which crossing it applies. Speech walk messages shall be used only at intersections where it is technically infeasible to install two accessible pedestrian signals at one corner separated by a distance of at least 10 feet.**
- 18 **Speech walk messages that are used at intersections having pedestrian phasing that is concurrent with vehicular phasing shall be patterned after the model: “Broadway. Walk sign is on to cross Broadway.”**
- 19 **Speech walk messages that are used at intersections having exclusive pedestrian phasing shall be patterned after the model: “Walk sign is on for all crossings.”**
- 20 **Speech walk messages shall not contain any additional information, except they shall include designations such as “Street” or “Avenue” where this information is necessary to avoid ambiguity at a particular location.**

Guidance:

- 21 *Speech walk messages should not state or imply a command to the pedestrian, such as “Cross Broadway now.” Speech walk messages should not tell pedestrians that it is “safe to cross,” because it is always the pedestrian’s responsibility to check actual traffic conditions.*

Standard:

- 22 **A speech walk message is not required at times when the walk interval is not timing, but, if provided:**
- A. **It shall begin with the term “wait.”**
 - B. **It need not be repeated for the entire time that the walk interval is not timing.**
- 23 **If a pilot light (see Section 4E.08) is used at an accessible pedestrian signal location, each actuation shall be accompanied by the speech message “wait.”**

Option:

- 24 Accessible pedestrian signals that provide speech walk messages may provide similar messages in languages other than English, if needed, except for the terms “walk sign” and “wait.”

Standard:

- 25 **Following the audible walk indication, accessible pedestrian signals shall revert to the pushbutton locator tone (see Section 4E.12) during the pedestrian change interval.**

Section 4E.12 Accessible Pedestrian Signals and Detectors – Tactile Arrows and Locator Tones

Standard:

- 01 **To enable pedestrians who have visual disabilities to distinguish and locate the appropriate pushbutton at an accessible pedestrian signal location, pushbuttons shall clearly indicate by means of tactile arrows which crosswalk signal is actuated by each pushbutton. Tactile arrows shall be located on the pushbutton, have high visual contrast (light on dark or dark on light), and shall be aligned parallel to the direction of travel on the associated crosswalk.**

- 02 **An accessible pedestrian pushbutton shall incorporate a locator tone.**

Support:

- 03 A pushbutton locator tone is a repeating sound that informs approaching pedestrians that a pushbutton to actuate pedestrian timing or receive additional information exists, and that enables pedestrians with visual disabilities to locate the pushbutton.

Standard:

- 04 **Pushbutton locator tones shall have a duration of 0.15 seconds or less, and shall repeat at 1-second intervals.**

- 05 **Pushbutton locator tones shall be deactivated when the traffic control signal is operating in a flashing mode. This requirement shall not apply to traffic control signals or pedestrian hybrid beacons that are activated from a flashing or dark mode to a stop-and-go mode by pedestrian actuations.**

- 06 **Pushbutton locator tones shall be intensity responsive to ambient sound, and be audible 6 to 12 feet from the pushbutton, or to the building line, whichever is less.**

Support:

- 07 Section 4E.11 contains additional provisions regarding the volume and sound level of pushbutton locator tones.

Section 4E.13 Accessible Pedestrian Signals and Detectors – Extended Pushbutton Press Features

Option:

- 01 Pedestrians may be provided with additional features such as increased crossing time, audible beaconing, or a speech pushbutton information message as a result of an extended pushbutton press.

Standard:

- 02 **If an extended pushbutton press is used to provide any additional feature(s), a pushbutton press of less than one second shall actuate only the pedestrian timing and any associated accessible walk indication, and a pushbutton press of one second or more shall actuate the pedestrian timing, any associated accessible walk indication, and any additional feature(s).**

- 03 **If additional crossing time is provided by means of an extended pushbutton press, a PUSH BUTTON FOR 2 SECONDS FOR EXTRA CROSSING TIME (R10-32P) plaque (see Figure 2B-26) shall be mounted adjacent to or integral with the pedestrian pushbutton.**

Support:

- 04 Audible beaconing is the use of an audible signal in such a way that pedestrians with visual disabilities can home in on the signal that is located on the far end of the crosswalk as they cross the street.

- 05 Not all crosswalks at an intersection need audible beaconing; audible beaconing can actually cause confusion if used at all crosswalks at some intersections. Audible beaconing is not appropriate at locations with channelized turns or split phasing, because of the possibility of confusion.

Guidance:

- 06 *Audible beaconing should only be considered following an engineering study at:*

- A. *Crosswalks longer than 70 feet, unless they are divided by a median that has another accessible pedestrian signal with a locator tone;*
- B. *Crosswalks that are skewed;*
- C. *Intersections with irregular geometry, such as more than four legs;*
- D. *Crosswalks where audible beaconing is requested by an individual with visual disabilities; or*
- E. *Other locations where a study indicates audible beaconing would be beneficial.*

Option:

- 07 Audible beaconing may be provided in several ways, any of which are initiated by an extended pushbutton press.

Standard:

- 08 **If audible beaconing is used, the volume of the pushbutton locator tone during the pedestrian change interval of the called pedestrian phase shall be increased and operated in one of the following ways:**
- A. **The louder audible walk indication and louder locator tone comes from the far end of the crosswalk, as pedestrians cross the street,**
 - B. **The louder locator tone comes from both ends of the crosswalk, or**
 - C. **The louder locator tone comes from an additional speaker that is aimed at the center of the crosswalk and that is mounted on a pedestrian signal head.**

Option:

- 09 Speech pushbutton information messages may provide intersection identification, as well as information about unusual intersection signalization and geometry, such as notification regarding exclusive pedestrian phasing, leading pedestrian intervals, split phasing, diagonal crosswalks, and medians or islands.

Standard:

- 10 **If speech pushbutton information messages are made available by actuating the accessible pedestrian signal detector, they shall only be actuated when the walk interval is not timing. They shall begin with the term “Wait,” followed by intersection identification information modeled after: “Wait to cross Broadway at Grand.” If information on intersection signalization or geometry is also given, it shall follow the intersection identification information.**

Guidance:

- 11 *Speech pushbutton information messages should not be used to provide landmark information or to inform pedestrians with visual disabilities about detours or temporary traffic control situations.*

Support:

- 12 Additional information on the structure and wording of speech pushbutton information messages is included in ITE’s “Electronic Toolbox for Making Intersections More Accessible for Pedestrians Who Are Blind or Visually Impaired,” which is available at ITE’s website (see Page i).

CHAPTER 4F. PEDESTRIAN HYBRID BEACONS

Section 4F.01 Application of Pedestrian Hybrid Beacons

Support:

- 01 A pedestrian hybrid beacon is a special type of hybrid beacon used to warn and control traffic at an unsignalized location to assist pedestrians in crossing a street or highway at a marked crosswalk.

Option:

- 02 A pedestrian hybrid beacon may be considered for installation to facilitate pedestrian crossings at a location that does not meet traffic signal warrants (see Chapter 4C), or at a location that meets traffic signal warrants under Sections 4C.05 and/or 4C.06 but a decision is made to not install a traffic control signal.

Standard:

- 03 **If used, pedestrian hybrid beacons shall be used in conjunction with signs and pavement markings to warn and control traffic at locations where pedestrians enter or cross a street or highway. A pedestrian hybrid beacon shall only be installed at a marked crosswalk.**

Guidance:

- 04 *If one of the signal warrants of Chapter 4C is met and a traffic control signal is justified by an engineering study, and if a decision is made to install a traffic control signal, it should be installed based upon the provisions of Chapters 4D and 4E.*
- 05 *If a traffic control signal is not justified under the signal warrants of Chapter 4C and if gaps in traffic are not adequate to permit pedestrians to cross, or if the speed for vehicles approaching on the major street is too high to permit pedestrians to cross, or if pedestrian delay is excessive, the need for a pedestrian hybrid beacon should be considered on the basis of an engineering study that considers major-street volumes, speeds, widths, and gaps in conjunction with pedestrian volumes, walking speeds, and delay.*
- 06 *For a major street where the posted or statutory speed limit or the 85th-percentile speed is 35 mph or less, the need for a pedestrian hybrid beacon should be considered if the engineering study finds that the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding total of all pedestrians crossing the major street for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4F-1 for the length of the crosswalk.*
- 07 *For a major street where the posted or statutory speed limit or the 85th-percentile speed exceeds 35 mph, the need for a pedestrian hybrid beacon should be considered if the engineering study finds that the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding total of all pedestrians crossing the major street for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4F-2 for the length of the crosswalk.*
- 08 *For crosswalks that have lengths other than the four that are specifically shown in Figures 4F-1 and 4F-2, the values should be interpolated between the curves.*

Section 4F.02 Design of Pedestrian Hybrid Beacons

Standard:

- 01 **Except as otherwise provided in this Section, a pedestrian hybrid beacon shall meet the provisions of Chapters 4D and 4E.**
- 02 **A pedestrian hybrid beacon face shall consist of three signal sections, with a CIRCULAR YELLOW signal indication centered below two horizontally aligned CIRCULAR RED signal indications (see Figure 4F-3).**
- 03 **When an engineering study finds that installation of a pedestrian hybrid beacon is justified, then:**
- A. **At least two pedestrian hybrid beacon faces shall be installed for each approach of the major street,**
 - B. **A stop line shall be installed for each approach to the crosswalk,**
 - C. **A pedestrian signal head conforming to the provisions set forth in Chapter 4E shall be installed at each end of the marked crosswalk, and**
 - D. **The pedestrian hybrid beacon shall be pedestrian actuated.**

Guidance:

- 04 *When an engineering study finds that installation of a pedestrian hybrid beacon is justified, then:*
- A. *The pedestrian hybrid beacon should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs,*

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

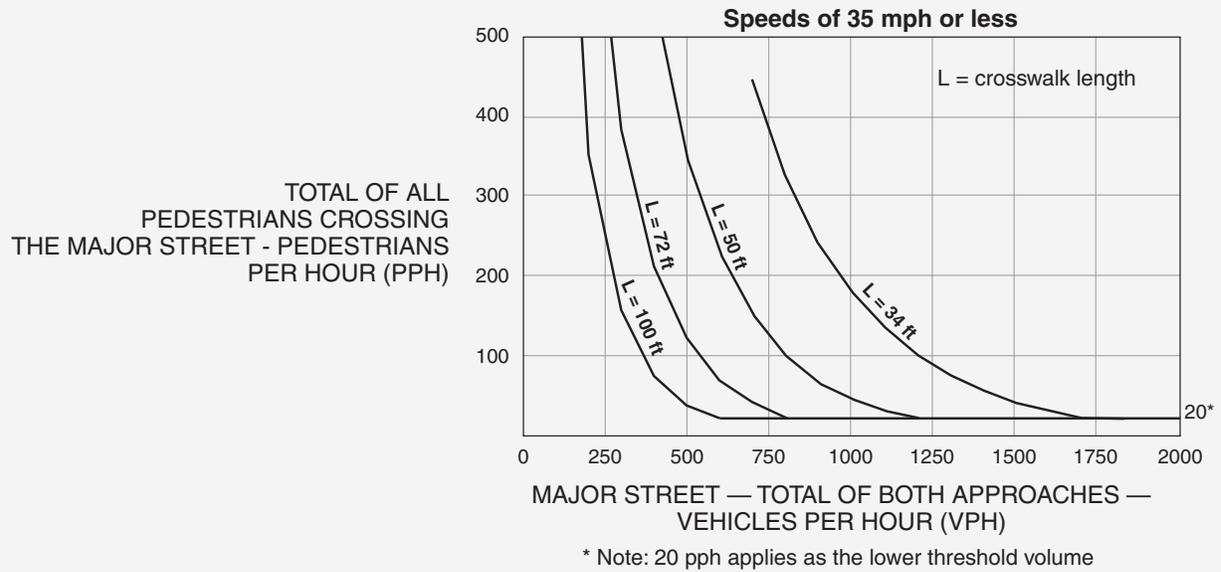


Figure 4F-2. Guidelines for the Installation of Pedestrian Hybrid Beacons on High-Speed Roadways

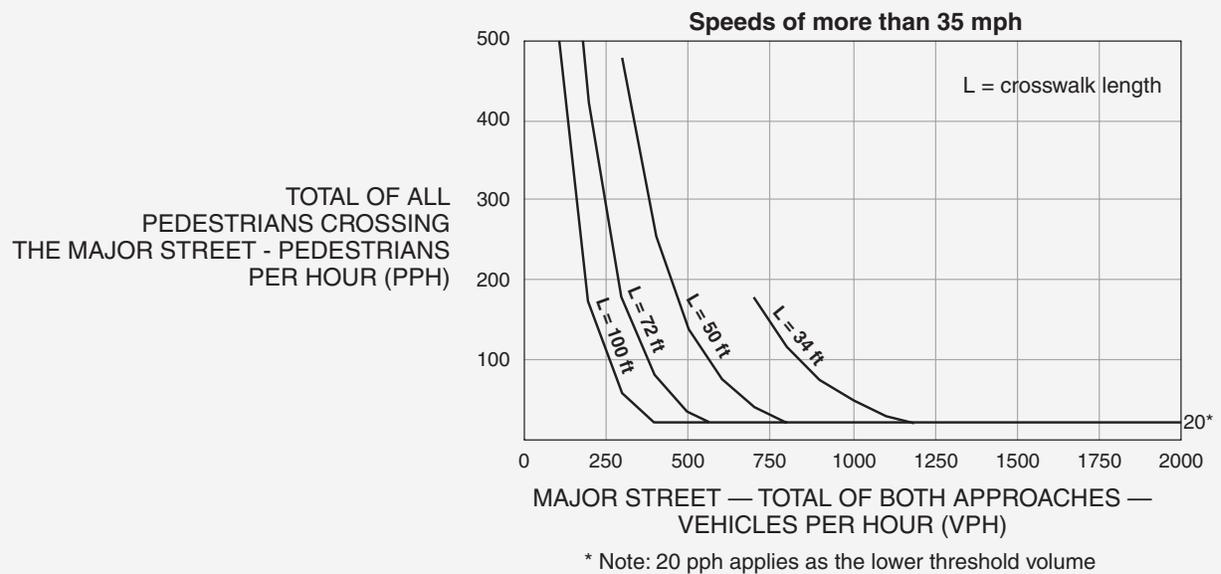
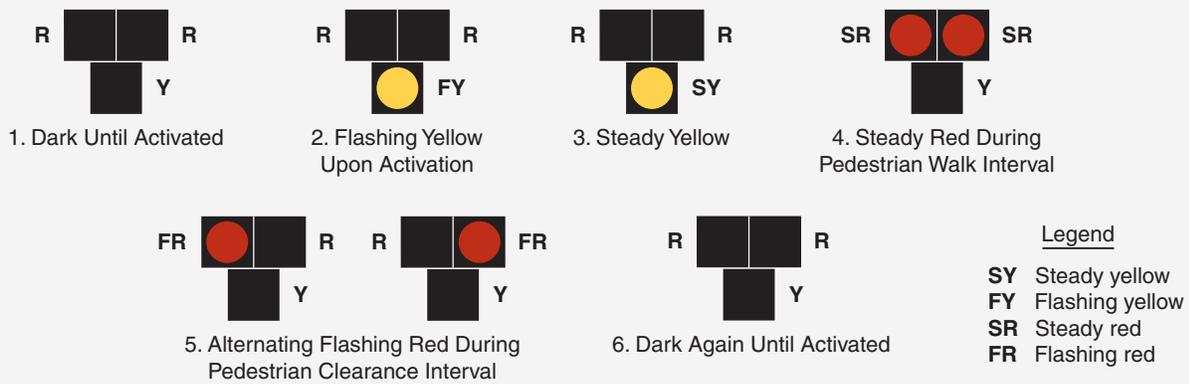


Figure 4F-3. Sequence for a Pedestrian Hybrid Beacon



- B. 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,
- C. The installation should include suitable standard signs and pavement markings, and
- D. If installed within a signal system, the pedestrian hybrid beacon should be coordinated.

- 05 On approaches having posted or statutory speed limits or 85th-percentile speeds in excess of 35 mph and on approaches having traffic or operating conditions that would tend to obscure visibility of roadside hybrid beacon face locations, both of the minimum of two pedestrian hybrid beacon faces should be installed over the roadway.
- 06 On multi-lane approaches having a posted or statutory speed limits or 85th-percentile speeds of 35 mph or less, either a pedestrian hybrid beacon face should be installed on each side of the approach (if a median of sufficient width exists) or at least one of the pedestrian hybrid beacon faces should be installed over the roadway.
- 07 A pedestrian hybrid beacon should comply with the signal face location provisions described in Sections 4D.11 through 4D.16.

Standard:

- 08 A CROSSWALK STOP ON RED (symbolic circular red) (R10-23) sign (see Section 2B.53) shall be mounted adjacent to a pedestrian hybrid beacon face on each major street approach. If an overhead pedestrian hybrid beacon face is provided, the sign shall be mounted adjacent to the overhead signal face.
- Option:
- 09 A Pedestrian (W11-2) warning sign (see Section 2C.50) with an AHEAD (W16-9P) supplemental plaque may be placed in advance of a pedestrian hybrid beacon. A warning beacon may be installed to supplement the W11-2 sign.

Guidance:

- 10 If a warning beacon supplements a W11-2 sign in advance of a pedestrian hybrid beacon, it should be programmed to flash only when the pedestrian hybrid beacon is not in the dark mode.

Standard:

- 11 If a warning beacon is installed to supplement the W11-2 sign, the design and location of the warning beacon shall comply with the provisions of Sections 4L.01 and 4L.03.

Section 4F.03 Operation of Pedestrian Hybrid Beacons

Standard:

- 01 Pedestrian hybrid beacon indications shall be dark (not illuminated) during periods between actuations.
- 02 Upon actuation by a pedestrian, a pedestrian hybrid beacon face shall display a flashing CIRCULAR yellow signal indication, followed by a steady CIRCULAR yellow signal indication, followed by both steady CIRCULAR RED signal indications during the pedestrian walk interval, followed by alternating flashing CIRCULAR RED signal indications during the pedestrian clearance interval (see Figure 4F-3). Upon termination of the pedestrian clearance interval, the pedestrian hybrid beacon faces shall revert to a dark (not illuminated) condition.

03 **Except as provided in Paragraph 4, the pedestrian signal heads shall continue to display a steady UPRAISED HAND (symbolizing DONT WALK) signal indication when the pedestrian hybrid beacon faces are either dark or displaying flashing or steady CIRCULAR yellow signal indications. The pedestrian signal heads shall display a WALKING PERSON (symbolizing WALK) signal indication when the pedestrian hybrid beacon faces are displaying steady CIRCULAR RED signal indications. The pedestrian signal heads shall display a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication when the pedestrian hybrid beacon faces are displaying alternating flashing CIRCULAR RED signal indications. Upon termination of the pedestrian clearance interval, the pedestrian signal heads shall revert to a steady UPRAISED HAND (symbolizing DONT WALK) signal indication.**

Option:

04 Where the pedestrian hybrid beacon is installed adjacent to a roundabout to facilitate crossings by pedestrians with visual disabilities and an engineering study determines that pedestrians without visual disabilities can be allowed to cross the roadway without actuating the pedestrian hybrid beacon, the pedestrian signal heads may be dark (not illuminated) when the pedestrian hybrid beacon faces are dark.

Guidance:

05 *The duration of the flashing yellow interval should be determined by engineering judgment.*

Standard:

06 **The duration of the steady yellow change interval shall be determined using engineering practices.**

Guidance:

07 *The steady yellow interval should have a minimum duration of 3 seconds and a maximum duration of 6 seconds (see Section 4D.26). The longer intervals should be reserved for use on approaches with higher speeds.*

Appendix C. TOTAL PEDESTRIAN DELAY CHARTS

This appendix provides a series of 15 quick-reference charts to assist evaluators in quickly estimating Total Pedestrian Delay. These charts were prepared by utilizing two worksheets from *NCHRP Report 562* to calculate Total Pedestrian Delay curves. The worksheets and list of variables and inputs that go into them also are provided at the end of this appendix for situations in which an evaluator needs to calculate Total Pedestrian Delay rather than rely on one of the quick-reference charts.

The quick-reference charts were developed using default assumptions and inputs for variables in the worksheets. Charts are provided for two speed categories (less than or equal to 35 mph, or greater than 35 mph) and for locations where the area population is less than 10,000. Within each of these three scenarios, one chart is provided for five different crossing distance assumptions: 12 ft., 24 ft., 36 ft., 48 ft., or 60 ft. Default values of 3.5 ft/sec for pedestrian walking speed and 3 sec for the pedestrian start-up and end clearance times were used.

Pedestrian Delay Charts

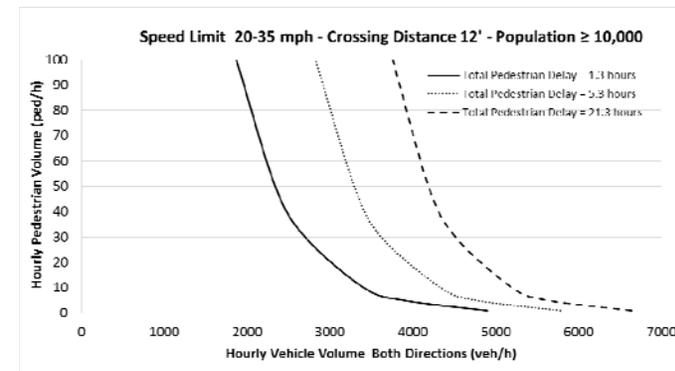
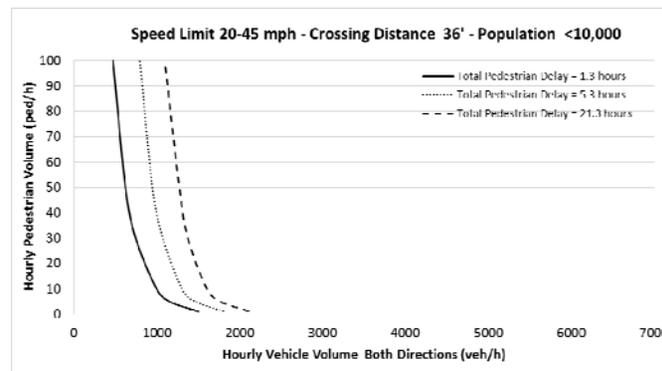
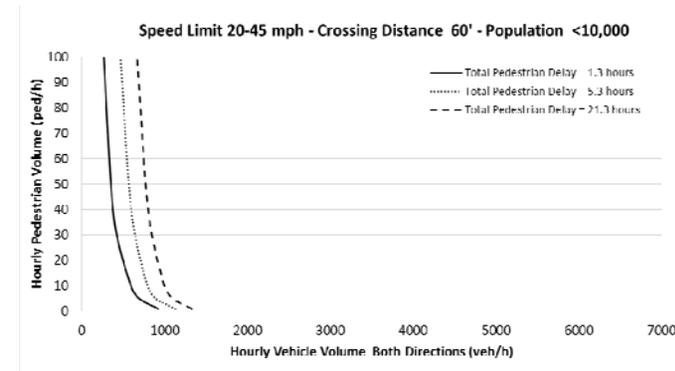
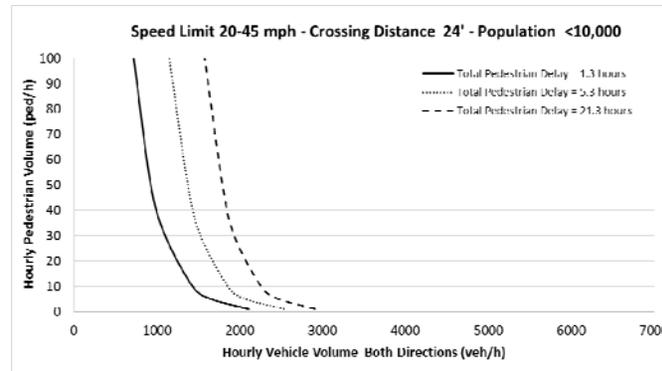
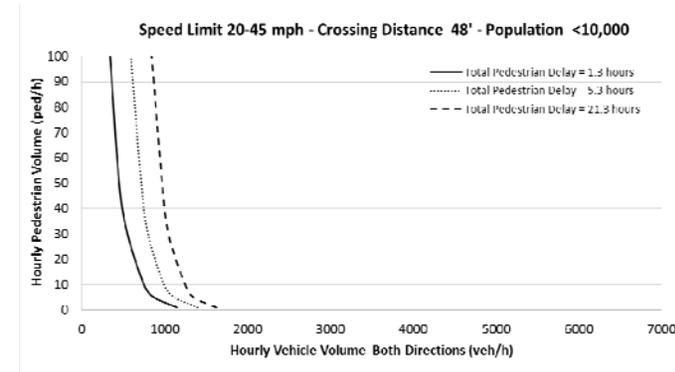
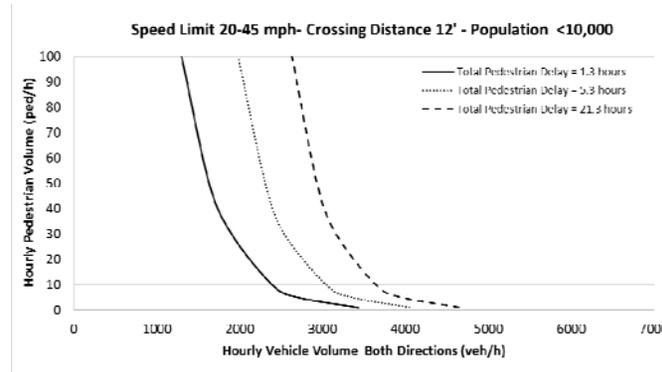
Use appropriate graph to estimated pedestrian delay based on the following inputs:

- Crossing Distance – distance pedestrian would cross to reach a median refuge island or the edge of pavement on far side,
- Speed – posted or 85th percentile operating speed of major road
- Pedestrian Volume – number of pedestrians crossing the major road in a peak hour, including crossings within 150 feet of the location
- Vehicle Volume – number of vehicles, including bicycles, on both approaches of the major road in a peak hour. If median refuge island present, treat volume for each approach separately

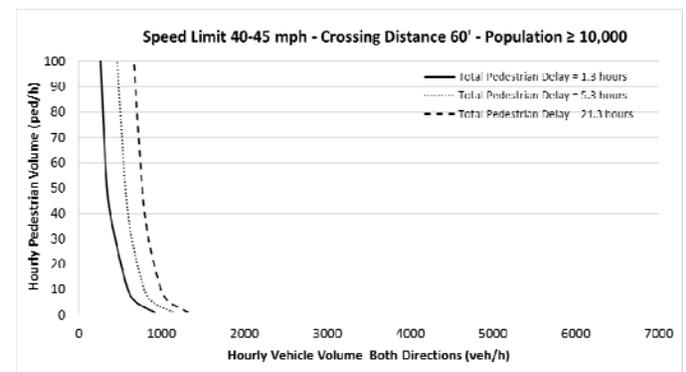
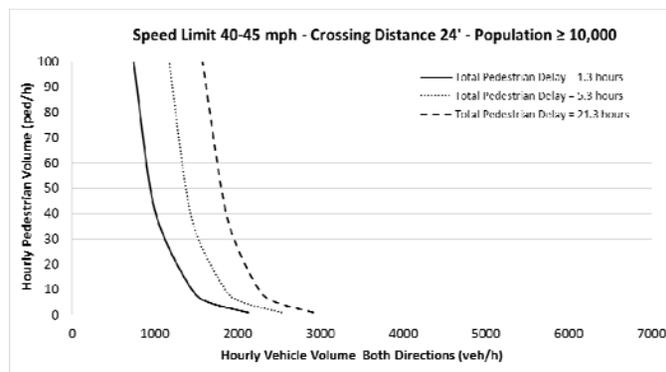
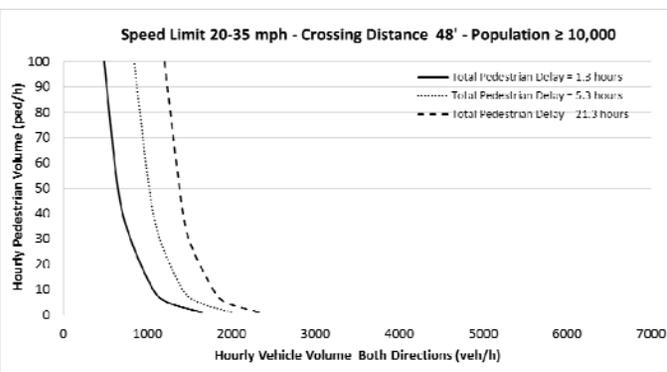
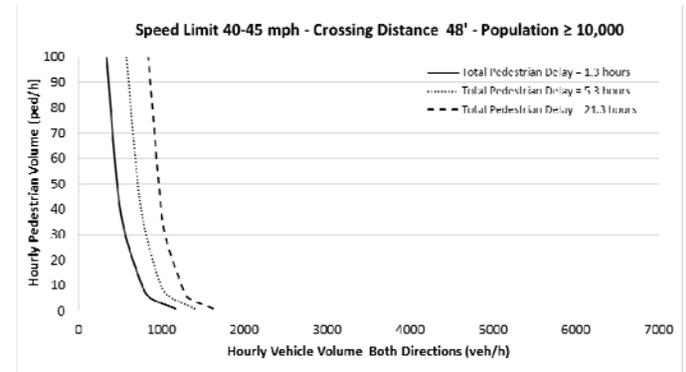
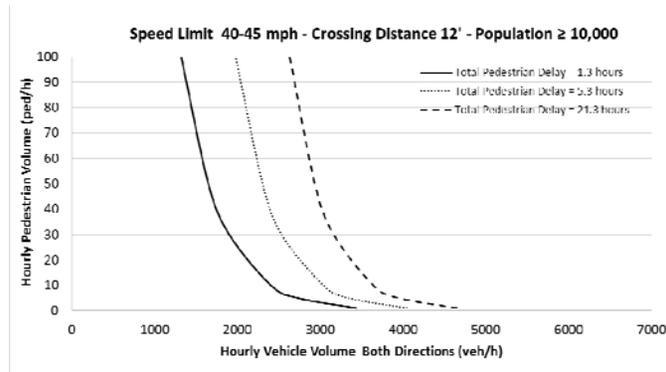
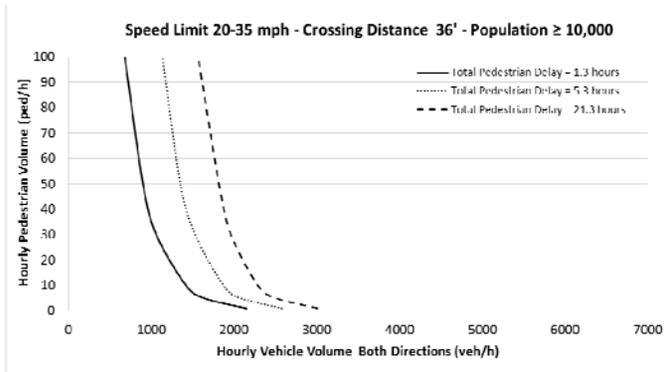
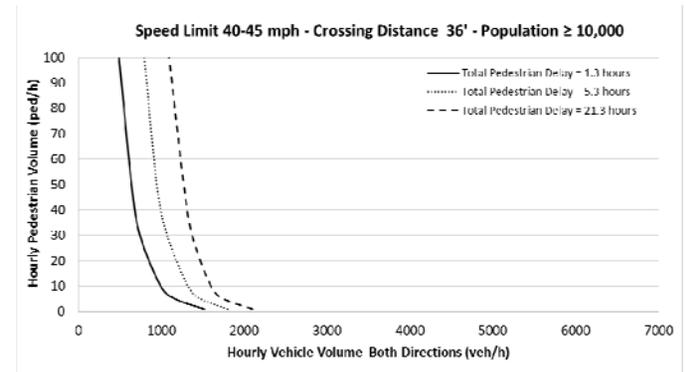
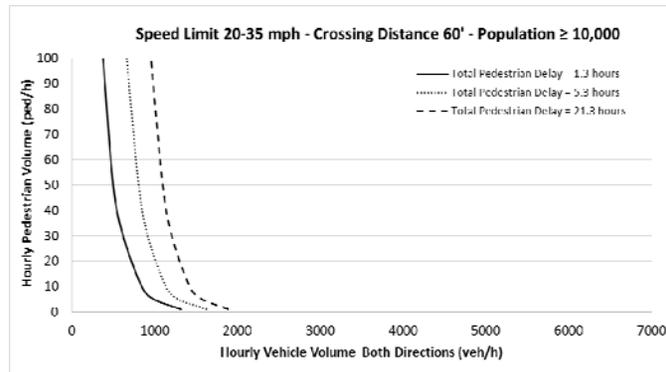
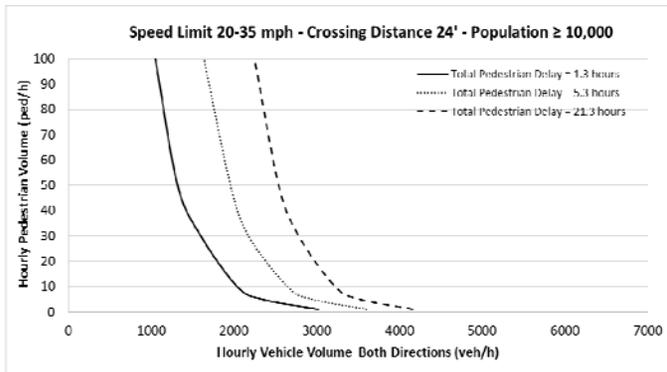
Based on where the point falls on the graph used, use table below to identify a treatment type or next step.

Treatment Selection Guidance

Speed Limit	Motorist Compliance	Pedestrian Delay			
		Low (< 1.3 ped-hr)	Medium-Low (≥ 1.3 ped-hr to < 5.3 ped-hr)	Medium-High (≥ 5.3 ped-hr to < 21.3 ped-hr)	High (≥ 21.3 ped-hr)
≤ 35 MPH	Low	Consider Marking Crosswalk	Consider Supplemental Treatments	Move to Step 4: PHB Assessment	Move to Step 4: PHB Assessment
	High	Consider Marking Crosswalk	Consider Supplemental Treatments	Consider Supplemental Treatments	Move to Step 4: PHB Assessment
> 35 MPH	Low	Consider Supplemental Treatments	Consider Supplemental Treatments	Move to Step 4: PHB Assessment	Move to Step 4: PHB Assessment
	High	Consider Supplemental Treatments	Consider Supplemental Treatments	Consider Supplemental Treatments	Move to Step 4: PHB Assessment



Last Updated April 14, 2015



Last Updated April 14, 2015

Table A-1. Input Variables for Guidelines for Pedestrian Crossing Treatment.

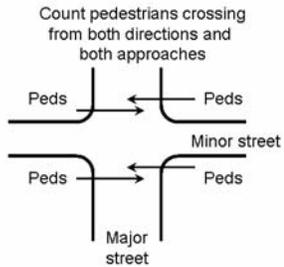
INPUT VARIABLES	TERM	DISCUSSION
ROAD CHARACTERISTICS		
Speed on the major street (mph)	S_{maj}	Use the major road posted or statutory speed limit for the facilities or, if available, the 85 th percentile speed to determine which worksheet is applicable. Worksheet 1 is used when the speed is 35 mph (55 km/h) or less, while Worksheet 2 is used when the speed exceeds 35 mph (55 km/h).
Pedestrian crossing distance (ft)	L	Pedestrian crossing distance represents the distance that a pedestrian would need to cross before reaching either the far curb or a median refuge island. The distance would be between the near and far curbs if a painted or raised median refuge island is not present, or to the median refuge island if the island is present. Note if a parking stall is present, its width should be included in the crossing distance measurement. Crossing distance rather than number of lanes was selected for the procedure so that the extra time needed by a pedestrian to cross bike lanes, two-way left-turn lanes, wide lanes, etc. could be considered.
COUNTS		
Peak-hour pedestrian volume crossing major roadway (ped/h)	V_p	<p>Pedestrian volume is the number of pedestrians crossing the major roadway in a peak hour. The count includes all pedestrian crossings of the major roadway at the location.</p> 
Major road peak hour vehicle volume (veh/h)	V_{maj-s} V_{maj-d}	Vehicle volume represents the number of vehicles and bicycles on both approaches of the major road during a peak hour. If a painted or raised median refuge island is present of sufficient size to store pedestrians (minimum of 6 ft [1.8 m] wide), then consider the volume on each approach individually. In the signal warrant calculations, use the volume on both approaches (V_{maj-s}). For the delay calculations, the volume (V_{maj-d}) would reflect either both approaches if a refuge island is not present or each approach individually if a refuge island is present.
LOCAL PARAMETERS		
Motorist compliance for region (high or low)	Comp	Compliance reflects the typical behavior of motorists for the site. If motorists tend to stop for a pedestrian attempting to cross at an uncontrolled location, then compliance is "high." If motorists rarely stop for a crossing pedestrian, then compliance is "low."
Pedestrian walking speed (ft/s)	S_p	Walking speed represents the speed of the crossing pedestrians. Recent research has suggested walking speeds of 3.5 ft/s (1.1 m/s) for the general population and 3.0 ft/s (0.9 m/s) for the older population. If calculating for a site, determine the 15 th percentile value of those using the crossing.
Pedestrian start-up time and end clearance time (s)	t_s	Start-up time is used in the calculation of the critical gap. A value of 3 s is suggested in the <i>Highway Capacity Manual</i> .

Table A-2. Calculations for Guidelines for Pedestrian Crossing Treatment.

CALCs	TERM	DISCUSSION
Signal warrant check (ped/h)	SC	Regression equations were determined for the plots shown in the 2003 <i>MUTCD</i> Figures 4C-3 and 4C-4. These equations can calculate the minimum number of vehicles that would be needed at the given major road volume to meet the signal warrant. The recommendation made in 2006 to the National Committee on Uniform Traffic Control Devices is that the vehicles signal warrants values for crossing two lanes be used as the pedestrian signal warrant values. Because the pedestrian signal warrant is to reflect total pedestrian crossings rather than just the number of pedestrians on the higher approach, the vehicle signal warrant values should be divided by 0.75 to reflect an assumed directional distribution split of 75/25. Different equations are provided for low-speed and high-speed conditions. The worksheets provide instructions on checking the peak hour. Both the peak vehicle hour and the peak pedestrian hour may need to be checked.
Critical gap (s)	T_c	Critical gap is the time in seconds below which a pedestrian will not attempt to begin crossing the street. For a single pedestrian, critical gap (t_c) can be computed using Equation 18-17 of the <i>2000 Highway Capacity Manual</i> . The equation includes consideration of the pedestrian walking speed (S_p), crossing distance (L), and start-up and end clearance times (t_s). $t_c = (L/S_p) + t_s$
Major road flow rate (veh/s)	v	Flow rate is a measure of the number of vehicles per second (v). For high-speed conditions, the number of vehicles is adjusted by dividing by 0.7. Flow rate is determined by: Low speed: $v = V_{maj-p}/3600$ high speed: $v = (V_{maj-p}/0.7)/3600$ It is based on the major road volume (V_{maj-d}), which is the total of both approaches (or the approach being crossed if median refuge island is present) during the peak hour (veh/h).
Average pedestrian delay (s/person)	d_p	The <i>2000 Highway Capacity Manual</i> includes Equation 18-21 that can be used to determine the average delay per pedestrian at an unsignalized intersection crossing (s/person). $d_p = \frac{1}{v} (e^{vt_c} - vt_c - 1)$ It depends upon critical gap (t_c), the vehicular flow rate of the crossing (v), and the mean vehicle headway.
Total pedestrian delay (ped-h)	D_p	Total pedestrian delay (D_p) uses the average pedestrian delay (d_p) and multiplies that value by the number of pedestrians (V_p) to determine the total pedestrian delay for the approach. $D_p = (d_p \times V_p)/3,600$

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

Analyst and Site Information		
Analyst:	Major Street:	
Analysis Date:	Minor Street or Location:	
Data Collection Date:	Peak Hour:	
Step 1: Select worksheet (speed reflects posted or statutory speed limit or 85 th 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 $2a \geq 20$ 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-s}	3a	
Minimum signal warrant volume for peak hour (use 3a for V_{maj-s}), SC $SC = (0.00021 V_{maj-s}^2 - 0.74072 V_{maj-s} + 734.125)/0.75$ OR $[(0.00021 3a^2 - 0.74072 3a + 734.125)/0.75]$	3b	
If $3b < 133$, then enter 133. If $3b \geq 133$, then enter 3b.		
If 15 th 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.		
If $2a \geq 3d$, 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-d}	4e	
Major road flow rate (veh/s), $v = V_{maj-d}/3600$ OR $[4e/3600]$	4f	
Average pedestrian delay (s/person), $d_p = (e^{v t_c} - v t_c - 1) / v$ OR $[(e^{4f \times 4d} - 4f \times 4d - 1) / 4f]$	4g	
Total pedestrian delay (h), $D_p = (d_p \times V_p)/3,600$ OR $[(4g \times 2a)/3600]$ (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 $5.3 \text{ h} \leq D_p < 21.3$ h and Comp = low	RED	
$1.3 \text{ h} \leq D_p < 5.3$ h (Comp = high or low) OR $5.3 \text{ h} \leq D_p < 21.3$ h and Comp = high	ACTIVE OR ENHANCED	
$D_p < 1.3$ h (Comp = high or low)	CROSSWALK	

Figure A-2. Worksheet 1.

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 85 th 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 $2a \geq 14$ 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-s}	3a	
Minimum signal warrant volume for peak hour (use 3a for V_{maj-s}), SC SC = $(0.00035 V_{maj-s}^2 - 0.80083 V_{maj-s} + 529.197)/0.75$ OR $[(0.00035 3a^2 - 0.80083 3a + 529.197)/0.75]$	3b	
If $3b < 93$, then enter 93. If $3b \geq 93$, then enter 3b.	3c	
If 15 th 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 $2a \geq 3d$, 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-d}	4e	
Major road flow rate (veh/s), $v = (V_{maj-d}/0.7)/3600$ OR $[(4e/0.7)/3600]$	4f	
Average pedestrian delay (s/person), $d_p = (e^{v t_c} - v t_c - 1) / v$ OR $[(e^{4f \times 4d} - 4f \times 4d - 1) / 4f]$	4g	
Total pedestrian delay (h), $D_p = (d_p \times V_p)/3,600$ OR $[(4g \times 2a)/3600]$ (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 $5.3 \text{ h} \leq D_p < 21.3$ h and Comp = low	RED	
$D_p < 5.3$ h (Comp = high or low) OR $5.3 \text{ h} \leq D_p < 21.3$ h and Comp = high	ACTIVE OR ENHANCED	

Figure A-3. Worksheet 2.

Appendix D. LITERATURE REVIEW AND STATE OF THE PRACTICE

Guidance for the application of pedestrian signal heads is principally provided in section 4E.03 of the 2009 Manual of Uniform Traffic Control Devices (MUTCD) (2009). The premise of the MUTCD guidance is to consider the use of pedestrian signal heads at locations where pedestrian volumes warrant them, where special populations may be present (i.e. a school crossing), or where vehicular signal indications provide insufficient guidance for pedestrians to safely decide when to cross, such as where signal phasing may confuse or cause conflicts with pedestrians or where they may have limited visibility of the signals. The MUTCD also provides general guidance and support about crosswalk markings. However, the MUTCD does not describe conditions under which a crosswalk must be marked, nor does it provide conditions under which the installation of a traffic signal or pedestrian hybrid beacon is required.

In research, Fitzpatrick et al. (Fitzpatrick, et al., TCRP Report 112/NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Intersections, 2006) performed a comprehensive review of pedestrian and vehicle interaction at unsignalized intersections, which included a thorough review of various pedestrian crossing treatments. That research is also the basis of the revised pedestrian volume traffic signal warrant (Warrant 4) in the 2009 MUTCD.

Even before the discussion of specific crossing treatments, the decision of whether or not to mark a crosswalk is an important consideration. In research performed by Zegeer et al. (Zegeer, et al., Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations, 2005) the authors quantified the safety performance of marked and unmarked crosswalks at uncontrolled locations, and they concluded that striping of crosswalks alone may in some cases actually have a negative impact on pedestrian safety. The research resulted in a table of guidelines for marking uncontrolled crosswalk locations as a function of crossing widths and vehicular traffic demands, which is reflected in the revised crosswalk marking guidance (section 3B.18.09) in the 2009 MUTCD.

In an effort to overcome some of the limitations of the MUTCD, several states and municipalities have developed their own guidance for the provision of pedestrian signals and other crossing treatments. Examples of this practice include the Pedestrian Guide or Signal Guidelines for states like Minnesota (2005), Alabama (Alabama Department of Transportation, 2007), California (California Department of Transportation, 2012), and Georgia (Georgia Department of Transportation, 2011), as well as municipal guidance including special pedestrian warrants for the City of Boulder, Colorado (City of Boulder Department of Transportation, 2011), or the Pedestrian Safety Guidelines for Sacramento, CA (Sacramento Transportation & Air Quality Collaborative, 2005). Even so, according to the Uncontrolled Crossings Task Force who conducted a survey of current practices in 2013, two-thirds of the jurisdictions who responded do not have written policies or guidelines other than the MUTCD for applying marked crosswalks. The majority of the agency respondents indicated the need for improved guidance for the installation of pedestrian crossing treatments, specifically on when to install a crosswalk and what treatment to apply. (Uncontrolled Crossings Task Force, 2014)

In general, the NCDOT relies on the MUTCD for guidance on crossing treatments and does not have additional written policies or guidelines. The NCDOT issued a policy of standard practice criteria and recommendations in February 2008 for marking and signing mid-block crosswalks specifically. The policy calls for an engineering study to be conducted to determine that a mid-block crosswalk would

improve operation and pedestrian safety in lieu of other traffic control measures, but it does not identify factors or locations where mid-block crosswalks should be considered. It does, however, provide guidance on where they should not be installed with considerations for speed, proximity to adjacent crossing locations, visibility, and traffic volume for both pedestrians and vehicles; and how they may be enhanced through the installation of refuge islands, in-street signage, high visibility markings and other treatments. (North Carolina Department of Transportation, 2008)

The 2009 MUTCD currently allows for many different styles of crosswalk markings including high visibility markings with longitudinal lines parallel to traffic flow. Little guidance is given on when to use a particular style of marking, which allows for agency flexibility; however, the National Committee on Uniform Traffic Control Devices (NCUTCD) issued a recommendation in 2011 to modify the MUTCD to clarify specification details when using high visibility markings. (Markings Technical Committee of the NCUTCD, 2011) This recommendation incorporates findings from research done by Fitzpatrick et al. on the daytime and nighttime visibility of different marking styles. (Fitzpatrick K. , Chrysler, Iragavarapu, & Park, November 2010) While the research determined high visibility markings were more easily detected further upstream compared with continental markings, no research was found that investigated whether yielding rates are impacted by different crosswalk marking styles.

In the consideration of pedestrian performance at signalized and unsignalized crossings, methodologies in the Highway Capacity Manual (Transportation Research Board, 2010) may be used to predict pedestrian delay at signalized intersections, with additional detail for unsignalized intersection theory given in Troutbeck and Brilon (Troutbeck & Brilon, 2002). Another valuable source for pedestrian treatments and countermeasures is PEDSAFE (Federal Highway Administration, 2013), which contains a variety of case studies on pedestrian treatment applications and describes 11 countermeasures specific to crossing locations. Guidance on pedestrian accommodations and performance at modern roundabouts is available in Rodegerdts et al. (Rodegerdts & et al., 2007), and while roundabouts are not the central piece of this research, lessons learned from the report can be applied to other unsignalized applications.

A key consideration in pedestrian accommodations is the special needs and civil rights of pedestrians with disabilities. To that effect, the US Access Board (US Access Board, 2006) has issued draft Guidelines for Accessible Public Rights of Way (PROWAG), which includes specific requirements for public rights of way that are expected to be adopted by the U.S. Department of Justice in the near future. The PROWAG references several countermeasures specific for pedestrians, many of which have been evaluated in recent work for the Federal Highway Administration (Fitzpatrick K. , Chrysler, Houten, Hunter, & Turner, 2011) (Fitzpatrick & Park, 2010). Additionally, a technical assistance memo jointly issued by the Department of Justice and the Department of Transportation to clarify curb ramp requirements states that “crosswalks constitute distinct elements of the right-of-way intended for pedestrian traffic.” (Department of Justice/Department of Transportation, July 8, 2013)

The review of the literature speaks to the complexity of the decision-making process for selecting pedestrian treatments, and specifically for the provision of pedestrian signals and marked crosswalks at intersections and midblock locations. This complexity clearly speaks to the need for this research, which will result in clear guidelines for application in North Carolina.

D.1 STATE OF THE PRACTICE

The researchers surveyed multiple agencies throughout North Carolina including the state highway divisions and the larger municipalities across the state. These agencies discussed the current practice and/or guidelines being followed for when to implement a crosswalk or other pedestrian crossing treatment in their division or municipality. Agencies outside of North Carolina were also contacted.

D.2 NORTH CAROLINA HIGHWAY DIVISIONS

All 14 of the North Carolina highway divisions were contacted about the current practices in their division regarding marking crosswalks and implementing additional pedestrian facilities. In most cases the division traffic engineer spoke on behalf of the division. All were initially asked some basic questions about how many requests are received each year for a pedestrian facility and how these requests are brought to the attention of the division traffic engineer. On average, each division receives around 10 to 15 requests from citizens or municipalities.

After a request is received, a site visit is conducted. Three main considerations are noted at the site: presence of an existing sidewalk network, pedestrian volumes, and site geometry:

- Most divisions said that if a sidewalk network was present, including curb ramps, then the crosswalk marking would most likely be approved. However, if the sidewalk network was not present, or if present but no curb ramps, then the crosswalk marking would either be denied or the division would propose a joint project with the municipality. If the municipality agreed to construct the sidewalks and/or construct the curb ramps, then the division would agree to mark the crosswalk.
- Pedestrian volume was recorded to justify a pedestrian signal or other pedestrian crossing treatment based on the MUTCD warrants. However, at the time they were interviewed, some divisions felt that the MUTCD warrants were too high and developed their own threshold of 20-30 pedestrian crossings per hour. Additionally, at locations where requests are simply to mark a crosswalk, the site was observed for pedestrian activity, and no specific counts were taken.
- Other site characteristics were considered, including width of the roadway, speed limit (85th percentile), site distance, proximity to a school or greenway, and if the location was for a crosswalk at an intersection or midblock. Marking crosswalks at intersections were more straightforward to approve than at midblock locations. Other considerations that were mentioned included crash history, vehicle volumes, constructability and cost.

The MUTCD was most often cited by NCDOT division staff for pedestrian warrants, but half of the divisions also mentioned Traffic Engineering Policies, Practices, and Legal Authority (TEPPL) Topic C-36 (North Carolina Department of Transportation, 2008) as the source used when considering mid-block crosswalks. Additionally, Division 3 has developed their own guidance for marking crosswalks in beach communities (NCDOT Division 3, December 21, 2010). This guideline considers beach access points, number of residential units, crash history, pedestrian population (i.e. handicapped or senior citizens) and the local adopted pedestrian plan.

High visibility crosswalks were mentioned by most of the divisions, though the use of high visibility crosswalks was varied. Some thought that high visibility crosswalks should only be placed at midblock

locations or at locations where pedestrians were unlikely to be, while others thought that high visibility should be applied to all crosswalks.

The divisions were asked to discuss what other crossing treatments beyond marked crosswalks are considered and the decision process(es) through which they are implemented. Pedestrian signals were mentioned as an additional treatment with most divisions using the MUTCD warrants as justification while others considered lower pedestrian volumes than the MUTCD. One division noted that it was unclear when to install a pedestrian signal based on the new complete street guidelines. Four divisions have used pedestrian hybrid beacons (PHB) and three have used rectangular rapid-flash beacons (RRFB) to enhance specific crossing locations.

Overall, the divisions seemed pleased that additional guidance through this research would soon be developed to aid in the decision-making process. Some requested more specific guidance for when to implement PHBs and RRFBs. Others mentioned that they preferred the guidelines be flexible so as not to rule out engineering judgment.

D.3 LARGE NORTH CAROLINA MUNICIPALITIES

Nine major municipalities within North Carolina gave information about how marked crosswalks are implemented within their cities, including: Asheville, Cary, Charlotte, Durham, Fayetteville, Greensboro, Raleigh, Wilmington, and Winston-Salem. Either a city transportation engineer or the city traffic engineer represented the city during the interview. The amount of requests that are received by each of these cities varies greatly, with some cities only receiving a few, while others receive hundreds a year.

Each of the cities conducts a site visit upon receiving a request for a pedestrian treatment. The major considerations that are noted while on site include the pedestrian volume and site characteristics. In most cases, the site is observed for pedestrian activity - counts are conducted when a pedestrian signal is being considered or for midblock locations. Site characteristics include nearby pedestrian generators (i.e. schools, proximity to city trails), crossing distances or number of lanes, landscape, grading, roadway alignment, street lighting, and presence of a refuge island and if the location will be a midblock or an intersection crosswalk. Another consideration mentioned by half the cities is the presence of an existing sidewalk and curb ramps. In most cases the city will try to install or update curb ramps, if needed, but this effort may be limited by available funds. Some cities are being proactive and are working to fill in gaps in the existing sidewalk network and mark crosswalks to extend the network. Furthermore, some cities are also being proactive with new construction projects by setting the stop bar and loop detectors back in anticipation of marking the crosswalk location when future need arises.

The cities referenced the MUTCD for signal warrants but also considered a multitude of other resources published from ITE, FHWA, and AASHTO, as well as the NCDOT Complete Street Planning and Design Guidelines. Some cities (Cary, Charlotte, Raleigh, and Wilmington) have developed their own set of guidelines for when to mark a crosswalk, specifically at unsignalized locations.

Similar to the additional pedestrian treatments mentioned by the highway divisions, a popular treatment for municipalities is the high visibility crosswalk. The application of these markings included crossings at or near: greenways, schools, midblock locations, high pedestrian crossing locations, and busy streets. More than half of the cities discussed providing midblock crossing locations as an additional pedestrian treatment, implemented at greenways and locations with high volumes of

pedestrians. Three cities have installed PHBs and three have installed RRFBs. Additional treatments mentioned included refuge islands, pedestrian warning signs, stamped crosswalks, striping an edge line to create a multi-use lane, flexible delineator posts, and camera detection of bicyclists and/or pedestrians at trail crossings.

At the end of the interview, the city representatives were asked for any additional comments they would like to add, and a great amount of feedback was collected.

- One city would like to use the In-Street Pedestrian Crossing sign (R1-6) in more locations but felt that they were restricted on the acceptable locations.
- Current NCDOT practices suggest that the state treats policy much of the “should” and “may” guidance in the MUTCD as “shall”, while municipalities tend to make use of the flexibility written in the MUTCD.
- One city suggested that a crossing difficulty index be included with the crosswalk guidance. The index would add weight or emphasis to special needs populations and specific origins-destinations. One example would be that a difficult crossing with a low volume of pedestrians would have a similar weight or emphasis as an easy crossing with a high volume of pedestrians.
- Another city solicits requests each year from the citizens and staff on locations that need improvement. This city works to fill in the gaps of the sidewalk network and construct as many crosswalks as allowed by the annual budget.
- In other areas, developers may be asked to provide pedestrian treatments if a new development is predicted to generate pedestrian volumes.

Overall the cities seemed to approve a majority of the crosswalk requests, within the limits of a specific budget. Many are trying to be proactive with pedestrian facilities and are working to promote walking. Additionally, the cities are eager to see the completed guidance, particularly information on PHBs and RRFBs.

D.4 OTHER STATES

To date, two agencies outside of North Carolina have been contacted about their current crosswalk guidelines; Minnesota DOT (MnDOT) and the city of Boulder, CO.

D.4.1 Minnesota Department of Transportation

A pedestrian and bicycle safety engineer for MnDOT discussed the current state crosswalk guidance being implemented. The *Guidance for Installation of Pedestrian Crosswalks in Minnesota* was first released in 2005 and is currently undergoing an update. The existing guidance includes a report and a flowchart, which is loosely based on the 2002 FHWA executive summary and recommended guidelines of the *Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations* (Zegeer, Stewart, Huang, & Lagerwey, *Safety Effects of Marked Vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines*, 2002). The Minnesota guidance has received mixed reviews; the pedestrian and bicycling community feels that it is too restrictive with too strong of wording, while city engineers tend to mark crosswalks more often than the guide would suggest, and the state engineers are content with the current guide. The new guideline being developed will implement changes based on the various feedback and criticisms MnDOT has received since the original guideline was released. These include the following:

- Addition of a table similar to the one in the 2002 FHWA study (Zegeer, Stewart, Huang, & Lagerwey, Safety Effects of Marked Vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines, 2002)
- Work to include more of the guidance from the 2002 FHWA study (Zegeer, Stewart, Huang, & Lagerwey, Safety Effects of Marked Vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines, 2002)
- Information on when to consider additional crossing treatments, like how the city of Boulder does for RRFBs
- Incorporate some of the information currently found only in the report into the flow chart as well
- Add information on additional countermeasures to improve safety, such as, curb extensions at crosswalk locations, intersection and street lighting, and address the multiple-threat scenario by, for example, using overhead RRFBs

MnDOT found that the report section of the original guide was being overlooked and that most engineers using the guide would view only the flow chart. Furthermore, the state often fields complaints from citizens about lack of consistency in its application across the state. The original guide was meant to standardize practice, but since the guideline is not mandated, inconsistencies remain.

One additional point that was made is that the state is currently conducting research into automated pedestrian and bicycle counts which will aid in the state being more proactive with pedestrian treatments and crossing facilities in the future.

D.4.2 City of Boulder, Colorado

A transportation operations engineer from the city of Boulder, CO was contacted to discuss the current crosswalk guideline being implemented by the city. The *Pedestrian Crossing Treatment Installation Guidelines* was created in 1996 and has since undergone three revisions, with the latest update in 2011.

The first version was found to be insufficient and relied heavily on engineering judgment. The current revision had the following updates:

- Added guidance on new crossing treatments including RRFBs
- Examined how to improve compliance
- Provided research sources to back up data

The current guide is typically used for low volume roads and to determine minimum pedestrian volume thresholds. Additionally, the latest version has received positive response from the bicycling and pedestrian community.

The current guideline contains a flow chart with thresholds originating from the 2005 FHWA study (Zegeer, et al., Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations, 2005) and have been verified by city engineers. The city also examined the effect of pedestrian volume on vehicle compliance, and found that 15-20 crossings per hour resulted in good compliance.

One of the new crossing treatments that was included in the guideline is the RRFB; on which the city has done extensive research from their own installations and from gathering information from other parts of the country. The first RRFB was installed 15 years ago. Since then, 20 different locations have been evaluated, with several of the locations eventually replaced with a traffic signal. Outside of the state,

the city has gathered information from Oregon where RRFBs are installed in rural locations with high speeds.

Besides RRFBs, the city has also implemented PHBs but has found these devices to not be very successful. Compliance did not improve with the installation of a PHB and produced similar results as a traffic signal. When deciding whether to install a PHB or a signal, the city prefers to install a traffic signal.

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