Pedestrian Crossings: *Uncontrolled Locations*

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Pedestrian Crossings: Uncontrolled Locations

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MnDOT Office of Maintenance
MnDOT Research Services Section
MS 330, 395 John Ireland Blvd.
St. Paul, Minnesota 55155
Phone: 651-366-3780
Fax: 651-366-3789
E-mail: research@dot.state.mn.us

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TECHNICAL ADVISORY PANEL MEMBERS

Tony Winiecki , Scott County
Pete Lemke, Hennepin County
Kate Miner, Carver County
Tim Plath, City of Eagan
Mitch Rasmussen, Scott County
Jason Pieper, Hennepin County
Mitch Bartelt, MnDOT
Melissa Barnes, MnDOT
Tim Mitchell, MnDOT
Alan Rindels, MnDOT
Mark Vizecky, MnDOT
Derek Leuer, MnDOT
Shirlee Sherkow, MnDOT
James McCarthy, FHWA
Jim Grothaus, CTS

DATA COLLECTION

John Hourdos and Stephen Zitzow, University of Minnesota

PRODUCTION

Research, Development, and Writing: Bryan Nemeth, Ross Tillman, Jeremy Melquist, and Ashley Hudson, Bolton & Menk, Inc.

Editing: Christine Anderson, CTS

Graphic Design: Abbey Kleinert and Cadie Wright Adikhary, CTS, and David Breiter, Bolton & Menk, Inc.

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The contents of this guidebook reflect the views of the authors, who are responsible for facts and the accuracy of the data presented. The contents do not necessarily reflect the views or policies of the Minnesota Local Road Research Board or the Minnesota Department of Transportation at the time of publication. This guidebook does not constitute a standard, specification, or regulation.

Document Information and Disclaimer

The information presented in this guidebook is provided as a resource to assist agencies in their efforts to evaluate uncontrolled pedestrian crossings and determine appropriate treatment options. The evaluation procedure provided in this guidebook takes into account accepted practice, safety, and operations.

Pedestrian crossings are an important feature of the multimodal transportation system. They enable pedestrians and bicyclists to cross conflicting traffic so they can access locations on either side of streets and highways. Pedestrian crossings can be either marked or unmarked and can be placed at intersections or mid-block locations. Uncontrolled pedestrian crossings are crossing locations that are not controlled by a stop sign, yield sign, or traffic signal.

This guidebook is a summary of the evaluation procedure presented in the *Uncontrolled Pedestrian Crossing Evaluation and Highway Capacity Manual Unsignalized Pedestrian Crossing Training Report*.

This guidebook considers best practices in pedestrian crossing evaluation by the Federal Highway Administration, the Minnesota Department of Transportation, the American Association of State Highway and Transportation Officials (AASHTO), the Transportation Research Board, and other research. The information is intended to offer agencies a consistent methodology for evaluating uncontrolled pedestrian crossing locations on their roadways that considers both safety and delay.

The final decision to implement the evaluation methodology or any of the crossing location treatment strategies presented in this guidebook resides with the agency. There is no expectation or requirement that agencies implement this evaluation strategy, and it is understood that actual implementation of the evaluation decisions will be made by agency staff.

It is the responsibility of agencies to determine if the procedure presented in this guide is appropriate and consistent with their needs.

- This guidebook does not set requirements or mandates.
- This guidebook contains no warrants or standards and does not supersede other publications that do.
- This guidebook is not a standard and is neither intended to be, nor does it establish, a legal standard of care for users or professionals.
- This guidebook does not supersede the information in publications such as:
    - Minnesota Manual on Uniform Traffic Control Devices
    - AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities
    - Minnesota's Best Practices for Pedestrian/Bicycle Safety
    - Best Practices Synthesis and Guidance in At-Grade Trail-Crossing Treatments
    - 2010 Highway Capacity Manual

Introduction and Background

According to 2013 Minnesota State Statutes, "where traffic-control signals are not in place or in operation, the driver of a vehicle shall stop to yield the right-of-way to a pedestrian crossing the roadway within a marked crosswalk or at an intersection with no marked crosswalk." Additionally, "Every pedestrian crossing a roadway at any point other than within a marked crosswalk or at an intersection with no marked crosswalk shall yield the right-of-way to all vehicles upon the roadway."

Although the state statute says that motorists should stop for a pedestrian within a marked crosswalk or crossing at an intersection, in practice motorists do not always stop for pedestrians and yield the right-of-way. Additionally, at locations with high traffic volumes, there may not be adequate gaps in the traffic stream to allow pedestrians to safely cross. These situations can result in crossings that are challenging to navigate and cause long delays for pedestrians, which may lead to a high risk-taking environment and decrease safety.

Pedestrian crossing treatments that either reduce the crossing distance or increase driver yield rates have been shown to reduce the potential delay experienced by a pedestrian. While state statutes support the rights of pedestrians at all intersections and marked crosswalks, it is a small comfort when a crash between a vehicle and a pedestrian occurs because a motorist failed to stop and yield the right-of-way.

Providing safe crossing situations for pedestrians relies on placing crosswalks and other pedestrian crossing treatments at appropriate locations in a way that also results in minimal pedestrian delay. The Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD) states that crosswalk pavement markings should not be placed indiscriminately and an engineering study should be completed when crosswalk markings are being contemplated at a crossing.

Defining where to place pedestrian crossing facilities—including markings, signs, and/or other devices—depends on many factors, including pedestrian volume, vehicular traffic volume, sight lines, and speed. This guidebook presents a methodology for the evaluation of pedestrian crossing locations that takes into account both pedestrian safety and delay.

Sources:
State of Minnesota, "2013 Minnesota Statutes 169.21 Pedestrian," 2013. Available: *https://www.revisor.mn.gov/statutes.* [Accessed January 2014].
Minnesota Department of Transportation, Minnesota Manual on Uniform Traffic Control Devices, Roseville, MN: MnDOT, January 2014.

Pedestrian Crossing Evaluation Methodology

The evaluation of a pedestrian crossing location should be thoroughly documented. This includes not only the location details, evaluation, decisions, and design process, but also any stakeholder involvement and public comments. The evaluation methodology presented is based on research on the safety of pedestrian crossings and the procedure developed in the 2010 *Highway Capacity Manual* on pedestrian delay.

The jurisdictional authority has the final decision on the control and design of pedestrian crossing facilities and features on their roadways.

The evaluation methodology guidance is shown in the flowchart on pages 6–7.

STEP 1 Field Data Review

A Data Collection Field Review Worksheet is provided at the end of this guidebook (pages 28–29). The field data review should consider and collect information about the following elements:

GEOMETRICS

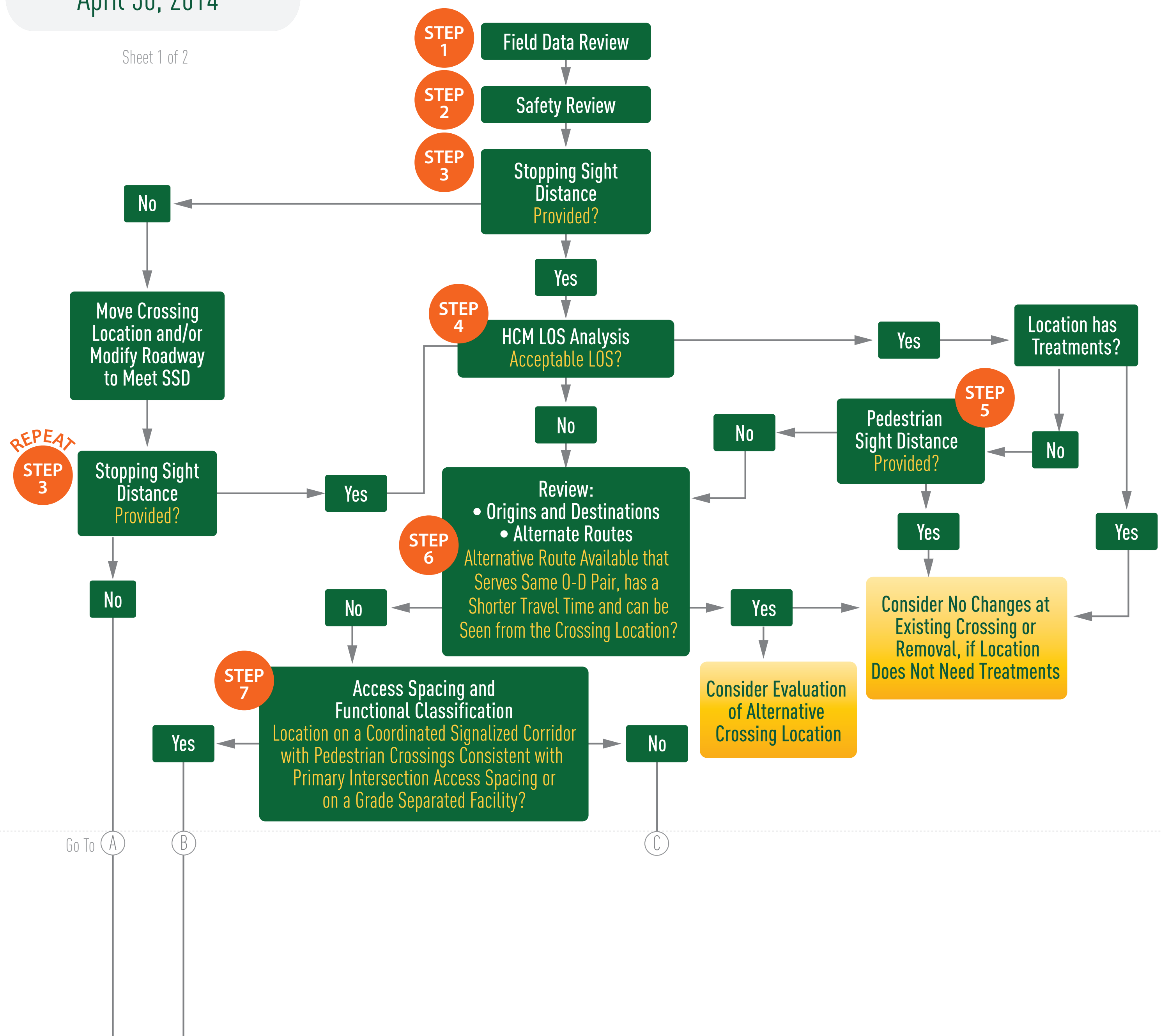
Crossing Length

- Shorter pedestrian crossing lengths are preferred by pedestrians.
- The crossing length (L) is measured from curb face to curb face and is the total length a pedestrian is exposed to conflicting traffic (as shown at right).
- If there is a median, two separate crossing lengths are measured.
- Pedestrian exposure is reduced on shorter crossings.

MEASURING CROSSING LENGTH

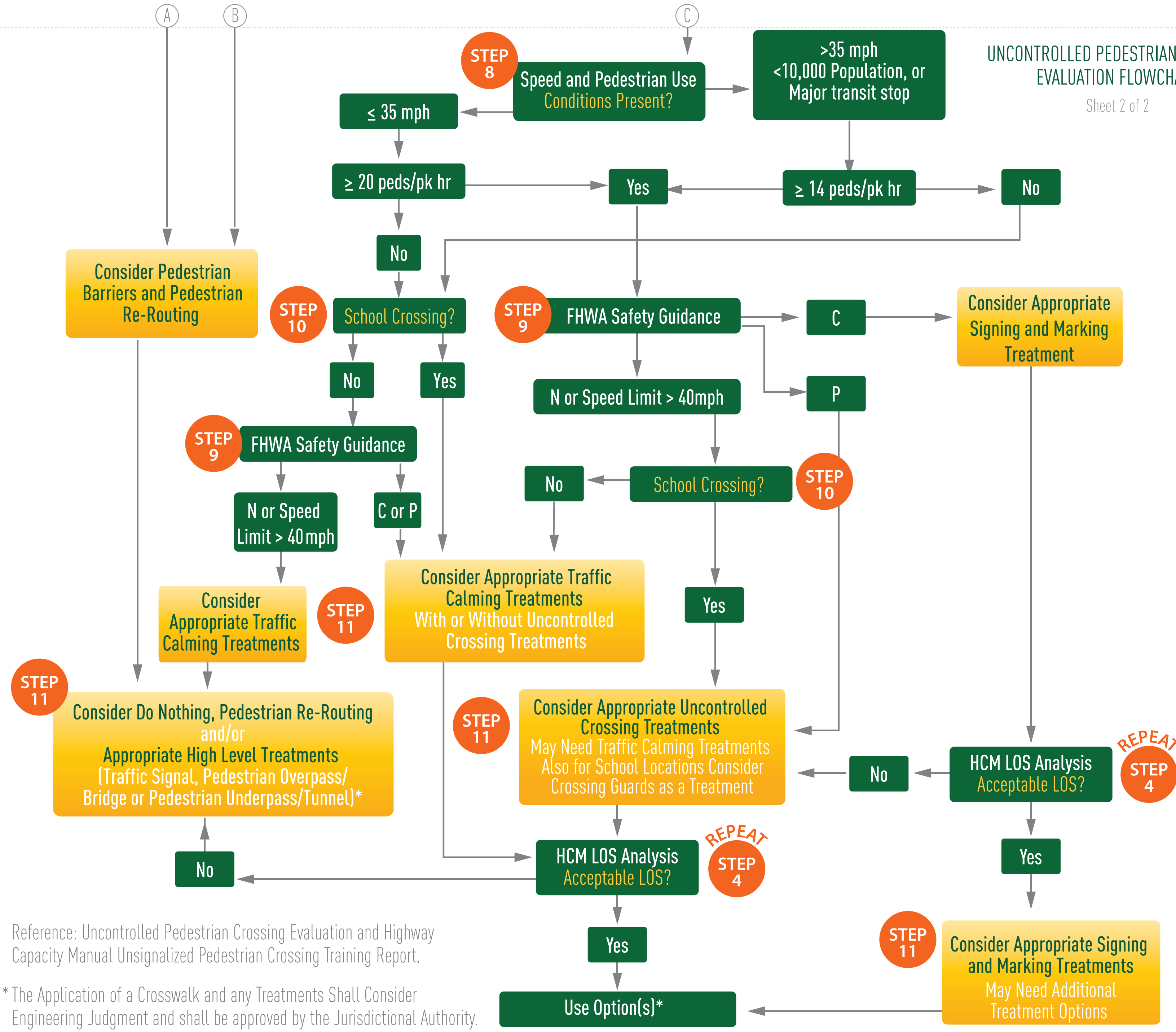
UNCONTROLLED PEDESTRIAN CROSSING EVALUATION FLOWCHART

April 30, 2014



UNCONTROLLED PEDESTRIAN CROSSING EVALUATION FLOWCHART

Sheet 2 of 2



Reference: Uncontrolled Pedestrian Crossing Evaluation and Highway Capacity Manual Unsignalized Pedestrian Crossing Training Report.

* The Application of a Crosswalk and any Treatments Shall Consider Engineering Judgment and shall be approved by the Jurisdictional Authority.

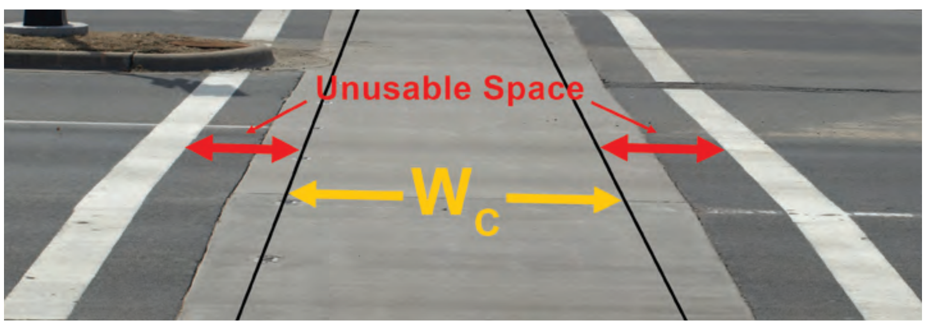
Median Width

- A median wider than 6 feet can provide a refuge space for pedestrians.
- A wider median is preferred by pedestrians.
- The median width (W) is measured from curb face to curb face (as shown below).
- A median should be sufficiently sized to handle the pedestrians using it.

MEASURING MEDIAN WIDTH

Crosswalk Width

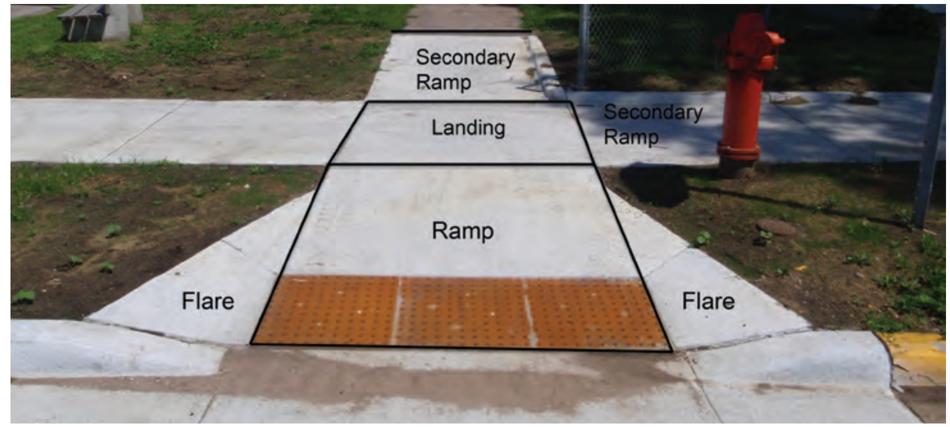
- Crosswalk width provide a defined area in which to cross.
- Effective crosswalk width is measured at the narrowest point of the crossing, be it in the ramp or the crosswalk.
- Crosswalk width (W_c) is the width measurement of at the narrowest point of the crossing (as shown at right), unless other space is usable by pedestrians (i.e., in downtown locations).



MEASURING CROSSWALK WIDTH

Curb Ramps

- Curb ramps provide equal access to all users.
- Pedestrian curb ramps are required for all pedestrian crossing locations.



CURB RAMP DIAGRAM

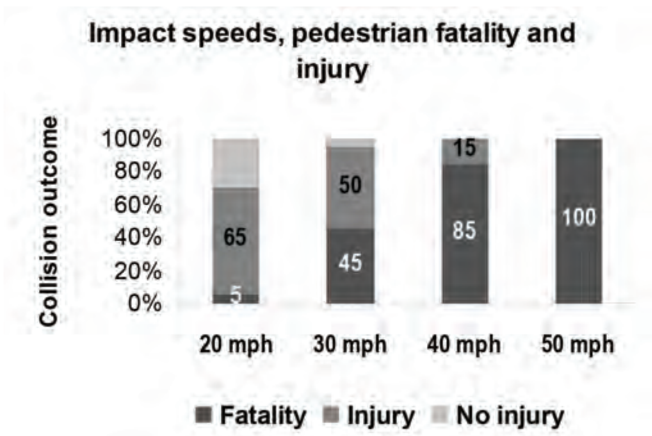
Americans with Disabilities Act (ADA) Requirements

- ADA requirements for pedestrian crossings include grades, tactile surfaces/truncated domes, ramp width, and landing areas.
- The requirements are expansive and are beyond the scope of this guidebook.
- Please see the Minnesota Department of Transportation Accessibility Design Guidance, *http:///www.dot.state.mn.us/ada/design .html*, for detailed information.

Sources:
Minnesota Department of Transportation, “Accessibility and MnDOT,” [Online]. Available: *http://www.dot.state.mn.us/ada/index.html.* [Accessed November 2013].

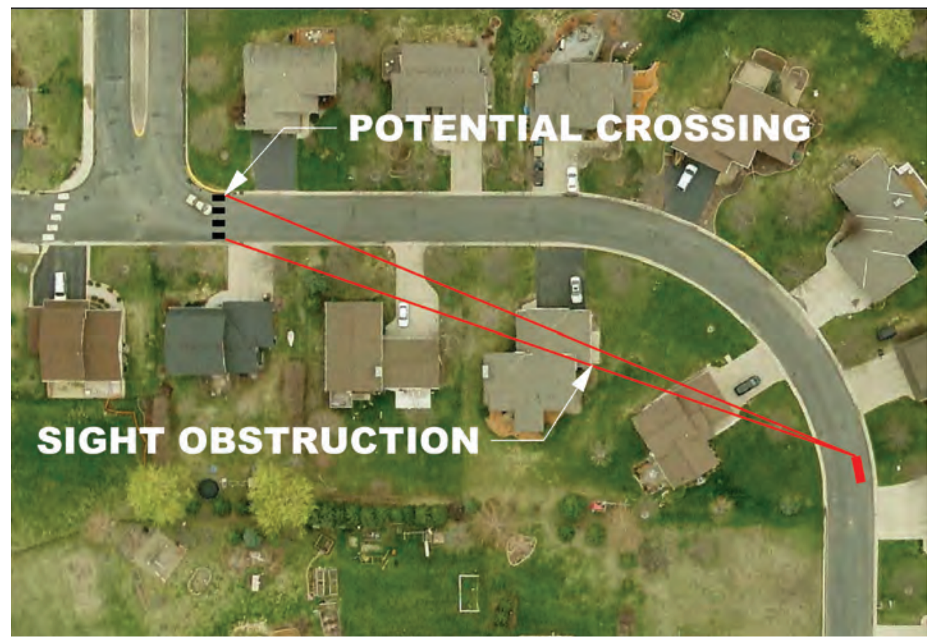
Roadway Speed

- Slower speeds are preferred by pedestrians.
- The speed of a vehicle directly impacts the sight distance needed and the braking time of a vehicle.
- The speed (S) is used to determine the stopping sight distance. The speed should be the 85th percentile speed of the roadway being crossed. In the absence of collected speed data, it is assumed that the 85th percentile speed is equal to the speed limit.
- Slower speeds have been shown to reduce the possibility of a fatal crash in pedestrian/vehicle crashes based on study results by the Washington State Department of Transportation, as shown in the chart below.



Roadway Curvature

- The vertical and horizontal curvature of a roadway can impact sight lines for both motorists and pedestrians.
- For more information on vertical and horizontal curvature, please see the American Association of State Highway and Transportation Officials: A Policy on Geometric Design of Highways and Streets (AASHTO Green Book).



SIGHT OBSTRUCTION CAUSED BY ROADWAY CURVATURE

Sources:
A. V. Moudon, L. Lin and P. Hurvitz, “Managing Pedestrian Safety I: Injury Severity,” Washington State Department of Transportation, Olympia, WA, February 2007.

Stopping Sight Distance

- Stopping sight distance (SSD) is the distance covered by a vehicle during a stopping procedure. SSD should be provided at all pedestrian crossings.
- The SSD considers both brake reaction distance and braking distance.

$$SSD = 1.47St + 1.075\frac{S^2}{30\left[\left(\frac{a}{32.2}\right) \pm G\right]}$$

Where:

SSD = stopping sight distance
S = speed (mph)
t = brake reaction distance, 2.5 s
a = deceleration rate, ft/s^2, default = 11.2 ft/s^2
G = grade, rise/run, ft/ft

For more information on SSD, please see the AASHTO Green Book.

Pedestrian Sight Distance

- While Minnesota State Statute requires that motorists stop for pedestrians legally crossing, many pedestrians wait for an adequate gap in traffic before crossing.
- Pedestrian sight distance (PedSD) is a term to describe the distance covered by a motorist during the time it takes a pedestrian to recognize an adequate gap in traffic and cross the roadway.

$$PedSD = 1.47S\left(\frac{L}{S_p} + t_s\right)$$

Where:

PedSD = pedestrian crossing sight distance
S = design speed (mph)
L = crossing distance (ft)
S_p = average pedestrian walking speed (ft/s), default = 3.5 ft/s
t_s = pedestrian start-up and end clearance time (s), default = 3.0 s

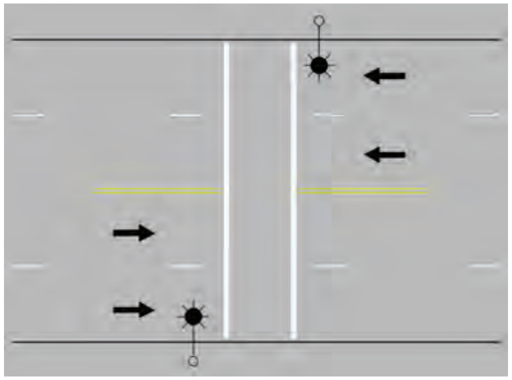
Traffic and Pedestrian Data

- The volume of vehicles on the roadway directly affects the number of gaps available for pedestrians to cross a roadway.
- The volume of pedestrians using the crossing affects how motorists view the crossing. A highly used crossing may be more recognizable to a motorist, resulting in a safer crossing.

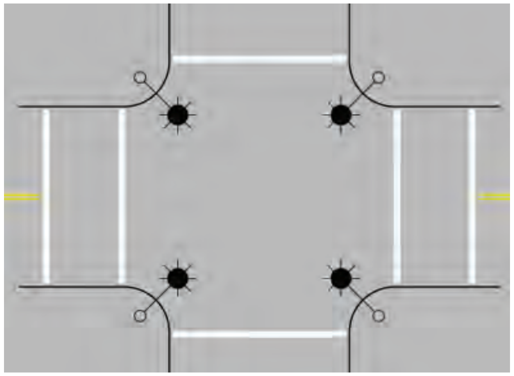
ADDITIONAL SITE CHARACTERISTICS

Lighting

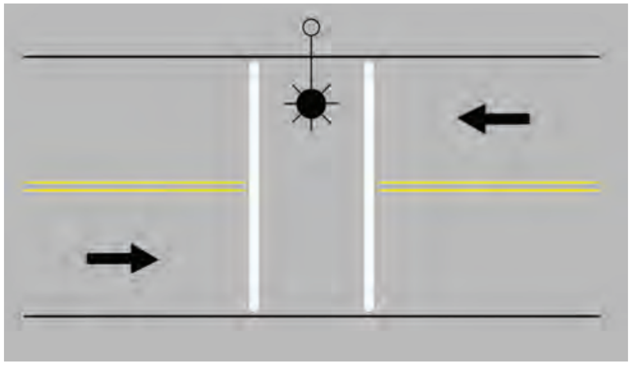
- Lighting should be provided at intersection crossings and marked crossings that are used at night.
- Intersection or pedestrian scale lighting may be appropriate to light the pedestrian crossing location.
- Continuous street lighting can provide adequate lighting of pedestrian facilities but may need to be supplemented at pedestrian crossing locations.
- Lighting should follow the recommended levels provided in the AASHTO Roadway Lighting Design Guide.
- Lighting should provide positive contrast if possible.
- Positive contrast lights the pedestrian from the front so they are more easily seen by approaching motorists.
- Examples of lighting configurations are shown in the diagrams below and at right.



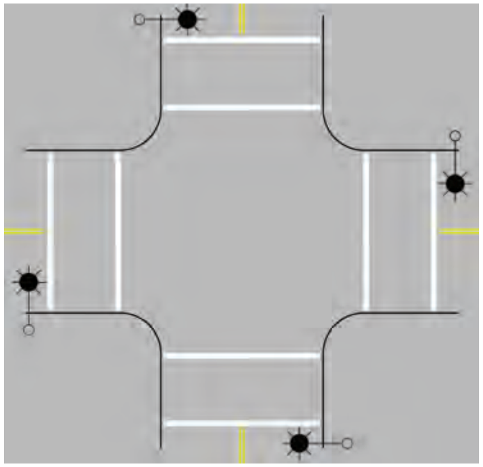
MULTI-LANE OR LONG MID-BLOCK CROSSING LIGHTING



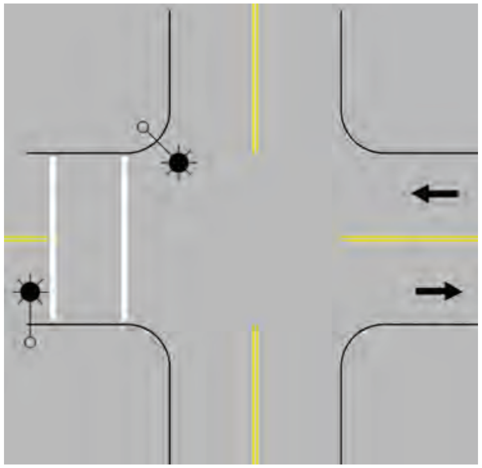
TRADITIONAL INTERSECTION LIGHTING (ALL LEGS)



TWO LANE MID-BLOCK CROSSING LIGHTING



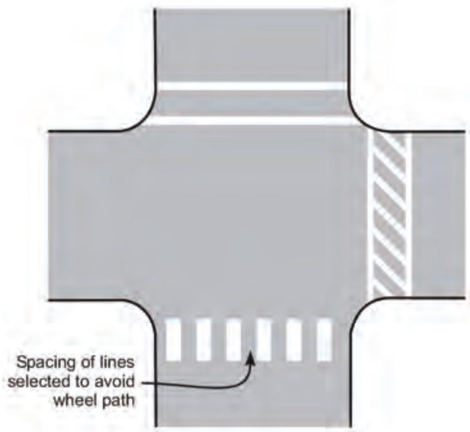
PEDESTRIAN CROSSING INTERSECTION LIGHTING (ALL LEGS)



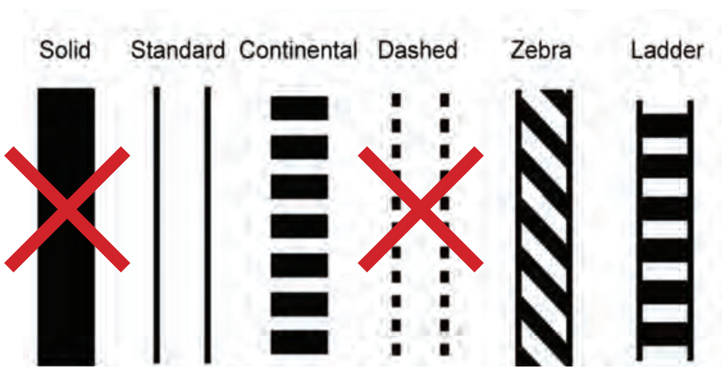
PEDESTRIAN CROSSING INTERSECTION LIGHTING (ONE LEG)

Crosswalk Pavement Markings

- Crosswalk markings shall follow the designs as stated in the MN MUTCD.
- High-visibility crosswalk markings include continental, zebra, and ladder (examples shown below and at right). Markings should be in good to excellent condition and highly visible to approaching traffic.



CROSSWALK MARKING EXAMPLES



ACCEPTABLE CROSSWALK MARKING PATTERNS

STANDARD/TRANSVERSE CROSSWALK PAVEMENT MARKINGS

CONTINENTAL CROSSWALK PAVEMENT MARKINGS

Signing

- Signing shall follow the design and placement as stated in the MN MUTCD.
- Signing options are shown in the images below.

PEDESTRIAN CROSSING WARNING SIGN PLUS IN-ROAD SIGNS

SCHOOL CROSSING WARNING SIGN

Sources:

Minnesota Department of Transportation, Minnesota Manual on Uniform Traffic Control Devices, Roseville, MN: Minnesota Department of Transportation, January 2014.

C. V. Zeeger, J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes and B. Campbell, "Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines," Federal Highway Administration, McLean, VA, September 2005.

Distance to Adjacent Pedestrian Crossing Facilities

- If there is a nearby pedestrian crossing facility that can serve the same movements with a shorter travel time—and if this nearby crossing facility can be seen from the crossing location being studied—the crossing location being studied may not be needed.
- In some cases, an existing pedestrian crossing may not serve the pedestrian movements of the area and should be moved to a more appropriate location.
- The other location may actually provide a shorter travel time when considering the time waiting to cross.
- If pedestrians are already crossing at a location, they are unlikely to choose to cross at another location unless it is shorter, regardless of safety. It is important to provide crossings at locations where pedestrians are already crossing, or consider creating physical barriers if safety can be achieved and direction to a nearby crossing is provided.

Distance to Adjacent Intersections with All-Way Stop, Signal, or Roundabout Control

- An adjacent controlled crossing location may provide a shorter travel time when considering the time waiting to cross.

Origins and Destinations

- Review pedestrian paths between nearby origins and destinations.
- Typical origins and destinations of importance include:
    - Bus stops to businesses and residences
    - High-density residential to bus stops and commercial/retail
    - Hospitals and medical centers to bus stops and parking
    - Retirement communities to bus stops and commercial retail
    - Schools/colleges/universities to housing and parking
    - Parks to residences
    - Recreational/community centers to residences and parking
    - Theatres and museums to parking
    - Trails to parks and other trails
    - Commercial/retail space to parking

STEP 2 Safety Review

The safety review includes evaluating the crash records for the crossing location. Pedestrian crashes may necessitate a more in-depth look at the issues and concerns at a crossing location.

Rear-end crashes at a location may indicate that motorists are stopping for pedestrians, but they may also indicate that there is inadequate stopping sight distance. Other types of crashes should be reviewed to determine if the conflicts are impacting the crossing safety and if they indicate other intersection concerns.

STEP 3 Stopping Sight Distance

Every pedestrian crossing location should have adequate stopping sight distance (SSD). If adequate SSD cannot be provided at a potential crossing location, the location may not be suitable for a pedestrian crossing. Adequate SSD ensures that most motorists under normal conditions will be able to stop for a pedestrian that has entered the roadway.

If adequate SSD is not provided, consider pedestrian barriers and pedestrian routing to alternate crossing locations.

STEP 4 HCM Level of Service Analysis

To determine the level of service (LOS) of the current crossing condition, follow the procedure outlined in the 2010 *Highway Capacity Manual*. The methodology follows a six-step program, as shown below.

Step 1: Identify Two-Stage Crossings

↓

Step 2: Determine Critical Headway

↓

Step 3: Estimate Probability of a Delayed Crossing

↓

Step 4: Calculate Average Delay to Wait for Adequate Gap

↓

Step 5: Estimate Delay Reduction due to Yielding Vehicles

↓

Step 6: Calculate Average Pedestrian Delay and Determine LOS

This six-step procedure to determine LOS for pedestrians at uncontrolled crossing locations is provided in the worksheets at the end of this guidebook (pages 30–34).

The input information for use in the equations is provided in the input table on the second worksheet. An explanation of measuring crosswalk length (L) and crosswalk width (W_c) can be found on page 4 of this guidebook.

LOS is generally deemed acceptable between A and D and deemed unacceptable at E or F. Local agency direction on acceptable service levels should be verified. If the LOS is acceptable and the location already has treatments such as signing and/or striping, consider making no changes at the existing crossing.

If LOS is unacceptable, skip to Step 6. If this procedure is completed after Step 11, consider applying appropriate treatment option(s) if LOS is acceptable. If LOS is deemed acceptable, consider making no changes at the crossing or possibly removing treatments if they are not needed.

STEP 5 Pedestrian Sight Distance

If adequate service levels are provided, pedestrian sight distance (PedSD) should be checked if the crossing is absent of any treatment options. This indicates that the crossing is unmarked and unsigned. If adequate PedSD is provided, consider no changes at the existing crossing.

STEP 6 Review: Origins and Destinations, Alternate Routes

The potential origins and destinations in the area should be reviewed for the most likely path to see how it lines up with the crossing being analyzed. The most important thing to remember is that pedestrians will take the shortest possible route. Understanding this is essential to understanding why a route is being used, especially when there are alternatives available that may actually be safer and provide less delay. In some cases, existing crossings may not actually be placed in locations where pedestrians are using them if the understanding of origins and destinations is incorrect.

Check to see if an alternative route can serve the same movements effectively while providing less delay. This includes the time to traverse to the alternative crossing, cross, and complete the movement to the destination. Average wait time at signals should be added into the equation if the crossing requires traversing a traffic signal.

If the primary origin-destination movements can be accomplished effectively at another crossing without much backtracking, consider making no changes at the existing crossing or adding pedestrian channelization and/or wayfinding. Also consider evaluating the alternate crossing location.

Sources:
American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets, 6th Edition, Washington DC: American Association of State Highway and Transportation Officials, 2011.
C. V. Zeeger, J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes and B. Campbell, "Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines," Federal Highway Administration, McLean, VA, September 2005.
Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington, DC: National Academy of Sciences, 2010.

STEP 7 Access Spacing and Functional Classification

The functional classification of the roadway and the current access control of the roadway being crossed should be considered.

Roadways that carry more than 12,000 vehicles per day and are classified as high-mobility corridors are generally not candidates for marked uncontrolled pedestrian crossings. Marked uncontrolled pedestrian crossings should only be implemented on signalized roadway corridors if the spacing between the signalized intersections does not adequately serve the pedestrian traffic in the community.

The spacing of pedestrian crossing facilities should follow the access spacing guidelines for signals and primary intersections on the corridor of interest. Primary access intersections are intersections that will remain full access over time while secondary access intersections may provide full or limited access over time.

Due to the limited access along grade-separated roadway facilities, marked and unmarked pedestrian crossings on those facilities are limited to interchanges, tunnels, and bridges. The high speed of the facilities, along with the driver expectations for conflicts, makes any at-grade crossing a safety concern.

Sources:

C. V. Zeeger, J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes and B. Campbell, “Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines,” Federal Highway Administration, McLean, VA, September 2005.

K. Fitzpatrick, S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park and J. Whitcare, “Improving Pedestrian Safety at Unsignalized Crossings,” Transportation Research Board of the National Academies, Washington, DC, 2006.

STEP 8 Speed and Pedestrian Use

Consistent with previous research and evaluation methods, the conditions present at the crossing location should be reviewed and the need for the crossing should consider pedestrian traffic volume using the crossing. It is important that the pedestrian use data be collected at multiple times of day to get an accurate picture of the pedestrian traffic need. The highest hour pedestrian need may not coincide with the highest hour traffic volume crossing the location. In such circumstances, the level of service should be evaluated for the highest pedestrian volume hour and the highest vehicle volume hour separately.

If the crossing location is on a roadway with speeds greater than 35 miles per hour (mph), is in a community of less than 10,000 people, or provides a connection to a major transit stop, there should be a minimum of 14 pedestrians using the crossing during one hour of the day.

If the crossing location is on a roadway with a speed of 35 mph or less, there should be a minimum of 20 pedestrians using the crossing during one hour of the day.

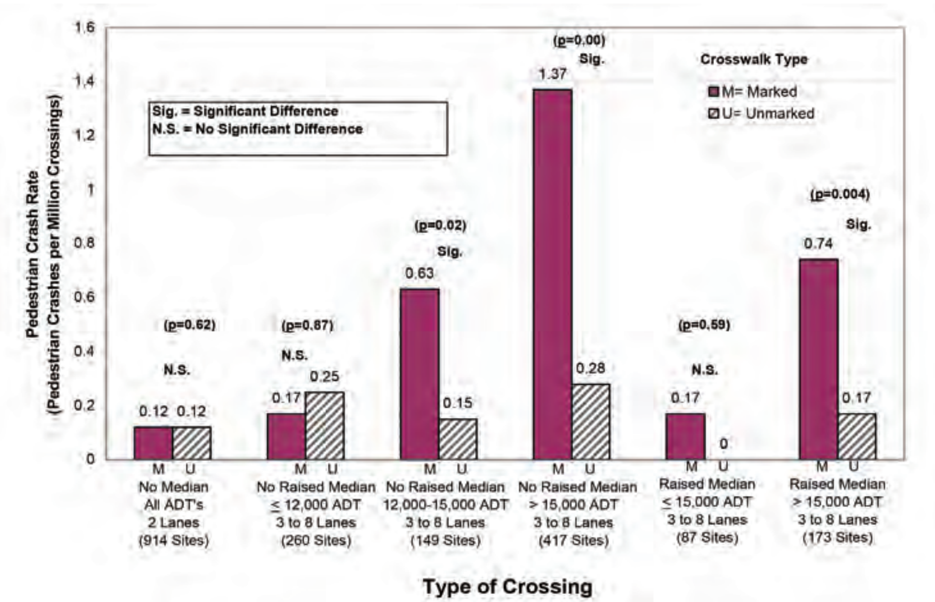
The above pedestrian volume thresholds can be reduced by 0.33 if more than 50 percent of the pedestrian traffic using the crossing consists of the elderly or children.

If these thresholds cannot be met, traffic calming treatments should be considered. In such cases, additional uncontrolled crossing treatments may be considered in conjunction with the traffic calming treatments. Uncontrolled crossing treatments should not be considered by themselves.

STEP 9 FHWA Safety Guidance

Federal Highway Administration (FHWA) guidance in the Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations should be determined based on the traffic volume, speed, and roadway type. The study indicates the types of treatments recommended for installing marked crosswalks at uncontrolled locations.

Research indicates that there is a statistically significant difference in the safety between a marked and unmarked crossing when traffic volume is over 15,000, or over 12,000 without a median, under most speeds, as shown in the table below.



This research provides the basis for the guidance in Table 1 on page 18. Guidelines provided in the table include intersections and midblock locations with no traffic signals or stop signs on the approach to the crossing.

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, etc.) as needed to improve the safety of the crossing.

Guidelines outlined in the table are general recommendations; good engineering judgment should be used in individual cases when deciding where to install crosswalks.

Sources:
C. V. Zeeger, J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes and B. Campbell, "Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guide lines," Federal Highway Administration, McLean, VA, September 2005.
K. Fitzpatrick, S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park and J. Whitcare, "Improving Pedestrian Safety at Unsignalized Crossings," Transportation Research Board of the National Academies, Washington, DC, 2006.

Table 1: FHWA Safety Guidance Table

Roadway Type (Number of Travel Lanes and Median Type)	Vehicle ADT ≤ 9,000			Vehicle ADT > 9,000–12,000			Vehicle ADT > 12,000–15,000			Vehicle ADT > 15,000		
	Speed Limit*											
	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)
Two lanes	C	C	P	C	C	P	C	C	N	C	P	N
Three lanes	C	C	P	C	P	P	P	P	N	P	N	N
Multilane (four or more lanes) with raised median**	C	C	P	C	P	N	P	P	N	N	N	N
Multilane (four or more lanes) without raised median	C	P	N	P	P	N	N	N	N	N	N	N

*Where the speed limit exceeds 64.4 km/h (40 mph), marked crosswalks alone should not be used at unsignalized locations.
**The raised median or crossing island must me at least 1.2 meters (4 feet) wide and 1.8 meters (6 feet) long to serve adequately as a refuge area for pedestrians, in accordance with MUTCD and Amerian 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 in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, and other factors may be needed at other sites. It is recommended that a minimum utilization of 20 pedestrian crossings per peak hour (or 15 or more elderly 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 improvements, to improve crossing safety for pedestrians.

STEP 10

School Crossings

The safety of children as they get to and from school is of special consideration and may require the implementation of a crosswalk at locations that might otherwise not be considered. A school crossing location will traditionally have significant use by children that occurs in conjunction with standard school start and dismissal times, making the crossing use noticeable to motorists. Consider appropriate uncontrolled treatment options, including crosswalk markings, signs, and crossing guards.

MARKED AND SIGNED SCHOOL CROSSING

ADULT SCHOOL CROSSING GUARD

STEP 11 Consider Appropriate Treatment Options

Appropriate treatment options should be considered for crossing locations based on the evaluation flowchart on pages 6–7. In many cases, the most appropriate option is to keep the location unmarked and unsigned, as any treatment may increase the crash potential at the location.

The treatment options have been organized into four separate categories depending on their primary function in serving pedestrian crossings. Some of the options have not been shown to noticeably affect motorist yielding and service levels, but they are provided as examples that have been implemented by some agencies.

SIGNING AND MARKING TREATMENTS

Signing and marking treatments are generally low cost and provide little to no benefit in terms of operational impacts. The most significant impact is for high-visibility markings. The treatments can be appropriate by themselves on low-volume and low-speed roadways unless accompanied by other types of treatments.

Potential signing and marking treatments are outlined in Table 2 on page 21 (treatments should be justified through an engineering study). Examples of selected treatments are also shown at right.

Sources:
"Minnesota's Best Practices for Pedestrian/Bicycle Safety," MnDOT Office of Traffic, Safety and Technology, September 2013.
"Best Practices Synthesis and Guidance in At-Grade Trail-Crossing Treatments," Minnesota Department of Transportation, St.Paul, MN, September 2013.
NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings. Transportation Research Board of the National Academies, Washington D.C., 2006.
Assessment of Driver Yield Rates Pre- and Post-RRFB Installation, Bend, Oregon. Oregon Department of Transportation, Washington D.C., 2011.
Bolton & Menk, Inc.
Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington D.C.: National Academy of Sciences, 2010.
Before-and-After Study of the Effectiveness of Rectangular Rapid-Flashing Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.

CROSSING WARNING SIGN

CROSSWALK MARKINGS AND SIGN

IN-STREET CROSSING SIGN

HIGH-VISIBILITY CROSSWALK MARKINGS

Table 2: Signing and Marking Treatments

Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate	Cost
Crosswalk Markings Only	• Inexpensive • Helps define a crossing location • Indicates to drivers that crossing location is present	• Very little effect at night • Speeds increase over time • Not shown to reduce crashes	• Not usually recommended alone • Low-volume and low-speed roadways • Where justified	NR	NR	$500–$2,000
Warning Signs	• Inexpensive • Helps define a crossing location • Warning to drivers that crossing location is present	• Tend to be ignored unless pedestrians use the crossing consistently • Proven to be ineffective at reducing crashes at uncontrolled intersections	• Where unexpected entries into the road by pedestrians may occur • At or before the crossing location • With or without a marked crosswalk	NR	NR	$300–$1,200
Overhead Warning Signs	• May decrease vehicle speed	• Requires overhead structure • Tend to be ignored unless pedestrians use the crossing consistently	• Multilane roadways • Mid-block crossing locations • Usually coupled with other measures such as RRFBs or beacons	NR	NR	$60,000–$75,000
Colored Concrete/Brick Pavers	• Inexpensive • Warning to drivers that crossing location is present • May decrease vehicle speed	• Can be expensive • Not shown to reduce crashes	• Downtown/urban conditions • Traffic signal locations • In conjunction with pavement markings	NR	NR	$10,000–$75,000
Crosswalk Markings and Signs	• Inexpensive • Warning to drivers that crossing location is present • May decrease vehicle speed	• Make snow removal more difficult • Need consistent maintenance and replacement due to vehicle hits	• Where justified	7%	7%	$800–$3,200
In-Street Crossing Signs (25–30 mph)	• Inexpensive • Additional warning to drivers that crossing location is present	• Not shown to reduce crashes • Speeds increase over time	• Downtown/urban conditions • Supplement warning signs at high pedestrian volume locations • In conjunction with pavement markings	87%	90%	$500–$1,000
High-Visibility Crosswalk Markings	• May decrease vehicle speed	• Not shown to reduce crashes • Speeds increase over time	• Where justified • Urban conditions	61% (25mph) 17% (35mph)	91% (25mph) 20% (35mph)	$5,000–$50,000

NR = No research found on effect to yielding rate

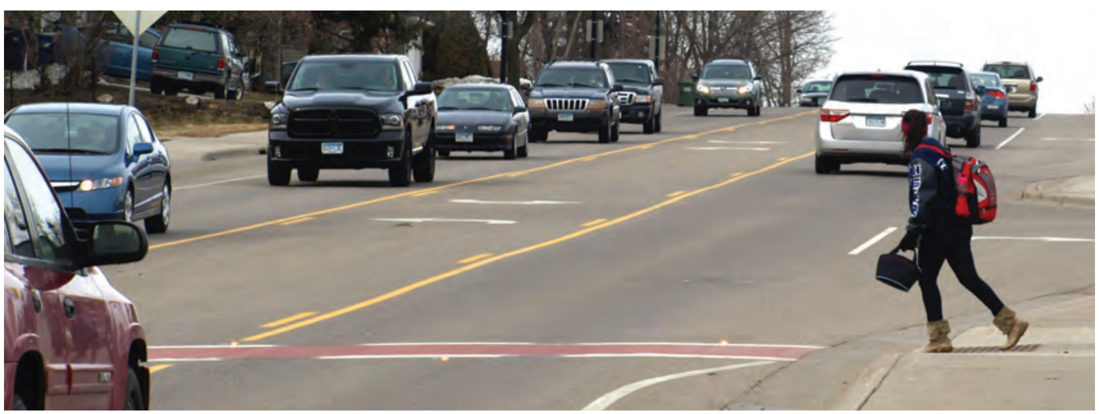
UNCONTROLLED CROSSING TREATMENTS

Uncontrolled crossing treatments generally provide some level of increased yielding rate. They are typically applied to locations with marked crosswalks to provide additional operational and safety benefits in areas with higher volumes and speeds.

Uncontrolled crossing treatement options are outlined in Table 3 on page 23 (treatments should be justified through an engineering study) . Selected treatment examples are also shown below.

OVERHEAD FLASHING SIGNAL BEACONS

CENTER MEDIAN WITH REFUGE ISLAND



IN-ROAD WARNING LIGHTS

PEDESTAL-MOUNTED FLASHING SIGNAL BEACONS

RAPID RECTANGULAR FLASHING BEACONS

Table 3: Uncontrolled Crossing Treatments (in conjunction with markings and signs)

Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate	Cost
Center Median with Refuge Island	• Decreases pedestrian crossing distance • Provides higher pedestrian visibility • Reduces vehicle speeds approaching the island • Reduces conflicts • Increases usable gaps • Reduces pedestrian exposure time	• May make snow removal more difficult • May be a hazard for motorists • Small islands not recommended on high-speed roadways (>40 mph)	• Wide, two-lane roads and multilane roads with sufficient right-of-way	34%	29%	Variable depending on length
School Crossing Guards	• Inexpensive • Provides higher pedestrian visibility • Highlights when a pedestrian crossing is being used	• May require trained staff or local law enforcement, especially on high-speed and high-volume roadways	• At school locations	NR	86%	Variable
Pedestrian Crossing Flags	• Inexpensive • Provides higher pedestrian visibility to drivers assuming the flag is held in a noticeable location	• No effect at night • Requires pedestrians to actively use a flag • Can be easily removed/stolen • Shorter crossings are preferred	• Downtown/urban locations • High pedestrian volume locations • Across low-speed (<45mph) roadways	65%	74%	<$500
Warning Sign with Edge Mounted LEDs	• Highlights a crossing both at night and during the day	• Requires pedestrian activation • Minimal to no effect on speed	• In conjunction with in-road warning lights • Downtown/urban conditions	NR	28%	$3,000–$8,000
In-Road Warning Lights	• Highlights a crossing both at night and during the day • Provides higher driver awareness when a pedestrian is present	• Snowplows can cause maintenance issues • No effect when road surface is snow covered • Requires pedestrian activation	• Downtown/urban conditions	NR	66%	$20,000–$40,000
Pedestal Mounted Pedestrian Flashing Signal Beacons	• Provides higher driver awareness when a pedestrian is present	• Requires pedestrian activation • Not advisable on multilane streets • Not shown to reduce crashes	• Low-speed school crossings • Two-lane roads • Midblock crossing locations	NR	57% (two-lane, 35mph)	$12,000–$18,000
Pedestrian Overhead Flashing Signal Beacons	• Provides higher driver awareness when a pedestrian is present	• Requires pedestrian activation	• Multilane roadways • Mid-block crossing locations • Lower speed roadways	active 47% passive 31%	active 49% passive 67%	$75,000–$150,000
Rectangular Rapid Flash Beacons (RRFBs)	• Provides higher driver awareness when a pedestrian is present • Increases yielding percentage • Increases usable gaps • Reduces probability of pedestrian risk taking • Can be seen from 360 degrees	• Requires pedestrian activation	• Supplement existing pedestrian crossing warning signs • School crossings • Midblock crossing locations • Low- and high-speed roadways	84%	81%	$12,000–$18,000

NR = No research found on effect to yielding rate

TRAFFIC CALMING TREATMENTS

Traffic calming treatments are generally applied to locations experiencing high traffic speeds. Traffic speeds should be lowered to enable any type of at-grade crossing. Traffic calming treatments can also be used to shorten crossing distances and improve pedestrian visibility. The shortened crossing distances reduce the total time of exposure to conflicting traffic, resulting in safer crossing environments. These treatments may be completed in conjunction with other uncontrolled crossing treatments.

A variety of traffic calming treatments are outlined in Table 4 on page 25 (treatments should be justified with an engineering study). Examples of selected treatment options are also shown at right.

For more information on traffic calming treatment options, please see these resources (in addition to the sources listed below):

- LRRB Report MN/RC-1999-01, Effective Traffic Calming Applications and Implementation;
- TRS 0801, Traffic Calming for High Speed Rural Highways
- LRRB Report 2013-31, Implications of Modifying State Aid Standards: Urban Construction or Reconstruction to Accommodate Various Roadway Users
- http://mndot.gov/planning/completestreets

CURB BUMP-OUTS

CHANNELIZED TURN LANE WITH RAISED CROSSING

ROAD DIET/4-LANE TO 3-LANE CONVERSION

CENTER MEDIAN WITH REFUGE ISLAND

Sources:
"Minnesota's Best Practices for Pedestrian/Bicycle Safety," MnDOT Office of Traffic, Safety and Technology, September 2013.
"Best Practices Synthesis and Guidance in At-Grade Trail-Crossing Treatments," Minnesota Department of Transportation, St.Paul, MN, September 2013.
NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings. Transportation Research Board of the National Academies, Washington D.C., 2006.
Assessment of Driver Yield Rates Pre- and Post-RRFB Installation, Bend, Oregon. Oregon Department of Transportation, Washington D.C., 2011.
Bolton & Menk, Inc.
Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington D.C.: National Academy of Sciences, 2010.
Before-and-After Study of the Effectiveness of Rectangular Rapid-Flashing Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.

Table 4: Traffic Calming Treatments

Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate	Cost
Center Median with Refuge Island	• Decreases pedestrian crossing distance • Provides higher pedestrian visibility • Reduces vehicle speeds approaching the island • Reduces conflicts • Increases usable gaps • Reduces pedestrian exposure time	• May make snow removal more difficult • May be a hazard for motorists • Small islands not recommended on high-speed roadways (>40 mph)	• Wide, two-lane roads and multilane roads with sufficient right-of-way	34%	29%	Variable depending on length
Raised Crossings	• Provides higher pedestrian visibility to vehicles • Can reduce vehicle speeds	• Make snow removal more difficult • May reduce emergency vehicle response times • Only appropriate in low-speed/urban environments	• Low-speed/urban environments	NR	NR	$5,000–$25,000
Lighting	• Can be inexpensive • Can reduce vehicle speeds	• No effect during daylight	• Targeted crossing locations not located on a street with continuous roadway lighting	NR	NR	$1,000–$40,000
Pavement Striping (Road Diet)	• Can be inexpensive • May decrease vehicle speed • May decrease illegal right-side passing • Can be an interim solution	• Does not provide a physical barrier between modes • Pedestrian crossing distance same as existing	• Four-lane undivided roadways • Locations with very long crossings	NR	NR	Variable depending on length
Curb Bump-Outs/ Extensions	• Can be inexpensive • Reduces pedestrian crossing distance • Provides higher pedestrian visibility to vehicles • Reduces speed for turning vehicles • Decreases in illegal right-side passing	• May make snow removal more difficult • Proximity of curb to through traffic may be a safety concern	• Downtown/urban locations	NR	NR	$5,000–$15,000 per crossing
Channelized Turn Lanes (Corner Islands) *(Not usually recommended as a pedestrian crossing treatment)*	• Decreases pedestrian crossing distance • Provides higher pedestrian visibility • Decrease in illegal right-side passing	• May require new pavement • Can be more challenging for visually impaired pedestrians • Right turning drivers often fail to yield to pedestrians • Can increase right-turn vehicle speeds • May make snow removal more difficult • Vehicle crashes may increase	• Intersections with wide approaches • Intersections with right turn lanes and sufficient corner right-of-way • Intersections with operational improvment needs	NR	NR	$50,000–$100,000 per intersection

NR = No research found on effect to yielding rate

HIGH-LEVEL TREATMENTS

High-level treatments are high cost and are generally implemented on high-volume and high-speed roadways. They are much more difficult to implement unless they are justified based on traffic and pedestrian volume.

Possible high-level treatments are outlined in Table 5 on page 27, and examples of selected treatment options are shown below. For additional information on Treatment Options, please see the sources listed below.

PEDESTRIAN HYBRID BEACON

TRAFFIC SIGNAL

UNDERPASS

OVERPASS

REPEAT STEP 4

Evaluate LOS for Treatment Options

Step 4 should be repeated after deciding on a treatment option. Determine the level of service (LOS) of the crossing condition with the potential treatment options following the procedure as outlined in the 2010 *Highway Capacity Manual*. An acceptable service level should be determined by the agency.

If acceptable service levels cannot be met:

- Do nothing (consider leaving the crossing unmarked and unsigned),
- Consider pedestrian routing to another location, and/or
- Consider appropriate high-level treatments.

Sources:
"Minnesota's Best Practices for Pedestrian/Bicycle Safety," MnDOT Office of Traffic, Safety and Technology, September 2013.
"Best Practices Synthesis and Guidance in At-Grade Trail-Crossing Treatments," Minnesota Department of Transportation, St.Paul, MN, September 2013.
NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings. Transportation Research Board of the National Academies, Washington D.C., 2006.
Assessment of Driver Yield Rates Pre- and Post-RRFB Installation, Bend, Oregon. Oregon Department of Transportation, Washington D.C., 2011.
Bolton & Menk, Inc.
Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington D.C.: National Academy of Sciences, 2010.
Before-and-After Study of the Effectiveness of Rectangular Rapid-Flashing Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.

Table 5: High-Level Treatments

Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate	Cost
Pedestrian Hybrid Beacon	• Provides higher driver awareness when a pedestrian is present • Has been shown to decrease pedestrian crashes	• Potential increase in vehicle crashes • Can have spotty compliance rates due to a lack of driver understanding	• Justified locations • Mid-block crossing locations	97%	99%	$150,000–$300,000
Traffic Signal	• Provides higher driver awareness when a pedestrian is present • Easily understandable	• May increase crashes due to the driver expectation of a green signal indication	• High pedestrian volume crossings • Justified locations, meets signal warrants	NA	NA	$150,000–$300,000
Underpass Grade Separation	• Removes pedestrian/vehicle conflicts	• Potential of the crossing not being used • Very location specific • Very expensive • Drainage within an underpass can be problematic • Underpass would require lighting	• Location with compatible grades • High pedestrian volume crossings • High-volume roadways • High-speed roadways	NA	NA	$800,000+
Overpass Grade Separation	• Removes pedestrian/vehicle conflicts	• Potential of the crossing not being used • Very location specific • Very expensive • Snow removal on overpass may be difficult	• Location with compatible grades • High pedestrian volume crossings • High-volume roadways • High-speed roadways	NA	NA	$1,200,000+

NA = Not applicable or no research found on effect to yielding rates

Uncontrolled Pedestrian Crossing Data Collection Worksheet

Location: ______________________ Date: ______________________

City, State: ______________________ Scenario: ______________________

Reviewer(s): ______________________ Agency: ______________________

Project #: ______________________ ID #: ______________________

The first step in understanding the pedestrian needs at a potential crossing location is completing a review of the location and adjacent facilities.

Geometrics

Crossing Length: Measure the crossing distance from curb to curb. Fill in Crossing 1 distance if there is no median. If there is a median at the crossing location, fill in Crossing 1 and 2 distances.
- Crossing 1 ____ ft.
- Crossing 2 ____ ft.

Median: width of median at crossing location ____ ft.

Crossing Width: effective crosswalk width ____ ft.

- Raised Median Available? ☐ Yes ☐ No
  - ADA Compliant Median Available (minimum 4' x 4' landing)? ☐ Yes ☐ No
- Curb Ramps Available? ☐ Yes ☐ No
  - ADA Compliant Curb Ramp Available (width, grades, truncated domes)? ☐ Yes ☐ No

Speed: Posted or 85th percentile speed ____ mph

Roadway Curvature and Sight Distances: Average walking speed ____ ft/s

- Is the crossing location within a horizontal or vertical curve? ☐ Yes ☐ No

Equations to calculate the following are located on the next page

Direction 1:	Stopping Sight Distance (SSD)	____ ft.	provided?	☐ Yes ☐ No
Direction 2:	Stopping Sight Distance (SSD)	____ ft.	provided?	☐ Yes ☐ No
Direction 1:	Pedestrian Sight Distance (PedSD)	____ ft.	provided?	☐ Yes ☐ No
Direction 2:	Pedestrian Sight Distance (PedSD)	____ ft.	provided?	☐ Yes ☐ No

Traffic and Pedestrian Data

Measure traffic and pedestrian volume in 15-minute increments on the roadway to be crossed.

Attach Counts

	vehicles:			pedestrians:		
		Daily	____		Daily	____
AM Peak	Hourly ____	Pk 15-min	____	Hourly ____	Pk 15-min	____
PM Peak	Hourly ____	Pk 15-min	____	Hourly ____	Pk 15-min	____

Additional Site Characteristics

Lighting:
- Is street lighting present and does it light the crosswalk location? ☐ Yes ☐ No

Crosswalk Pavement Markings: Is the pedestrian crossing currently marked? ☐ Yes ☐ No
- What is the condition of the markings? ☐ Excellent ☐ Good ☐ Fair ☐ Poor
  - Are the markings easily defined? ☐ Yes ☐ No
  - Do they need replacement? ☐ Yes ☐ No
  - What is the crosswalk marking pattern? ____

Signing: Currently signed at crosswalk? ☐ Yes ☐ No
- Currently signed in advance of crosswalk? ☐ Yes ☐ No
- Distances? direction 1 ____ ft. direction 2 ____ ft.

Enhancements: What enhancements are currently at the crossing location? ____

Adjacent Facilities: Distance to nearest marked crosswalk? ____ ft.
- What pedestrian control devices are present at the nearest adjacent marked crosswalk? ____
- Distance to nearest all-way stop, roundabout or signalized intersection ____ ft.
- Could another location serve the same pedestrian crossing movement? ☐ Yes ☐ No
- Could another location serve the the movement more effectively? ☐ Yes ☐ No

Uncontrolled Pedestrian Crossing
Data Collection Worksheet

Mark the following: site distances and potential conflicts, pavement markings (crosswalk, edge lines, center lines, lane lines, stop lines, and any other markings), signing, location of lighting units, curb ramps, truncated domes, presence of any other crosswalks or crossing locations parallel to and nearby the location being studied, adjacent intersection traffic control, parking, intersection width, lane lengths, shoulder widths, sign placement, and nearby orgins and destinations .

draw or insert map of location being studied

Notes: ______________________________

____

____

____

____

Sight Distance Calculations:

Stopping sight distance (SSD), ft = $1.47St + 1.075S^2/a$

Pedestrian sight distance (PedSD), ft = $1.47S(L / S_p + t_s)$

where: S = design speed, mph

L = length of crossing, ft

where:	defaults:
t = brake reaction time, s	2.5
a = deceleration rate, ft/s^2	11.2
S_p = average pedestrian walking speed, ft/s	3.5
t_s = pedestrian start-up and end clearance time, s	3.0

2010 Highway Capacity Manual (HCM)

Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations
Intersection and Mid-Block Crossings

Introduction:

The Worksheets provide a procedure for evaluating the Level of Service (LOS) at uncontrolled pedestrian crossings according to the methodology presented in Chapter 19 of the 2010 Highway Capacity Manual. Uncontrolled pedestrian crossings include: marked crossings at mid-block locations; marked crossings at intersections; and unmarked crossings at intersections, that are not controlled by a traffic control device such as signals and stop or yield signs.

Use of these Worksheets in Microsoft Excel results in an automated procedure. While this automated procedure has been checked for accuracy using multiple examples, no warranty is made by the developers as to the accuracy, completeness, or reliability of the equations and results. No responsibility is assumed for incorrect results or damages resulting from the use of these worksheets.

This process is not for use at signalized crossings and has not been verified to be accurate for unsignalized pedestrian crossings within a signalized corridor.

The equations and methodology presented through this process is contained within the 2010 Highway Capacity Manual (HCM). Any questions on the approach, assumptions, and limitations of the procedure or for verification of equations are directed to the 2010 HCM.

This material was developed by Bolton & Menk, Inc. in coordination with the Local Road Research Board (LRRB) for the use by practicioners. These Worksheets are made without charge and under no circumstances shall be sold by third parties for profit.

Submitted for Approval: May 12, 2014
Updated June 6, 2014

2010 Highway Capacity Manual (HCM)

Pedestrian Level of Service (LOS) at Uncontrolled Crossing Locations
Intersection and Mid-Block Crossings

Crossing Location:		Date:	
City, State:		Scenario:	
Reviewer(s):		Agency:	
Project Number:		ID #:	

The following is the base information needed to complete the analysis.
If this is a one-stage crossing, use only Crossing 1.
If this is a two-stage crossing, each stage must be evaluated separately using Crossing 1 and Crossing 2.

Crossing 1: ____________

Evaluation Inputs:

Evaluation Inputs	defaults:		Input Table:	
L = crosswalk length (ft)			L =	
S_p = average pedestrian walking speed (ft/s)	S_p =	3.5	S_p =	
t_s = pedestrian start-up and end clearance time (s)	t_s =	3.0	t_s =	
V = vehicular hourly volume (veh/hr)			V =	
v_p = pedestrian flow rate (ped/s)	v_p =	0*	v_p =	
v = vehicular flow rate (veh/s) = V/3600	v =	V/3600	v =	
W_c = crosswalk width (ft)	W_c =	8.0	W_c =	
N = number of through lanes crossed (Integer)	N =	INT(L/11)	N =	

*no platooning observed

Crossing 2: ____________ (only used for two-stage crossings)

Evaluation Inputs:

Evaluation Inputs	defaults:		Input Table:	
L = crosswalk length (ft)			L =	
S_p = average pedestrian walking speed (ft/s)	S_p =	3.5	S_p =	
t_s = pedestrian start-up and end clearance time (s)	t_s =	3.0	t_s =	
V = vehicular hourly volume (veh/hr)			V =	
v_p = pedestrian flow rate (ped/s)	v_p =	0*	v_p =	
v = vehicular flow rate (veh/s) = V/3600	v =	V/3600	v =	
W_c = crosswalk width (ft)	W_c =	8.0	W_c =	
N = number of through lanes crossed (Integer)	N =	INT(L/11)	N =	

*no platooning observed

Crossing Treatment Yield Rate

	Input Table:	
M_y = motorist yield rate (decimal)	M_y =	

Entering data into the tables above will populate the evaluation tables in Microsoft Excel.

Results:

Average Delay		sec/ped
LOS		

LRRB

Uncontrolled Pedestrian Crossing Level of Service
Evaluation Worksheet

Crossing Location: ______ Date: ______
City, State: ______ Scenario: ______
Reviewer(s): ______ Agency: ______

Step 1: Identify Two-Stage Crossings

Is there a median available for a two-stage crossing? ☐ Yes ☐ No
If yes, does the median refuge meet ADA requirements (4' x 4' landing)? ☐ Yes ☐ No
If yes, do pedestrians treat this as a two-stage crossing location? ☐ Yes ☐ No

Step 2: Determine Critical Headway

Critical headway is the time below which a pedestrian will not attempt to begin crossing the street. Pedestrians use judgement to determine whether the available headway is sufficent for a safe crossing.

For a single pedestrian:

$$t_c = \frac{L}{S_p} + t_s$$

where: t_c = critical headway for a single pedestrian (s)
L = crosswalk length (ft)
S_p = average pedestrian walking speed (ft/s)
t_s = pedestrian start-up and end clearance time (s)
S_p = 3.5 ft/s
t_s = 3 sec

crossing 1		crossing 2	
L =	**t_s =**	**L =**	**t_s =**
S_p =	**t_c =**	**S_p =**	**t_c =**

If pedestrian platooning is observed, the spatial distribution of pedestrians should be computed:

1. use field observations or estimate platoon size using equation:

$$N_c = \frac{v_p e^{v_p t_c} + v e^{-v t_c}}{(v_p + v) e^{(v_p - v) t_c}}$$

where: N_c = total number of pedestrians in crossing platoon (ped)
v_p = pedestrian flow rate (ped/s)
v = vehicular flow rate across crossing (veh/s)
t_c = single pedestrian critical headway (s)

crossing 1		crossing 2	
v_p =	**t_c =**	**v_p =**	**t_c =**
v =	**N_c =**	**v =**	**N_c =**

2. compute spatial distribution:

$$N_p = INT\left[\frac{8.0(N_c - 1)}{W_c}\right]$$

where: N_p = spatial distributions of pedestrians (ped)
N_c = total number of pedestrians in crossing platoon (ped)
W_c = crosswalk width (ft)
8.0 = default clear width used by a single pedestrian to avoid interference with other pedestrians (ft)
clear width, if other than 8: ______ ft.

crossing 1		crossing 2	
N_c =		**N_c =**	
W_c =	**N_p =**	**W_c =**	**N_p =**

3. compute group critical headway:

$$t_{c,G} = t_c + 2(N_p - 1)$$

where: $t_{c,G}$ = group critical headway (s)
t_c = single pedestrian critical headway (s)
N_p = spatial distributions of pedestrians (ped)

crossing 1		crossing 2	
N_p =		**N_p =**	
t_c =	**$t_{c,G}$ =**	**t_c =**	**$t_{c,G}$ =**

Step 3: Estimate Probability of a Delayed Crossing

Probability that a pedestrian will not incur any crossing delay is equal to the likelihood that a pedestrian will encounter a gap greater than or equal to the critical headway immediately upon arrival at the intersection.

$$P_b = 1 - e^{\frac{-t_{c,G} v}{L}}$$

$$P_d = 1 - (1 - P_b)^L$$

where: P_b = probability of blocked lane
P_d = probability of delayed crossing
N = number of through lanes crossed
$t_{c,G}$ = group critical headway (s) = t_c, if no platooning
v = vehicular flow rate across crossing(veh/s)

crossing 1		crossing 2	
$t_{c,G}$ =		**$t_{c,G}$ =**	
v =	**P_b =**	**v =**	**P_b =**
N =	**P_d =**	**N =**	**P_d =**

Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

Step 4: Calculate Average Delay to Wait for Adequate Gap

Average delay assumes that no motor vehicles yield and the pedestrian is forced to wait for an adequate gap.

$$d_g = \frac{1}{v}\left(e^{vt_{c,G}} - vt_{c,G} - 1\right)$$

where: d_g = average pedestrian gap delay (s)
$t_{c,G}$ = group critical headway (s)
v = vehicular flow rate across crossing (veh/s)

crossing 1		crossing 2	
$t_{c,G}$ =		$t_{c,G}$ =	
v =	d_g =	v =	d_g =

Average delay for a pedestrian who is unable to cross immediately upon reaching the intersection (e.g., any pedestrian experiencing nonzero delay.)

$$d_{gd} = \frac{d_g}{P_d}$$

where: d_{gd} = average gap delay for pedestrians who incur nonzero delay
d_g = average pedestrian gap delay (s)
P_d = probability of a delayed crossing

crossing 1		crossing 2	
d_g =		d_g =	
P_d =	d_{gd} =	P_d =	d_{gd} =

Step 5: Estimate Delay Reduction due to Yielding Vehicles

(If yielding is zero, then skip step 5)

When a pedestrian arrives at a crossing and finds an inadequate gap, that pedestrian is delayed until one of two situations occurs: (a) a gap greater than the critical headway is available, or (b) motor vehicles yield and allow the pedestrian to cross. While motorists are legally required to stop for crossing pedestrians in MN at all intersections and at all marked crossings, motorist yield rates actually vary considerably.

Some crossing treatments and yield rates based on research are provided on the next page.

Average pedestrian delay

$$d_p = \sum_{i=1}^{n} h(i-0.5)\,P(Y_i) + \left(P_d - \sum_{i=1}^{n} P(Y_i)\right) d_{gd}$$

where: d_p = average pedestrian delay (s)
i = crossing event (i=1 to n)
h = average headway for each through lane = N/v
$P(Y_i)$ = probability that motorists yield to pedestrian on crossing event i
n = Int(d_{gd}/h), average number of crossing events before an adequate gap is available, >0
j = crossing event (j=0 to i-1)
$P(Y_j)$ = probability that motorists yield to pedestrian on crossing event j

crossing 1		crossing 2	
h =	n =	h =	n =
	d_p =		d_p =

1. One-Lane Crossing

$$P(Y_i) = P_d M_y (1 - M_y)^{i-1}$$

2. Two-Lane Crossing

M_y = motorist yield rate (decimal) M_y =

$$P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right]\left[\frac{(2P_b(1-P_b)M_y) + (P_b^2 M_y^2)}{P_d}\right]$$

3. Three-Lane Crossing

$$P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right]\left[\frac{P_b^3 M_y^3 + 3P_b^2(1-P_b)M_y^2 + 3P_b(1-P_b)^2 M_y}{P_d}\right]$$

4. Four-Lane Crossing

$$P(Y_i) = \left[P_d - \sum_{j=0}^{i-1} P(Y_j)\right] \text{x} \left[\frac{P_b^4 M_y^4 + 4P_b^3(1-P_b)M_y^3 + 6P_b^2(1-P_b)^2 M_y^2 + 4P_b(1-P_b^3)M_y}{P_d}\right]$$

Summary	
Average	
LOS	

Step 6: Calculate Average Pedestrian Delay & Determine LOS

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

Uncontrolled Pedestrian Crossing Level of Service Evaluation Worksheet

Motorist Yield Rate = M_y

Determine if there is a crossing treatment used that could provide vehicle yielding. This then provides a possible reduction in delay.

Crossing Treatment	Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate
Crosswalk Markings and Signs Only [1]	7%	7%
Median Refuge Islands [1]	34%	29%
Pedestal Mounted Flashing Beacon (2-Lane, 35 mph) [3]	N/A	57%
Overhead Flashing Beacon (push-button activation) [1]	47%	49%
Overhead Flashing Beacon (passive activation) [1]	31%	67%
Pedestrian Crossing Flags [1]	65%	74%
School Crossing Guards [5]	N/A	86%
In-street Crossing Signs (25-30 mph) [1]	87%	90%
Warning Sign with Edge Mounted LEDs [6]	N/A	28%
In-road warning lights [1]	N/A	66%
High-visibility Signs and Markings (35 mph) [1]	17%	20%
High-visibility Signs and Markings (25 mph) [1]	61%	91%
Rectangular Rapid-Flash Beacon (RRFB) [2][4]	84%	81%
School Crossing Guards with RRFB [5]	N/A	91%
Pedestrian Hybrid Beacon (HAWK) [1]	97%	99%
	N/A: No Research Found on Effect to Yielding Rate	

Sources: (1) Fitzpatrick, K., S.M. Turner, M. Brewer, P.J. Carlson, B. Ullman, N.D. Trout, E.S. Park, J. Whitacre, N. Lalani, and D. Lord. NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings. Transportation Research Board of the National Academies, Washington D.C., 2006.
(2) Lewis, R., J.R. Ross, D.S. Serpico : Assessment of Driver Yield Rates Pre- and Post-RRFB Installation, Bend, Oregon. Oregon Department of Transportation, Washington D.C., 2011.
(3) Bolton & Menk Field Data Collection
(4) Transportation Research Board, HCM 2010 Highway Capacity Manual, Washington D.C.: National Academy of Sciences, 2010.
(5) Brewer, Marcus A., Kay Fitzpatrick. Before-and-After Study of the Effectiveness of Rectangular Rapid-Flashing Beacons Used with School Sign in Garland, Texas. Texas Transportation Institute, College Station, TX, April 2012.
(6) Kipp, Wendy M.E., Jennifer M. V. Fitch. Evaluation of SmartStud In-Pavement Crosswalk Lighting System and BlinkerSign Interim Report. Vermont Agency of Transportation, Report 2011-3, Montpelier, VT, February 2011. (Rate Normalized to High Visibility Markings and Signs at 35 mph)